Inquiry-oriented learning in science: Transforming practice through forging new partnerships and perspectives

Final Report 2013

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Acronyms/abbreviations

ACDS Australian Council of the Deans of Science
ACSME Australian Conference on Science and Mathematics Education
AFFA ALTC Fellowship Funded Activity
ALTC Australian Learning and Teaching Council Ltd
ANU Australian National University
ARK Adaptable Resource Kit
ASELL Advancing Science by Enhancing Learning in the Laboratory
CSIRO Commonwealth Scientific and Industrial Research Organisation
CSU Charles Sturt University
CVF Competing Values Framework
CUUII CSIRO-University Undergraduate Inquiry Initiative
EOI Expression of interest
HERSDA Higher Education Research and Development Society of Australasia
HSC Higher School Certificate
IOL Inquiry-Oriented Learning
IBL Inquiry-Based Learning
IR Inspiring Research
LTAS Learning and Teaching Academic Standards
NSW New South Wales
OLT Australian Government Office for Learning and Teaching
PEN Physics Education Network
POGIL Process-Oriented Guided-Inquiry Learning
QLD Queensland
QUT Queensland University of Technology
SA South Australia
SAM-Net Science and Mathematics Network
SCU Southern Cross University
STEM Science, Technology, Engineering and Mathematics
TAS Tasmania
TEQSA Tertiary Education Quality and Standards Agency
TLO Threshold Learning Outcome
UK United Kingdom
UNE University of New England
UNSW University of New South Wales
UQ University of Queensland
US United States
USyd University of Sydney
UTas University of Tasmania
UTS University of Technology, Sydney
WA Western Australia
WIL Work integrated learning
Executive summary

Empirical research supports the proposition that student learning improves when academics move from teacher-centred instruction to instructional strategies incorporating active learning which are student-centred, such as learning through inquiry (Etkina et al., 2010; Boud et al., 1989).

Inquiry-oriented learning (IOL) and similar instructional strategies enhance problem-solving skills, stimulate creativity and foster innovation within students (Lee, 2012). These are essential attributes for students who complete a degree in science (LTAS, 2011). Through IOL activities, students: engage with scientific questions that have no predetermined answer; develop and implement approaches to address those questions; refine their approaches in order to enhance the quality of their data; gather evidence, and; communicate explanations and conclusions based on that evidence.

Despite the promise of enhanced student learning through inquiry, instructional strategies that place inquiry centre stage, such as inquiry-oriented, inquiry-guided and activity-led learning, (Lee, 2012 and Wilson-Medhurst, 2008) are not in widespread use. This fact, coupled with strong national and international drivers to enhance learning in science through inquiry (eg Office of the Chief Scientist, 2012 and Boyer Commission, 1998), made this fellowship, and its focus on inquiry, particularly timely. Goals of this fellowship included facilitating transformation of practice towards inquiry-oriented approaches to learning and playing a prominent role in shaping the national conversation on inquiry in the undergraduate science curriculum.

Through this fellowship I wished to better understand how to facilitate learning through inquiry-oriented activities, especially in large enrolment science classes. I also wanted to tap directly into the student experience to inform the design of curricula that employ inquiry-oriented approaches to learning.

In the approaches I used to promote and support the transformation of practice, I was inspired by Elton (2003) who proposed:

*The appropriate collaboration of relevant agencies, both inside and outside universities may be able to use certain systematic strategies to achieve positive systemic change.*

Elton expressed the view that in order to effectively promote changes in practice, ‘education and reason’ (which essentially means describing an innovation to an audience through a seminar, workshop or similar, and giving convincing evidence of the value of the innovation) are necessary but not sufficient for change to occur. I too took the position that the participation of relevant agencies allied to other strategies could achieve what education and reason alone could not. These agencies included myself as ALTC National Teaching Fellow, the Office for Learning and Teaching as well as technical staff, academics and senior administrators including Deans and PVCs.

Through the ALTC Fellowship Funded Activity (AFFA) initiative, science academics from across Australia developed IOL activities for inclusion in the curriculum in their own
institutions. These activities, encompassing the disciplines of biology, chemistry and physics, and involving groups of academics from seven universities in NSW, QLD, WA, SA and TAS, were supported by a small amount of funding from the fellowship. The fellowship also supported the development of the activities in other ways (for example through organising, running and analysing the data from focus groups with students who had recently completed an IOL activity).

I went beyond the usual suspects to draw in CSIRO, Australia’s premier scientific organization. The concept for the CSIRO-University Undergraduate Inquiry Initiative (CUUII) was to connect universities and CSIRO in order to co-develop IOL resources for students. These resources allow students to explore contemporary scientific issues of national significance, enhancing student engagement, especially in the first year at university. Through the fellowship, prototype resources were co-developed by University of Technology, Sydney and CSIRO and trialled with students. An evaluation of the resources indicates that they offer undergraduates engaging, context-rich learning opportunities.

Through hands-on workshops delivered in Australia and overseas, workshop participants assumed the role of students to explore IOL and examined: IOL activities from a student perspective, the scaffolding of activities which would best support students learning through inquiry, challenges faced by students carrying out the experiment and those faced by academics in supporting students, professional development needed for academics facilitating learning through inquiry-oriented activities, unique learning opportunities they offer and processes by which such activities can be developed, trialed and evaluated.

A fellowship website was created: <www.iolinscience.com.au/>. The purpose of the website is to collate and provide information to the scientific community and other stakeholders on IOL and other inquiry-type instructional strategies. The site articulates IOL, its benefits, and contains examples of IOL activities, including those developed through the AFFA initiative. The website documents the fellowship plan, activities undertaken through the fellowship, outlines the new partnerships developed and perspectives explored.

A National Forum at University of Technology, Sydney in September 2012 brought together students, educational developers, school teachers and casual and full-time academics from around Australia and overseas to focus on innovative strategies, new technologies and methodologies that harness the power of inquiry to enhance student engagement and learning. The forum was entitled Enhancing learning through inquiry and technology and featured presentations by esteemed overseas and Australian speakers. Feedback from participants indicates that the forum was well received.

Dissemination was integral to the fellowship, occurring throughout the fellowship period. The AFFA activities and the hands-on workshops were key components of the dissemination. They allowed understandings and interpretations of IOL to grow, spread and have direct and immediate impact on the undergraduate curriculum and the professional development strategies adopted to assist those new to IOL. Seminars, workshops, keynotes and face to face interactions with senior policy makers within and outside academia acted to broaden and deepen the conversation on learning through inquiry.
Outcomes and deliverables.

Through this fellowship, I:

- engaged students, full time and casual academics, science policy makers and high profile national organisations including CSIRO and the Australian Council of the Deans of Science in this fellowship. In doing so, I shaped and broadened the national conversation on learning through inquiry in science;
- facilitated changes in practice at seven universities in five States through supporting the development, trialling and embedding of IOL activities into the curriculum in biology, chemistry and physics (see chapter 2);
- captured and examined the student perspective of IOL through focus groups run in five universities in QLD, SA, NSW and TAS (see chapter 3);
- presented 13 hands-on inquiry workshops in universities in the UK, New Zealand and Australia, including an invited workshop at the 2012 HERDSA conference in Hobart (see chapter 4);
- organised and delivered a successful National Forum focusing on IOL, attended by over 100 academics, educational developers, school teachers and students (see chapter 5);
- collaborated strategically with CSIRO to co-develop adaptable IOL activities for use with large enrolment first year classes showcasing science issues of national significance. (see chapter 6);
- created a comprehensive fellowship website devoted to IOL (<www.iolinscience.com.au/>) (see chapter 7);
- created materials (available on the website) to support the development of IOL activities, including an Adaptable Resource Kit (ARK) (see chapter 7 and appendix E)
- delivered 19 fellowship seminars on IOL in the US, UK, New Zealand and Australia (see appendix F), and;
- accepted an invitation from the LTAS project science scholars to prepare, with Associate Professor Elizabeth Johnson of LaTrobe University, a Good Practice Guide on Inquiry and Problem Solving.
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Chapter 1: Mainstreaming inquiry-oriented learning (IOL)

In an address to the National Press Club in May 2012, Australia’s Chief Scientist, Professor Ian Chubb AC, expressed the view that: The teaching of science should resemble the practice of science more than it does; and the relevance of science as it is taught should be as obvious as the standards are high.

Professor Chubb’s remarks were directed principally at primary and secondary education, but they are equally apposite to higher education in Australia. For example, the undergraduate laboratory experience very often does not resemble the practice of science, nor the processes scientists adopt in their pursuit of new knowledge. This is especially true for laboratory programs embedded in large enrolment first-year subjects which remain dominated by uninvolving cookbook-style experiments. Such experiments have been criticised for the best part of a century. As Bless wrote in 1933:

*Cookbook instructions certainly do not stimulate the student’s capacity for reasoning or ...ingenuity. If anything they are stifled under such a procedure. The instructions for carrying out a given experiment should be conspicuous by their absence...* (Bless, 1933)

This view was echoed more than 60 years later by White, who stated:

*..open-ended investigations followed by class discussions of the merits of different methods ... would be better for promoting how science is done than the common predetermined exercises in most laboratory manuals ...* (White, 1996)

The move from constrained and constraining undergraduate experiences in the laboratory (and the field) to those more aligned to the practice of scientists, such as learning through inquiry, has progressed at a modest pace in all science disciplines. Nevertheless, there are good examples of where inquiry-oriented activities have been introduced into the undergraduate curriculum (see, as examples Casotti et al. 2008 and Armbuster et al. 2009). Activities which enhance learning through inquiry expose students to, and involve them in, the processes of science reflecting much better what scientists actually do. At the same time, well designed inquiry-type activities develop high level investigative skills (Suits, 2004).

Influential advocates, including Australia’s Chief Scientist and the Australian Council of the Deans of Science (ACDS) are putting their weight behind reinvigorating science curricula through inquiry at secondary and tertiary levels. A powerful driver for large-scale reform towards inquiry in the science curriculum originating from within the community of tertiary science educators is the Science Learning and Teaching Academic Standards Statement (2011). The Statement describes, through the articulation of Threshold Learning Outcomes (TLOs) what science graduates should know and be able to do (as a minimum). The TLOs have brought fresh emphasis and impetus to inquiry in the curriculum. More specifically, TLO3, which focuses on inquiry and problem solving, requires students be able to critically analyse and solve scientific problems by: gathering, synthesising and critically evaluating
information from a range of sources; designing and planning an investigation; selecting and applying practical and/or theoretical techniques or tools in order to conduct an investigation, and collecting, accurately recording, interpreting and drawing conclusions from scientific data.

It is against this backdrop that the fellowship activities occurred. I adopted a number of approaches aimed at promoting a national conversation on learning science through inquiry in Australian universities. I engaged not only academics in this conversation, but students, academic policy makers and others from outside the university sector including teachers and senior executives of the CSIRO. Most particularly, I was intent on facilitating demonstrable changes in practice, over the period of the fellowship, towards inquiry-oriented learning (IOL). Through IOL activities, students:

- engage with questions that have no predetermined answer
- develop and implement approaches to address those questions
- work to refine their approaches in order to enhance their methods/the quality of the data
- gather evidence
- formulate and communicate explanations/conclusions based on that evidence

In science, IOL activities may occur naturally in the laboratory or the field, but they are not confined to these locations.

1.1 Approaches adopted to promote the mainstreaming of IOL

No one strategy of itself will successfully promote change towards adopting inquiry-oriented approaches to learning. Several complementary approaches were adopted to facilitate the mainstreaming of IOL. This section represents a summary of those approaches. Throughout the fellowship I assumed various roles to support mainstreaming of learning through inquiry. In terms of the Competing Values Framework (CVF), those roles included innovator, broker, coordinator, facilitator and mentor (Quinn, 1996). More detail can be found in the chapters referred to in table 1.1.

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1 I do not attempt to distinguish or discriminate in this report between Inquiry-Oriented Learning and other similar approaches such as Inquiry-Based Learning (IBL). For many people, and for most practical purposes, the terms are interchangeable. For a review of several similar approaches, see Eberlein et al. 2008.
<table>
<thead>
<tr>
<th>To:</th>
<th>I:</th>
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<tbody>
<tr>
<td>facilitate and support the embedding of IOL activities in science curricula in universities across Australia</td>
<td>initiated a program to support academics across the country developing IOL activities in the biological, chemical and physical sciences. Academics applied for competitive funding to support an ALTC Fellowship Funded Activity (AFFA). The intent of the program was to involve academics, educational developers and others in developing and embedding IOL activities within the curriculum in each institution and to connect groups across universities in order to encourage collaboration and stimulate dissemination. The program provided support to individuals through: face to face contact, telephone conference calls involving the AFFA recipients connecting them to recent and relevant information and running focus groups with students who engaged in the IOL activities (more information can be found in chapter 2 and in appendix B).</td>
</tr>
<tr>
<td>impact on IOL-related teaching and learning issues of high national prominence and significance</td>
<td>worked with the science Discipline Scholars of the Learning and Teaching Academic Standards (LTAS) project to provide advice on the development of Threshold Learning Outcomes (TLOs). One outcome of this involvement was an invitation from the Scholars to unpack TLO3 at a national forum in 2012 attended by Associate Deans Teaching and Learning from across Australia.</td>
</tr>
<tr>
<td>examine the student experience of IOL and incorporate the student perspective into the evaluation of IOL activities</td>
<td>with Andrea Mears, organised, delivered and analysed responses from student focus groups at five universities in four States in order to explore commonly expressed attitudes towards IOL and, importantly, why and how deeply these attitudes are held. Questions were developed in conjunction with academics in each institution focusing on issues that included how students responded to different elements of the activity and how IOL affects skill development and confidence (more information can be found in chapter 3).</td>
</tr>
<tr>
<td>stimulate a national conversation on IOL in the undergraduate curriculum</td>
<td>organised and delivered a national forum on Enhancing Learning in Science through Inquiry and Technology, bringing together prominent national and international speakers, academics from around Australia, educational developers, students and school teachers to explore IOL. I also ran hands-on workshops nationally and internationally at 13 universities examining IOL in context (more information can be found in chapters 4 and 5).</td>
</tr>
<tr>
<td>inspire the next generation of Australian scientists to play a leading role in research</td>
<td>established an innovative partnership with Australia's premier scientific organisation, CSIRO, through which I co-developed inquiry-in-context resources, drawing on CSIRO research and innovation that encourage student learning in meaningful contexts. Prototype resources have been developed, trialled and will go live with students in 2013 (for more information, see chapter 6).</td>
</tr>
<tr>
<td>communicate both the progress of the fellowship, and national and international good practice of IOL</td>
<td>developed a fellowship website (&lt;www.iolinscience.com.au/&gt;) and gave invited seminars and keynotes on IOL. I presented the work of the fellowship at conferences nationally and internationally including at HERDSA, ACDS conferences and the AIP Congress (more information can be found in chapter 7).</td>
</tr>
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support and connect with national science networks | played a major role in the creation of the Physics Education Network (PEN) whose initial focus was on the development of physics TLOs through the PEN. I also supported the SaM-Net project through the mentoring of an academic who was developing IOL activities. In addition I was an invited presenter and participant at the the University of Queensland ASELL Biology Workshop in 2011.

promote IOL in my own institution | delivered an invited keynote on the Student Experience and Research-Integrated Learning, nominated (successfully) for the 2012 UTS Medal for Teaching and Research Integration. In response to a suggestion by Professor Shirley Alexander, DVC Teaching, Learning and Equity at UTS, I created a UTS Community of Practice (CoP) on ‘Inquiry and Research Integrated Learning’. Professor Alexander has committed funds to support the CoP. This community of practice is not restricted to science, but is drawing in academics from other faculties at UTS.

Table 1.1: Approaches adopted to mainstream IOL.

1.2 Links with other ALTC/OLT-funded projects and fellowships


Several drivers including the formation of the Tertiary Education Quality and Standards Agency (TEQSA) in 2011 (<www.teqsa.gov.au/about>) led to a focus on teaching and learning standards in higher education and consideration of how such standards can be assured. I was invited onto the advisory group to provide advice to the science Discipline Scholars, Professor Sue Jones and Professor Brian Yates (both of the University of Tasmania) who led the development of Threshold Learning Outcomes (TLOs). The development of the TLOs was part of the Learning and Teaching Academic Standards (LTAS) project funded by the ALTC. The work I did during this fellowship placed me in a prominent position to provide informed and timely input to the Scholars on inquiry and its place in the undergraduate curriculum. It is worth remarking that inquiry is strongly represented among the science TLOs.

2) ALTC-funded project (2008) Educational technologies: enhancing the learning of scientific inquiry skills for bioscience students in Australian universities

This project focused on the challenge in the biosciences of ensuring that students develop skills during their undergraduate studies such as the capacity to analyse problems, appraise information critically and formulate a hypothesis. The project also considered how educational technology could be used to develop such capacities. During the fellowship I visited Associate Professor Elizabeth Johnson who was one of the leaders of the project and gained valuable insights into the approaches adopted to inquiry skill development in the biosciences. I invited Professor Johnson to present at the National Forum on Enhancing learning in science through inquiry and technology. The presentation can be found at <www.iolinscience.com.au/wp-content/uploads/2012/05/Johnson_IOL_Sep2012_final.pdf>
3) ALTC National Teaching Fellowship (2008) awarded to Professor Angela Brew on Enhancing undergraduate engagement through research and inquiry

With its overall aim to “enhance student engagement in learning through supporting the development, in Australia, of undergraduate research and inquiry”, Professor Brew’s fellowship links strongly to themes in my fellowship. Professor Brew brought a focus to undergraduate research with the establishment of a national centre for the integration of research, teaching and learning. I was invited by Professor Brew to contribute to the online publication, Undergraduate Research News Australia (URNA). URNA published our article Towards mainstreaming inquiry-oriented learning in the undergraduate science curriculum in September 2012 (see <www.mq.edu.au/ltc/altc/ug_research/files/URNA4_Undergrad_Research_News.pdf>)


Consideration of student experiences in the laboratory emerged as a major theme in my Associate Fellowship. In the conclusion to the fellowship report, I wrote:

[surveys across many Australian universities] showed that students by and large did not view the labs as a positive learning experience.... The development of engaging, relevant and challenging laboratory programs for non-physics majors is an area that deserves to be given more attention, as so many non-physics majors nationally are required to enrol in a physics service subject. This is a direction that I would like to pursue further.

My National Teaching Fellowship responded to issues of student engagement, broadening and deepening consideration of learning in the laboratory and, more generally, through inquiry.


This ALTC-funded project was carried out by the Australian Council of Deans of Science (ACDS). The project focused on the experience of students in first year laboratories (in physics, chemistry and biology). One of the recommendations of the project echoes the urgent emphasis that needs to be given to laboratory work. A key recommendation of the project Reconceptualising Tertiary Science Education for the 21st Century that is in sympathy with this fellowship is that:

[The] ACDS [should] develop a policy statement on the inclusion of laboratory experience in entry-level science courses, addressing the broad rationale and learning objectives for it in a way that acknowledges the diversity of student backgrounds and potential futures.
The work of this fellowship complemented and extended the work of Rice et al. by going into the laboratory to explore the student experience first-hand. Student attitudes towards the inquiry in the laboratory were examined through focus groups.

6) ALTC project (2006-2009) *Forging New Directions in Physics Education in Australian Universities* co-led by me and Associate Professor Manju Sharma from Sydney University.

Major strands of this project considered service teaching and undergraduate experimentation, (see <www.olt.gov.au/project-forging-new-directions-physics-uts-2006> and <www.physics.usyd.edu.au/super/ALTC/>). There are significant synergies between this fellowship and the ALTC project, in particular with regard to the focus on the impact of the inquiry in the laboratory and the student experience. A recommendation from the ALTC project was that the Australian tertiary physics community should:

*recognise that the laboratory experience of students in first year physics subjects ... across the majority of the tertiary physics institutions in Australia is a matter of concern, demanding urgent action.*

This fellowship is a response to the call for urgent action.
Chapter 2: ALTC Fellowship-funded activities (AFFAs)

To facilitate changes in the undergraduate science curriculum in several universities towards IOL, I borrowed and adapted a successful strategy from another ALTC National Teaching Fellowship.

In his fellowship on *Curriculum and pedagogic bases for effectively integrating practice-based experiences* [www.olt.gov.au/resource-integrating-practice-based-experiences-griffith-2011], Professor Stephen Billett from Griffith University convened groups from around the country to pursue Work Integrated Learning (WIL) projects. To promote this, each group was modestly funded by Professor Billett’s fellowship.

As Professor Billett remarks in his final report:

... [academics’] interest was the key motivating factor, not the small amount of funding which was there to assist and support their project.

Inspired by this strategy, and also recognising that a ‘climate of readiness’ (Southwell et al., 2005) was a key to successful dissemination of innovations, I invited expressions of interest (EOI) from academics already intent on developing, trialling and embedding inquiry-oriented activities in their curriculum and supported each successful EOI with funding of $2000. These activities became known as the ALTC Fellowship Funded Activities (AFFAs).

In promoting the AFFAs, I was also inspired by Elton (Elton, 2003) who stated:

*The appropriate collaboration of relevant agencies, both inside and outside universities may be able to use certain systematic strategies to achieve positive systemic change.*

It was my intention, acting as an external agent who assumed several roles, including facilitator and mentor, (Quinn, 1996) to give groups the opportunity to be part of a national, multi-disciplinary group and to share their experiences and progress with others engaged in similar activities at several universities across Australia. Ten applications were funded (though one did not proceed as the principal applicant moved to another university). The nine that did proceed originated in science faculties at the Universities of Queensland, Adelaide, New England and Tasmania, as well as Charles Sturt, Flinders and Murdoch Universities. The core science disciplines of physics, chemistry and biology were equally represented amongst the AFFAs.

I encouraged the formation of small teams with diverse backgrounds and capabilities to develop, trial and embed IOL activities within the curriculum. Through the AFFA initiative I wished to: engage institutional leaders, senior academics and educational developers in the IOL development; enhance recognition for the work being done by academics in developing inquiry activities within their own institution by being involved with a national program of activities; act as a seed to attract more funding internally and externally.
Support from the fellowship for AFFA recipients came in several forms; perhaps the most valuable was the running of focus groups with students to explore their experience of, and attitude towards, IOL activities. The focus groups and their findings are described in Chapter 3 and appendix C. Participants expressed the view that the AFFA gave them the “impetus to act”. Feedback from AFFA recipients can be found at <www.iolinscience.com.au/our-iol-activities/new-partnerships-and-networks/>.

The advice given to academics intending to apply for funding and the EOI pro forma can be found in appendix A.

### 2.1 Successful AFFA applicants and their activities

The AFFAs, as initially described in the EOIs submitted by the applicants, were as follows:

<table>
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<tr>
<th>First named applicant/institution</th>
<th>Discipline</th>
<th>Brief description of the AFFA activity</th>
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<tr>
<td>Associate Professor Juliet Roberts/ University of New England</td>
<td>Biology</td>
<td>Development of an IOL activity in the PSIO210 practical classes for both on-campus and off-campus students with intention to extend the concept within PSIO210 and also into other units in Physiology.</td>
</tr>
<tr>
<td>Dr Regina Magierowski/ University of Tasmania</td>
<td>Biology</td>
<td>Design and introduction of two inquiry-based learning activities in a first-year zoology unit plus evaluation through student feedback and formal examination results.</td>
</tr>
<tr>
<td>Dr Kirsten Zimbardi/ University of Queensland</td>
<td>Biology</td>
<td>Creation of a series of narrative vignettes documenting the experiences of participants in undertaking IOL activities</td>
</tr>
<tr>
<td>Dr Natalie M. Williamson/ University of Adelaide</td>
<td>Chemistry</td>
<td>POGIL-style activities developed for all topics within Chemistry IA and IB, particularly in the area of introductory organic chemistry.</td>
</tr>
<tr>
<td>Dr Danielle Ryan/Charles Sturt University</td>
<td>Chemistry</td>
<td>Development and evaluation of inquiry-based laboratory experiences for students in the capstone Instrumental Analysis subject (CHM320).</td>
</tr>
<tr>
<td>Dr Susan Pyke/ Flinders University</td>
<td>Chemistry</td>
<td>Development of a bank of (POGIL-style) inquiry-based learning activities to be used to help students fill gaps in their knowledge and build confidence.</td>
</tr>
<tr>
<td>Dr Margaret Wegener/ University of Queensland</td>
<td>Physics</td>
<td>Development of a physics open-ended experiment for biologists based around thermal regulation.</td>
</tr>
<tr>
<td>Dr Chris Creagh/ Murdoch University</td>
<td>Physics</td>
<td>Development of IOL activities for both first year internal and distance students to enrich their learning experiences</td>
</tr>
<tr>
<td>Dr Maria Parappilly/ Flinders University</td>
<td>Physics</td>
<td>Development of computer-based modules to teach students the background material for each of the laboratory experiments in introductory physics topics ‘Physics for the Life Sciences A and B’.</td>
</tr>
</tbody>
</table>

Table 2.1: Details of successful AFFA recipients and their activities.
In addition to a small amount of funding, the fellowship provided support to individuals through:

- face to face contact, communication by telephone, connecting the AFFA participants to recent and relevant information, and providing a newsletter;
- visiting all AFFA recipients at least once over the fellowship period to discuss their project and provide support and feedback on progress;
- meeting with senior academic policy makers in each institution (including Heads of School, Deans and Associate Deans and DVCs) to raise the profile of the fellowship generally, but more specifically to make them directly aware of the IOL activities being developed within their Faculties. The senior policy makers were unfailingly positive and encouraging about the developments. This augurs well for the continuing support for the development of IOL activities within each institution.
- encouragement for AFFA recipients to link up with other initiatives, including SaM-Net.
- hands-on IOL workshops at all but two of the universities who were recipients of AFFA funding.
- running focus groups to offer the activity developers an insight into the student reaction to the inquiry activities created through the AFFA initiative. Outcomes of the focus groups have been a) immediate feedback to the academics outlining the findings, main issues and recommendations, b) a review and analysis of student attitudes to learning through inquiry. Focus groups were run with students from five of the nine AFFA recipients.

AFFA recipients were awarded $1000 on their EOI being accepted, with the second $1000 transferred when an interim report outlining progress had been received.

An outcome of the AFFA initiative has been short reports written by the participating academics describing: the progress of the AFFA supported projects; who the activity was trialled on and any assessment of the outcomes; who was involved during the development of the activity; plans for dissemination plans; plans for further development; the extent to which the projects are being supported internally; reflections on the value of the AFFA initiative to the academics and/or institution. All nine AFFA reports can be found in appendix B and also on the fellowship website <www.iolinscience.com.au/our-iol-activities/new-partnerships-and-networks/>

Here are extracts from one report, briefly describing the aim, processes and outcomes of the AFFA and the reflections of the AFFA recipients.

**Project Aim**

*The aim of this project was to develop POGIL-style activities in the area of introductory organic chemistry, with their construction guided by feedback from current chemistry students. Very few [Process Oriented Guided Inquiry Learning ] POGIL activities exist for introductory organic chemistry …*
Workshop
... Students in the November workshop also provided some constructive ideas on how to improve the activities, especially commenting on the need for the activities to be less text-focused. Based on this feedback, the activities were updated in early 2012 and then trialled again in April 2012 in a workshop session featuring a mixture of second year and postgraduate chemistry students.

On the value of the workshops and focus groups
The use of workshops and a focus group to trial the activities were extremely beneficial... The focus group held after the April workshop resulted in a wide-ranging discussion between participants. It was clear that these students wanted to use their perspective as senior chemistry students to enhance the activities. The focus group participants all recognised the need to incorporate interactivity in lectures, and were extremely supportive of the introduction of this style of learning into the new Foundations of Chemistry courses, with one participant commenting “I wish my lectures were like that now”. Additional comments during the focus group session further supported the use of inquiry-based learning: “It definitely helps you to develop skills more than traditional lectures” and “What really helps with learning is that you are doing it yourself rather than the traditional where someone is telling you something and you take in one word out of every thirty.”

The AFFA group’s reflections
The group agreed that it would be beneficial if inquiry-based learning was introduced into science (not just chemistry) courses at higher year levels; however, they stressed that beyond first year, it was important that inquiry-based learning be used to support traditional lectures (for example, in tutorials), rather than replace them entirely.

2.2 Reflections on the AFFA initiative
The AFFA initiative was effective at encouraging changes in practice within a tight timescale. Most AFFA recipients designed and trialled the activities they developed within the period of the fellowship. The work done by the recipients on developing their activities was well in excess of the modest amount of seed funding they received.

An important lesson was learned from this initiative. It is that if academics and others, working together on an innovation that excite them, are given a small amount of funding, and a discipline-based agent works with them to facilitate, support, validate and disseminate their activities locally and nationally then the innovation pays dividends for students, academics and their institution.

The development and evaluation of IOL activities was at the core of the initiative, but other benefits emerged: professional relationships of immediate and long-term value were built up between AFFA recipients. Advising senior academic policy makers and meeting them in person while I was visiting the AFFA recipients placed the initiative on a strong footing and accorded the recipients valuable institutional recognition of their efforts.

The payment of the small grant in two lots of $1000 to nine groups was administratively intensive and had it not been for an excellent administrative assistant at UTS, Mrs Linda Foley, the distribution and tracking of the funds could have wasted much time. As each institution has its own procedure for dealing with money from external sources, I would urge any future Fellows wishing to adopt a similar approach of supporting academics to explore in detail the requirements of the recipient universities as early as feasible.
Chapter 3: Student focus groups explore IOL

Main author: Andrea Mears

How do students view learning through inquiry? For an informed insight into this, we researched the student experience by the means of focus groups which took place at a number of universities. Ethics approval was sought and granted at each university participating in the research.

Between April and June 2012 seven focus groups were conducted with science students at five universities in four States. Examination of attitudes and experiences through focus groups was chosen as a primary research method as they not only allow an understanding of commonly expressed attitudes to emerge, but also encourage exploration of issues that materialise during the focus group sessions that have not been anticipated.

We conducted focus groups with students who had recently completed an inquiry-type experiment or activity. Questions relating to the student experience were developed in conjunction with academics in each institution. While some questions specifically addressed the activity students had completed, other questions focused on more general themes, including:

General Context: How did students enjoy and respond to the experiment/activity and how are enjoyment, relevance and learning viewed by students?

Activity specifics: How do students respond to different elements of the experiment/activity and how does learning through inquiry affect skill development and confidence?

Learning Outcomes: How is learning experienced in guided and inquiry activities?

Overall Impact and Sustainability: What are students’ expectations of an inquiry activity and what are their recommendations for the future?

What emerged through the groups was an analysis of each activity, its success, challenges and the factors impacting on student enjoyment, engagement and learning.

A confidential report outlining the research findings and an analysis of these findings was provided to academics within each university to support the development and evaluation of their inquiry-oriented activities.

Focus groups’ discussions went beyond a review of the activities to provide a commentary on the strengths and weaknesses of introducing inquiry learning in undergraduate science and how students would like their learning supported. Participants identified key factors to consider when introducing inquiry activities and what factors would allow student learning to be maximised. Brief details of the focus groups and their findings are presented in this chapter with more detail given in appendix C.

Groups involved
Seven focus groups consisting of volunteer students from five universities across four States were conducted between April and June 2012. In all, fifty-two students participated in the focus groups.

Details of the location of the focus groups:
- Four were conducted in metropolitan universities in three States (QLD, SA, TAS)
• Two were conducted in an outer metropolitan university (NSW)
• One was conducted in a regional university (NSW)

The students represented:
• 33 woman and 19 men
• 29 first-year undergraduate students and 21 second-year undergraduate students
• One Masters degree student and one PhD student
• The majority of students were science students and presented from a mix of Schools, approximately 15 per cent were engineering students
• Students in their first year of study were asked if they had completed Year 12 in the discipline they were now studying. Fifty per cent had completed Year 12.

Key findings:
• Students prefer inquiry to traditional activities even if their personal experience of inquiry has not been positive.
• As students progress through their degree they believe the level of inquiry will increase.
• Inquiry is more fun, interesting, challenging and has valuable real-world relevance.
• Stressful experiences of inquiry were reported when students lacked an understanding of the content, lacked the time to complete the activity and felt workload pressure.
• Well-supported inquiry activities were demonstrably successful, creating strong student engagement.
• First-year students are less keen on inquiry-oriented activities than later stage students.
• Students believe undertaking inquiry activities builds confidence, requires more thinking and allows a deeper understanding and skill set to develop.

3.1 Reflections on the focus groups

How students engage with learning activities may differ in many important respects from what was intended by those who designed the activities. The focus groups played an important role in bringing the student perspective to bear on issues of activity design, resourcing and support within the setting of the activity. Examination of the student perspective permitted designers to modify and refine their activities to enhance learning outcomes for students.
Chapter 4: Institutional workshops exploring IOL

Learning outcomes accruing through participating in inquiry are likely to differ in many respects from those that accumulate when students follow well-established recipes (Boud et al. 1989). Inquiry-oriented activities require students to be imaginative, inventive and ‘think outside the box’. The student perspective of an IOL activity and the challenges facing demonstrators intent on supporting students carrying out IOL activities was explored in 13 institutionally based workshops in Australia and overseas.

By placing academics and others in the role of students, I shifted the perspective of those participating in the workshops to more closely align with that of students. This allowed for an exploration of the value and challenges of IOL activities from the student viewpoint.

I developed workshops in which participants, who included full-time and casual academics, technicians, educational developers and senior academic managers, carried out an IOL activity, then critiqued the activity, examining the challenges facing those students carrying out the activity. The workshops encouraged participants to reflect on their own views of learning in the laboratory and leaned on a design-based research methodology in which a better understanding of the student experience is derived from assuming the role of the student in authentic settings, such as the laboratory (Barab and Squire, 2004).

In the workshops, participants experienced an inquiry-oriented activity leading to an examination of the:

- activity from a student perspective;
- scaffolding of activities which would best support students;
- challenges faced by students carrying out the activity experiment;
- challenges faced by academics in supporting students in inquiry-oriented activities;
- professional development requirements of academics facilitating learning through inquiry-oriented activities;
- unique learning opportunities offered by inquiry-oriented activities;
- process of developing, trialling and evaluating such activities.

The workshops (which were typically two to three hours long) were held in Australia, Scotland and New Zealand, attracting over 200 participants. Table 4.1 gives details of where and when the workshops were held.

<table>
<thead>
<tr>
<th>Date</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>2nd August 2011</td>
<td>Queensland University of Technology</td>
</tr>
<tr>
<td>29th August 2011</td>
<td>Flinders University</td>
</tr>
<tr>
<td>14th-15th September 2011</td>
<td>Charles Sturt University</td>
</tr>
</tbody>
</table>
To maximise the value of the workshop to the participants and to the institution, I wrote a report about the workshop and its outcomes and sent it to each workshop participant. A short anonymous survey was administered at the end of the workshop. Feedback from the survey was collated and included in the report (with personal details removed).

The workshops were well received. Several universities, including the Australian National University and Monash University, indicated that they would use the workshop as an element of their own professional development sessions for their demonstrators. Appendix D includes details of the workshop and feedback obtained from an Australian institution. Reaction to the workshop from international participants is given in Table 4.2, which contains feedback from Otago University in New Zealand.

### Feedback from participants

The best aspects of the workshop for me were:

<table>
<thead>
<tr>
<th>Participant</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Discussion! Great to have everyone’s personal experience</td>
</tr>
<tr>
<td>B</td>
<td>Role Modelling; Practical example of hands on; Fun</td>
</tr>
<tr>
<td>C</td>
<td>[No response]</td>
</tr>
<tr>
<td>D</td>
<td>Practical activity</td>
</tr>
<tr>
<td>E</td>
<td>Being a student</td>
</tr>
<tr>
<td>F</td>
<td>Carrying out the experiment and discussing the variety of methods and results; Reflecting on how inquiry experiments such as this can be incorporated into my own teaching.</td>
</tr>
<tr>
<td>G</td>
<td>Ideas on open-ended labs – how to run them in a practical sense.</td>
</tr>
<tr>
<td>H</td>
<td>Although we do a similar thing with our students, it is good to see it from a ‘student’s point of view’.</td>
</tr>
<tr>
<td>I</td>
<td>Hearing of the issues of other health sciences courses.</td>
</tr>
<tr>
<td>J</td>
<td>Surprising and accessible problem that engaged a wide range of skills. Left [me] wanting to do more measurements, design a new expt, etc.</td>
</tr>
<tr>
<td>K</td>
<td>Discussion of demonstrator’s role.</td>
</tr>
<tr>
<td>L</td>
<td>Modelling the inquiry process and the report back session linking what learned to the classroom.</td>
</tr>
<tr>
<td>M</td>
<td>Perspective of others’ experience.</td>
</tr>
<tr>
<td>N</td>
<td>Reflection on student and demonstrators’ perspectives; seeing the science threshold learning outcomes.</td>
</tr>
<tr>
<td>O</td>
<td>Working together was good.</td>
</tr>
</tbody>
</table>
Seeing how every group approached the problem from different angles.

Discussion.

Plenty of time for discussion.

Collaborative discussion.

Interactivity within and between groups.

Discussion with colleagues from different disciplines.

Table 4.2: Feedback from the Otago University workshop that took place on 28 May 2012

4.1 Impact of workshops

As an example of the impact of the workshops, I include the following from the hosts of the Monash University workshop.

1 October 2012

Hi Les,

The Monash crew would like to provide you with some feedback on the impact of your Inquiry-Oriented Learning fellowship on our teaching and learning endeavours at Monash. We first started discussing the integration of inquiry-type teaching in our first year labs around mid-2011. We concluded that if we were to develop IOL practical experiences for students in our own disciplines, it should be done in an integrated, interdisciplinary way. This would maximise the potential impacts on students and also strengthen collaborations among these science disciplines. Shortly afterwards, you travelled to Melbourne to run your IOL workshop, which was attended by academic staff from the faculties of Science and Medicine, Nursing and Health Sciences.

Your IOL workshop was collegial and constructive and highly valued by all who attended it. The workshop, together with further discussions with you about our IOL initiatives, galvanised our IOL program and laid the foundations for development and later implementation of IOL-based practicals in first year units in biology, chemistry and physics. Your workshop also provided a catalyst for us to consider the teaching associate (demonstrator) perspective, given their importance in student learning in science teaching laboratories. The September IOL Forum and our ACSME presentation on interdisciplinary integration of IOL also facilitated the opportunity for valuable discussions with fellow science educators.

Good luck with your Fellowship and we look forward to collaborating with you on future IOL initiatives in tertiary science education.

Kind regards,
Gerry Rayner (Biology),
Chris Thompson (Chemistry)
Theo Hughes (Physics)
4.2 Reflections on the workshops

Perhaps the greatest value of these workshops was to encourage a diverse range of stakeholders (including casual and full-time academics, technical staff, educational developers and designers) to examine not only the student perspective on IOL activities but also *their own views* on IOL activities. That the facilitator (me) and participants spoke the same disciplinary language (i.e. the language of science) and had first-hand experience of the challenges faced by demonstrators supporting student learning was advantageous. This allowed for exploration of the scientific, technical and instructional issues inherent in the activity.

The workshops encouraged participants to immerse themselves in the challenges faced by students carrying out IOL activities. It exposed them to the anxieties and uncertainties that students, especially students new to university, experience when required to engage in an activity that places much of the responsibility for the conduct of that activity on their shoulders.

I believe the workshops were exciting, revealing and thought-provoking for many workshop participants, taking them out of their comfort zone, as we do to our students on a daily basis. The workshops encouraged forthright discussions and occasionally conflicting conclusions regarding the student experience of learning through inquiry. Direct involvement in an IOL activity was an excellent way to explore which elements of IOL would best work for the participants’ students and the challenges faced by demonstrators supporting learning through inquiry.
Chapter 5: National Forum

A successful one-day National Forum entitled *Enhancing learning in science through inquiry and technology* attended by 102 full-time and casual academics, educational developers, teachers from 18 universities was held at UTS in September 2012. To maximise attendance at the forum, it was timed to occur in the same week as the Australian Conference on Science and Mathematics Education (ACSME), which took place at Sydney University.

The intention of the forum was to bring prominence to learning through inquiry, including the use of technology to support IOL by attracting tertiary education academics and secondary education educators who were:

- engaged in curriculum development in science
- keen to know more about how inquiry can be incorporated into the curriculum
- eager to understand the role that technology can play in supporting and enhancing learning through inquiry.

We also wanted to appeal to

- students wanting to engage with, or contribute to, the conversation on learning through inquiry
- educational developers/designers working with science academics on inquiry
- science policy makers wanting to explore the likely impact of inquiry on the science curriculum

The forum was supported and sponsored by my fellowship, the Office of the DVC (Research) at UTS and the Faculty of Science at UTS. It consisted of international keynotes, topic-driven presentations and a panel discussion. Goals of the forum included bringing national prominence to IOL and this fellowship, intensifying the conversation on IOL and, more specifically, to provide forum participants with the ideas, tools and techniques to support student learning through inquiry and technology. The forum program can be found at <www.iolinscience.com.au/wp-content/uploads/2012/05/program_booklet.pdf>

The forum was formally opened by Professor Attila Bruns, DVC (Research) at UTS.
In his opening address to the forum, Professor Brungs emphasised the importance of inquiry in the undergraduate curriculum:

*As the Deputy Vice-Chancellor (Research), I recognise the role of inquiry in inspiring the next generation of talented researchers, which is so critical for creating a strong, vibrant and sustainable research culture.*

*Presenters at the forum are of national and international standing. I have no doubt that the diversity of perspectives and insights they will bring to the forum will lead to a broadening and deepening of the national conversation on learning through inquiry.*

Professor Brungs’ views were echoed by the OLT which explained, in its Welcome to the forum, that:

*....the OLT and Les’ Fellowship share the aim of bringing about change in learning and teaching; in this particular case, by encouraging the science learning and teaching community to take part in a national discussion about the importance of inquiry-oriented learning in undergraduate students' experience of university.*

I was delighted that representatives from the OLT, including Ms Siobhan Lenihan and Ms Marguerite de Sousa, were able to attend the forum.

### 5.1 Presenters

Professors Gabriela Weaver (Purdue University, US) and Mick Healey (University of Gloucestershire, UK) were invited to deliver keynote presentations at the forum. Both are internationally recognised leaders in promoting and supporting learning through inquiry in the undergraduate curriculum. Their presentations, and those of the other presenters can be found at <www.iolinscience.com.au/iol-2012-forum/contributions/>
Forum presenters included academics prominent in designing and delivering curricula with a strong inquiry focus, including many who have explored, or are exploring, how technology can be used to assist in enhancing student learning through inquiry. Students also presented at the forum. The shared contribution of both students and staff prompted rich discussions on promoting learning through inquiry.

Figure 5.2: Forum snapshots

5.2 Forum feedback

A short survey was administered to participants at the end of the forum. The results were as follows:

7. Overall I was satisfied with the Forum
6. The Forum was well organised
5. The Forum increased my interest in introducing learning through inquiry in my practice or institution
4. The Q&A session at the end of the Forum generated interesting discussions about learning science through inquiry
3. The other sessions I attended were informative about learning science through inquiry
2. The Plenary Presentation was valuable for understanding more about learning science through inquiry
1. The Keynote Addresses were valuable for understanding more about learning science through inquiry

Figure 5.3: Feedback from forum participants
As a specific example of the impact of the forum on participants, I present feedback from Professor Ieva Stupans, Professor of Pharmacy in the School of Science and Technology at the University of New England.

[the forum] got me thinking back to the principles of experiential learning – as a lot of what came out, would be considered in health sciences as experiential and not inquiry based learning.

Maybe there is a case of synthesising learning from health and from “science” about the nature and definitions of inquiry- and how principles from one could be extended to the other eg the principles of reflection in experiential health learning –how do these principles get picked up in science. Ideas [from the forum] that I’m going to apply:

1) I’ve already picked up ideas from Mick Healey’s materials re maintaining standards whilst encouraging diversity and creativity. Some of these materials will inform the design of my pharmacy honours and pharmacy practice projects. It was really good to see the case studies which demonstrated creativity.

2) Simon Pyke’s presentation was good- I believe we should do something like that here, but I try to limit my focus otherwise I end up doing too much and spread myself too thin.

3) I also enjoyed hearing about the CSIRO project- we have a small division of CSIRO up here in Armidale and engagement around teaching between UNE and CSIRO is limited to research students. It’s good to hear that potentially that may expand.

Professor Ieva Stupans, November 2012

5.3 Forum reflections

The forum brought prominence to, and enhanced awareness of, work happening nationally and internationally on learning through inquiry. The diversity of backgrounds, interests and experiences of the participants is a testament to the contemporary importance of inquiry in the undergraduate curriculum. The forum attracted students, teachers, senior academic policy makers, the ACDS and academics from other disciplines, including engineers as well as science academics and educational developers. An oft-heard concern about educational-based forums, is that they attract the same people. This forum was successful in broadening the conversation about IOL by encouraging networking between individuals and groups that rarely have an opportunity to meet.

I was particularly pleased that school teachers attended the forum, and that at least in one case this led to a school becoming directly involved in developing and trialling an IOL activity with their students (see <www.plc.nsw.edu.au/page/newsletters-2012/issue-18-2012/physics-students-visit-uts>).

The opening of the forum by Professor Brungs sent a strong message to the entire academic community that IOL was not only a vital component of the undergraduate curriculum, but that it makes a crucial contribution to the development of the next generation of researchers and indeed to the whole institutional research agenda.
Chapter 6: The CSIRO-University Undergraduate Inquiry Initiative (CUUII)

In a meeting with Dr Cathy Foley, Chief of Division of Materials Science and Engineering at CSIRO, and Fellowship Reference Group member, an ambitious initiative emerged to promote learning through inquiry in the undergraduate curriculum. This became known as the CSIRO-University Undergraduate Inquiry Initiative (CUUII). The goal of the initiative was to harness the complementary skills and energies of CSIRO and Australian universities to co-develop adaptable inquiry-rich learning resources that enhance undergraduates’ capacities to explore contemporary scientific issues of strategic importance to Australia and Australians.

The co-developed resources to explore contemporary scientific issues were designed to enhance student engagement especially in the first year at university. We anticipated that connecting undergraduates at universities with CSIRO would be of profound medium and long-term value to CSIRO and Australian universities: it will raise the profile and visibility of CSIRO within a large and influential group of citizens, namely undergraduate students who will be the next generation of Australian scientists, science policy makers and scientifically literate members of society; for universities the resources developed would offer their undergraduates context-rich opportunities to engage in practice-oriented and research-integrated learning.

The intended outcome of this initiative was the development of pilot learning resources with an inquiry focus that would stimulate undergraduate students, from first year onwards, to experience and explore science-based issues of national significance in ways that have meaning for those students. Another intention of the initiative was to multiply and enhance links between higher education and Australia’s premier scientific organisation.

6.1 People and prototype

The initiative gained much momentum when Dr Foley suggested that Professor Jim Peacock of CSIRO and ex Australian Chief Scientist, might become involved in the initiative. Professor Peacock, who is the architect and patron of the Scientists in Schools initiative (<www.scientistsinschools.edu.au/>) was immediately enthusiastic about the CUUII and its potential. He facilitated introductions within CSIRO, and in doing so fast-tracked the initiative within the organisation.

Professor Peacock also offered advice on how to progress the initiative and gave particular emphasis to the co-development of a prototype activity, which could act, in essence, as a ‘proof of concept’.

In visits to the University of Queensland, the Australian National University and Murdoch University it became clear that there was interest in shadowing the development of IOL with CSIRO with a view to adapting resources that might be created so that they could be introduced into the undergraduate curriculum within each institution.
The prototype activity co-developed with the CSIRO was based on research into organic solar cell technology being led by Dr Scott Watkins, Stream Leader for Organic Photovoltaics, at CSIRO in Clayton in Victoria (<www.csiro.au/en/Organisation-Structure/Flagships/Future-Manufacturing-Flagship/Flexible-Electronics/ScottWatkins.aspx>). The activity offers significant scope for students to design and carry out an investigation into technology that taps into a renewable energy source. The activity has been developed, trialled, reviewed and refined (see appendix E for details for the activity). The activity will go live with several hundred first year students at UTS in Autumn 2013.

Impact: Already interest has been expressed within my own institution to tap into the initiative and broaden its reach beyond physics. The School of Chemistry and Forensics at UTS are in talks with CSIRO to explore the co-development of an inquiry experiment for first year students.

6.2 Reflections on the CUUII

This initiative was not imagined at the start of the fellowship. It emerged during a critical conversation with Dr Cathy Foley. With the right nurturing, the initiative has the potential to impact significantly on the way in which IOL resources are conceived and developed and it is perhaps the most important original contribution of this fellowship to the national conversation on inquiry and its place in the undergraduate curriculum.

Working with industry and government bodies to conceive and develop valuable resources that tap into issues of national or global dimension must be the way forward if we want to attract and enthuse students about science and its capacity to identify and address 21st century challenges.
Chapter 7: Dissemination

Profile building and dissemination, in this case dissemination of learning through inquiry, were built into aspects of the fellowship program through the direct and continuous involvement of academics and institutions predisposed to move towards inquiry-oriented learning.

As Southwell et al. pointed out (2005): A climate of readiness is important if successful innovation and dissemination are to take place. Such a climate recognises the need for change, engages in reflective critique, supports risk-taking, … and recognises and rewards those engaged in enhancing teaching and learning, and builds capability. That climate of readiness to move towards learning through inquiry characterised the AFFA recipients and played a large part in the success of their developmental activities.


Adopters [of innovations] usually encountered projects through some form of personal contact, such as discussion with a colleague or participation in a project workshop, … and, adaptation, implementation and embedding at the curriculum and departmental levels typically involved reinvention of the innovation.

Face to face visits as well as hands-on workshops were key to building engagement as well as forging links between academics. By working closely with academics in several universities the fellowship program had local relevance, while simultaneously creating a platform for disseminating those outcomes that have national value.

Dissemination of IOL occurred at national forums, for example through means of a workshop at the 2012 HERDSA and UniServe Science conferences. Workshops, and seminars were held within many institutions during the fellowship period in order to engage practitioners and disseminate the findings of the fellowship. Keynotes and plenary presentations were additional opportunities to communicate the messages of the fellowship and to engage academics in consideration of IOL.

7.1 Fellowship website

A website, <www.iolinscience.com.au/>, was a key fellowship deliverable. The website was created and went live early in 2012. It outlines the fellowship mission, draws together strands of the fellowship, gives a rationale for activities that took place during the fellowship period and provides an effective means of disseminating fellowship events and activities such as the National Forum that took place at the end of 2012. The website also acts as a repository for resource material created during the fellowship, such as the Adaptable Resource Kit (ARK) which provides resources to assist staff developing new, or revising existing, student experiments to incorporate a strong inquiry orientation2.

The look and feel of the website was largely due to a collaboration between Fellowship Program Officer, Ms Andrea Mears and Mr Mark Parry of Parryville who managed and coordinated the website content. This resulted in a website of high quality that is visually appealing, informative and easy to navigate.

The website described the background to the fellowship, its goals and strategies and allowed us to communicate the activities of the fellowship, including the work of academics who had been funded through the AFFA initiative. It is intended to update the website periodically and to maintain it for the next three years.

Table 7.1 below indicates national/international meetings where the fellowship was been represented. Information about the plenaries and seminars delivered as part of this fellowship can be found in appendix F.
<table>
<thead>
<tr>
<th>Event date</th>
<th>Event/Meeting title</th>
<th>Location: city and country</th>
<th>Brief description of participation</th>
</tr>
</thead>
<tbody>
<tr>
<td>28th-29th September 2011</td>
<td>Informa, 2nd National Learning and Teaching Forum</td>
<td>Sydney</td>
<td>I was invited to give a presentation to a national audience in which I explored the benefits to student, academics and institutions of connecting undergraduate students to research, with examples of how that can be accomplished.</td>
</tr>
<tr>
<td>10th-12th October 2011</td>
<td>Transforming Education: From Innovation to Implementation</td>
<td>Purdue, US</td>
<td>I presented at this international meeting. Title of my talk: Changing practice towards inquiry-oriented learning: what role(s) can an external agent play?</td>
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<tr>
<td>23rd November 2011</td>
<td>Festival of Learning: Adelaide University</td>
<td>Adelaide</td>
<td>This was an invited keynote in which I examined the potential benefits in connecting first year students to research and how those connections can be made.</td>
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<tr>
<td>7th February 2012</td>
<td>Implementing the Science TLOs</td>
<td>Melbourne</td>
<td>I ran a workshop which included unpacking the Inquiry and Problem Solving Threshold Learning Outcome</td>
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<tr>
<td>24th February 2012</td>
<td>Meeting of the Monash Educational Excellence Research Group (MEERG)</td>
<td>Melbourne</td>
<td>I ran an extended interactive seminar that discussed the processes the fellowship program adopted in order to stimulate and facilitate change in Australian universities towards inquiry-oriented learning in science, with a special focus on large first-year classes</td>
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<tr>
<td>2nd July 2012</td>
<td>HERDSA conference</td>
<td>Hobart</td>
<td>Invited workshop: Experiencing an inquiry-oriented activity: How was it for you? (This workshop was co-presented with Ms Katrina Waite of the Institute for Media and Learning at UTS)</td>
</tr>
<tr>
<td>19th-20th July 2012</td>
<td>ACDS Teaching and Learning conference</td>
<td>Sydney</td>
<td>This invited presentation examined: examples to assist in mainstreaming scientific inquiry in the undergraduate science curriculum; the role that a National Teaching and Learning Centre can play in progressing and supporting the mainstreaming of inquiry in the undergraduate science curriculum.</td>
</tr>
<tr>
<td>1st November 2012</td>
<td>ALTF National Forum</td>
<td>Melbourne</td>
<td>I gave my end-of-fellowship presentation to my peers. Title of presentation: Inquiry-oriented learning (IOL) in science: Transforming practice through forging new partnerships and perspectives. I also contributed my perspective and experiences on 'how to engage your own institution' (in your fellowship).</td>
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<tr>
<td>12th December 2012</td>
<td>Australian Institute of Physics Congress</td>
<td>Sydney</td>
<td>I presented a plenary at this biennial meeting. Title of presentation: Preparing demonstrators to facilitate learning in inquiry-oriented practicals</td>
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Table 7.1: National/international meetings at which the fellowship was represented
As evidence of international impact of the dissemination activities, I present feedback from Dr Peter Coolbear, Director of Ako Aotearoa, the National Centre for Tertiary Teaching Excellence in New Zealand.

Ako Aotearoa, New Zealand’s National Centre for Tertiary Teaching Excellence, was delighted to have the opportunity to host Professor Les Kirkup in May 2012. We hosted a workshop based at Victoria University, Wellington, and also facilitated Les meeting with the schools science curriculum team at NZCER and with key science educators at Massey University who have similar interests. Les’ visit was very timely given the emerging debate about both the science curriculum and pedagogy in science at secondary and tertiary levels within New Zealand. We have particular concerns about the transition from school to tertiary science and the disconnect between strong understandings about the nature of science gained through the New Zealand secondary school curriculum and the content overload experienced by many students in undergraduate science courses. The IOL approach provides some real opportunities to resolve that tension.

Of considerable interest to us was that some of the attendees at Les’ workshop at VUW were not science teachers. Our staff member, Ian Rowe, who hosted the workshop at Victoria provided the following comment: “For me as the organiser, the most revealing comment came from two tutors from Whitireia [Community Polytechnic] who taught on a social work degree. Their comment was that they were certain the method could be used in their non-science subject and they were excited to plan how they would alter some parts of their work to include enquiry methods.”

We are most grateful that the ALTC fellowship allowed Les’ excellent work to be extended to New Zealand. Dr Peter Coolbear, February 2013

7.2 Community of Practice on Inquiry and Research Integrated Learning (IRIL)

There is much interest in IOL that extends beyond the Faculty of Science at UTS. In response to a suggestion towards the end of the fellowship period made by Professor Shirley Alexander, DVC Teaching Learning and Equity at UTS, I created a Community of Practice (CoP) on Inquiry and Research Integrated Learning (sponsored by Professor Alexander) in part to explore and disseminate IOL across UTS. The IRIL brings a strong institutional/faculty focus to the role of inquiry in the undergraduate curriculum. The CoP is drawing in colleagues who might be on ‘the fringe’, but are nevertheless interested in exploring (and developing) inquiry in the curriculum.
Chapter 8: The fellowship experience

8.1 Factors critical to the success of the fellowship

The success of the fellowship was built on:

- an excellent Program Officer: Andrea Mears has exceptional organisational skills and a very student-centred orientation. These were a perfect match for this fellowship, and the fact that we worked so well together meant that many of the core goals of the fellowship were achieved;
- working together with the OLT/ALTC to maximise the impact of the fellowship, throughout the fellowship period and beyond. This led to opportunities that would have been missed, (for example to work with Engineers at Adelaide University) had it not been for timely advice from Siobhan Lenihan regarding the engineers’ interest in developing new inquiry-type experiences for their undergraduates;
- seeking the input of many people as the fellowship progressed. In particular all of the fellowship reference group were engaged in the fellowship and offered suggestions/insights at key stages of the fellowship. Their encouragement and commitment to fellowship, as much as anything else, ensured that its momentum was maintained;
- creating and strengthening relationships with academics and senior academic policy makers across science disciplines and across universities. In addition to assisting in mainstreaming IOL, the networks that have built up (some formal, other less so) will lead to the conversation on IOL (and other teaching and learning issues of national significance) continuing well beyond the fellowship period, and;
- timely input and feedback from the external evaluator. The complementary and extensive background and experience of the evaluator brought an important perspective to the fellowship. The evaluation can be found at http://www.olt.gov.au/resource-kirkup-les-uts-altc-national-teaching-fellowship-final-report-2013

I believe the success of the fellowship owed much to responding to the needs of stakeholders and proactively adapting the fellowship to areas of greatest potential and impact. For example through the interaction with Dr Cathy Foley of the CSIRO, it became apparent that CSIRO were keen to co-develop inquiry-type resources with universities (partly due to its potential to enhance CSIRO’s profile and give it a platform on which to engage with undergraduate science students). To move forward with a bold national initiative to connect with CSIRO and co-develop activities it was critical to bring in influential individuals (such as Professor Jim Peacock, ex Australian Chief Scientist) early to help shape the initiative.

Professor Peacock advised us not to be too ambitious, but to identify an area of national importance in which CSIRO was active that could act as a pilot and be, in effect, a proof of
concept. As described in chapter 6, a pilot activity (based around organic solar cells) has now been co-developed with Scott Watkins (Stream Leader, Organic Photovoltaics, at CSIRO at Clayton, Melbourne) and trialled with students and demonstrators. The activity will be embedded within the undergraduate science curriculum at UTS in 2013. More than 600 students will engage in the activity in 2013.

In engaging with a broad group of stakeholders we observed:

- While reaction to the fellowship workshops has been positive, it is apparent that work needs to be done to provide the incentive to move teaching and learning in the direction of IOL.
- There is a strong need for more specific, Australian-based, examples of the type described in appendix B developed by the AFFA recipients.
- Engagement of academics differs greatly and is largely dependent on an individual’s point in their career, their institutional responsibilities and the rewards/recognition accorded the developmental activities promulgated through this fellowship. Accordingly, there is need to tailor the delivery of the message about the value of engaging with IOL to the stakeholder(s).
- The appetite for engagement in IOL more broadly is driven by the quality assurance agenda. This agenda became more of a focus as the fellowship progressed.

A number of practical lessons have been learnt. Given the multi-faceted nature of the project it was necessary to be highly organised, communicate effectively at all levels, be persistent (but patient!), remain innovative and effectively integrate strategies in the given timeframe.

Ethics approval in particular was a challenging and time consuming activity with universities taking different views regarding the approval required (for example) for focus groups. Though Andrea Mears and I did successfully work through these issues with six universities, the cost in time was quite high.

8.2 Managing factors with potential to affect the progress of the fellowship

There was a temptation to play a bigger role in activities at my own university than is consistent with carrying out a fellowship program. My approach was to stay connected to my university and to be actively involved where I believed what I was doing benefitted both the fellowship and my university. An example of this was an initiative in physics at UTS to enhance the professional development of demonstrators in the lab – in particular to assist demonstrators to explore learning through inquiry and to also explore what they can do to assist students to learn through inquiry.
Another factor that can impede success is the transition period from full-on fellowship to full-on teaching. I was not as successful at the transition as I had hoped. I found that I was in the middle of very important fellowship business (in particular organising and delivering the national Fellowship Forum) and at the same time managing and delivering a significant amount of undergraduate teaching. I cannot say that this transition had a pervasive influence on the outcomes of the fellowship – but I believe that the issue of transition management is one that future fellows should be aware of.

8.3 Lessons learned, challenges and unexpected successes

Many opportunities to work with people and give seminars/workshops have emerged that were not foreseen when the original fellowship application was developed and submitted. Indeed the AFFA initiative only took shape after the fellowship began. Likewise, the CUUII initiative, with its potential for profound institutional and systemic change was not imagined until well after the fellowship was underway, emerging only after a key conversation with Dr Cathy Foley of CSIRO.

While what was done has been exciting and worthwhile, I ran the risk of following too many avenues taking time away from the activities approved in the nomination document. However these developing avenues were indicators of the extent of the need for IOL. There was also the risk of being too conservative and foregoing valuable opportunities that could have profoundly positive influences on the fellowship and its outcomes. Thus the fellowship has been a balance between following the original fellowship plans and making the most of opportunities for the long-term development and embedding of IOL. It is important for initiatives to secure institutional buy-in if they are to be sustained, and to this end the fellowship engaged academics at a range of levels and seniority and academic policy makers throughout this fellowship.
References


Appendix A: EOI

The ALTC Fellowship Funded Activities (AFFAs) were supported through a scheme in which applicants applied competitively for a small amount of funds to support the development and evaluation of an IOL activity. Below is the EOI pro forma that applicants were required to complete and submit.

Inquiry-oriented learning in science: Transforming practice through forging new partnerships and perspectives

General information for submitters of expressions of interest (EOIs) to support the development of inquiry-oriented activities

Inquiry-oriented learning in science: Transforming practice through forging new partnerships and perspectives is the subject of an ALTC National Teaching Fellowship recently awarded to Les Kirkup <www.olt.gov.au/altc-national-teaching-fellow-les-kirkup/>

A strand of the fellowship aims to facilitate the development of engaging, authentic, inquiry-oriented activities.

EOIs are invited from academics intent on developing, trialling and embedding inquiry-oriented activities into their curriculum.

This is a unique opportunity to be part of a national, multi-disciplinary community of practice and will provide successful applicants with opportunities to share their experiences and progress with others engaged in similar activities at several universities across Australia.

Successful applicants will develop, trial and evaluate an inquiry-oriented activity with the support from the fellowship, and prepare a short report on the process and outcomes of the development. They will also be expected to present their activity at a local or national workshop or seminar.

Each successful EOI will attract funding of $2000 and up to 10 EOIs will be funded. $1000 is available as the development of the activity commences with a further $1000 on completion of the trialling of the experiment.

A completed template should be submitted to Les Kirkup at Les.Kirkup@uts.edu.au by Friday 19th August 2011.

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3 Through inquiry-oriented activities, students:
- engage in scientifically oriented questions;
- develop approaches to address those questions;
- gather and evaluate evidence and formulate explanations based on that evidence;
- evaluate their explanations in light of alternative descriptions;
- communicate and justify their proposed explanations.

Adapted from Olson & Loucks-Horsley, 2000
If the number of EOI s submitted exceeds that which can be funded, then the selection of EOI s for funding will be based on the:

- clarity and completeness of the EOI;
- the extent to which the development draws in other staff, such as support staff or educational developers;
- potential influence of the activity (for example with respect to diversity and number of students impacted upon);
- quality of the dissemination strategy within your institution;
- practicality of proposed steps to sustain the activity;
- extent of endorsement by the Head of School or equivalent.

The successful EOI s will be selected by the fellow and at least one member of the fellowship reference group.

Expressions of interest

Please keep the completed pro forma to no more than three pages (excluding any attachment). The type should be no smaller than 10pt.

Please e-mail completed EOI s to les.kirkup@uts.edu.au, by Friday 19th August 2011.

<table>
<thead>
<tr>
<th>Name(s) of applicant(s), including titles, and affiliation</th>
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<th>Position(s) within the institution (please indicate if the positions are continuing, fixed term or casual)</th>
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<th>Activity and context: describe in broad terms the activity you plan to develop, any drivers for the development, which subject or unit it will impact upon, the level of the subject/course, and the typical number of students taking the subject/unit each semester</th>
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<th>Participants: who will you involve in developing the activity and how will they be involved?</th>
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<tr>
<td><strong>Timeline for the development of the activity</strong></td>
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<tr>
<td><strong>Dissemination:</strong> How will you disseminate your activity and its outcomes within your institution?</td>
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<tr>
<td><strong>Sustainability:</strong> What steps will you take to sustain your activity and embed it within the curriculum?</td>
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<tr>
<td><strong>Endorsement of your head of school/department or equivalent (this can be in the form of an attachment to the completed pro forma)</strong></td>
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Support for the production of this document has been provided by the Australian Learning and Teaching Council Ltd, an initiative of the Australian Government.
Appendix B: AFFA reports

This appendix includes reports from all nine AFFA recipients. The reports include details of the activities and how they were developed, trialled and analysed.

An inquiry-based physics lab for biologists (University of Queensland)

Margaret Wegener, Tim McIntyre
School of Mathematics and Physics, University of Queensland

Introduction
In the introductory service course “The Physical Basis of Biological Systems” students come from a wide range of backgrounds, many not having taken physics at high school. They are generally interested in biological or medical sciences. There are also some engineering students catching up on physics fundamentals. After previous success in developing an extended experiment especially for the BBiomed cohort in this course, we were keen to introduce another activity so that all students in PHYS1171 would be able to experience an inquiry-based lab. This approach fits with our interest in developing active learning in physics. The project fits well with the University of Queensland’s strategy of encouraging undergraduate research experiences, along with its drive for sustainable energy.

We have developed an inquiry-based laboratory module to illustrate concepts related to heat. We aim to improve student learning through inquiry-based activity. The goal is for students in small groups to take charge of the experimental design, developing their own method and analysis (with some guidance). The benefits of this experiment are that students:

- become more familiar with physical phenomena and their relative importance in a particular situation, in a research-like experience
- need to develop understanding of the relevant concepts and apply that knowledge to successfully perform the experiment
- work as a group to design their experiment and make decisions to optimise its effectiveness.
- practice general scientific skills such as interpretation of graphs in a meaningful way.
- gain experience with using modern sensors and digital data.

Methods
The topic of heat transfer and how thermal properties of materials affect that process is introduced in lectures. Various mechanisms that exist in nature are discussed. Examples include heat being transferred through a layer of body fat and radiated to the surrounds.

This experiment focuses on the physics of how the temperature inside a building varies over
time, depending on heat from the sun, atmospheric conditions, and the way it’s built. We were inspired to do this by an ANU undergraduate experiment. As reference, we used materials developed by others for similar activities.

The initial stage of the development process was feasibility experiments with sample sensors and materials. With a working prototype, we designed the learning activity. First implementation was with students enrolled in PHYS1171 in Semester I, 2012 (170 students). We evaluated the student experience and made some modifications. All non-BBiomed students in PHYS1171 in Semester II (enrolment of 310 students) did the revised activity.

Besides us (the two academics who teach the course), development of this lab module involved a number of other people. The Teaching Laboratory Manager and Workshop designer designed and created items for the experimental setup. The Lab Manager was also involved in sourcing instrumentation and writing required Occupational Health and Safety documentation. IT support staff set up remote monitoring of the experiment. UQ solar PV array researchers ensured that our students could access local weather and solar irradiance data. Through participation in the AFFA scheme we gained access to expert advice and independent external observers. The PHYS1171 laboratory tutors as a group worked through the experiment, spending considerable time discussing the apparatus and theory, and provided informal and structured feedback.

The activity is done in the later part of the semester, after students have some lab experience. It is structured as two three-hour sessions for students in small teams. In the first session, students start with guided experiments similar to the style they have done previously. They become familiar with heat transfer by exploring the importance of the type and thickness of insulating materials (using an adapted commercial experiment kit), and then making measurements with digital sensors in very short independent experiments. Teams then build a simple model house using a modular structure, choosing from a limited range of materials. The house is instrumented and placed in a safe location on the lab building rooftop to experience ambient conditions over a 24-hour period. Students are able to view their house’s internal temperature (and outside conditions) live via the internet. Images of the experiment are now also streamed live so students can see the progress of their experiment. In the second session, students discuss and explain the temperature data of the class houses, and then teams decide their own goal for the temperature of a structure, develop a design based on their acquired knowledge of heat transfer, and build it. This structure is tested in a similar manner. After each session students download their data for analysis and write a report.

We evaluated the lab via:

- observation and analysis of students working
- focus group of first student users
- survey of staff involved in delivering the activity

Academics visited the labs to observe students working on the experiment. The first time that the lab ran was observed by the ALTC Fellow. In the first implementation (Semester I), the course lecturers supervised and interacted with students when setting up experiments.
on the rooftop. All made professional judgements about what students were doing in the lab. Survey questions provided by the ALTC Fellow were used to obtain structured evaluation from staff (tutors, lab manager, academic).

**Analysis**

Assessment of outcomes occurred with three foci - practicalities, student attitudes and student learning.

With regard to practicalities, the experimental setup passed testing. Measurably different temperatures were obtained inside structures made of the various materials, and expected trends were apparent. Remote access to the data worked reliably. The activity was able to be done by students in the time available. Management of people and apparatus took more effort than usual for teaching staff. Acquiring extra equipment relieved pressure in one aspect, but it is still necessary to move some apparatus between lab and rooftop, and to have students supervised in both places. Using a rooftop tutor in Semester II made the experiment sustainable in terms of involvement of academic staff. The controlled variation in design made the activity’s supervising and marking load workable. Surveyed staff all agreed or strongly agreed that “The experiment worked”, “The laboratory manual had sufficient detail”, and “Assessment was manageable”.

Staff agreed or strongly agreed that “The experiment is interesting”. Students concur. All focus group participants agreed that the experiment was involving - “one of the best experiments we have done interest-wise”. The relationship to the real world was valued, and very successful in engaging students. They were entertained by the idea, eg: for the simple structure some announced they were going to build a “metal shed” or “esky”; someone’s report was labelled “The Hotbox”. The activity engaged students through a feeling of some ownership of design: “There was more room and control that made it different, it made it fun”. One group was sufficiently motivated to bring in their own materials to use on their structure. Students were interested in the novel experience of monitoring progress of their experiments remotely. Positive student attitudes to the activity were also apparent in the way that they were confident (and correct!) in their reasons for design choices based on physics of heat transfer.

As a measure of student learning, how the students performed on assessment was encouraging - tutors reported that most students got reasonable experimental results, and the standard of write-ups was fine in general. The experiences of the tutors were very valuable feedback. Assessment requirements were an area they suggested for more development, and some refinements were made in the assessment scheme and how students were directed in the lab, for the second offering.

Staff agreed or strongly agreed that “Students developed their conceptual understanding of physics”, “The experiment assists students to develop experimental skills” and “The experiment encourages students to think critically”. Students were conscious of the demands of this experiment on them: “You wonder ‘why’ and ‘why’ is a way of improving on what you know and consolidating what you brought into the experiment”. Advice from the external observer about using class discussions was particularly beneficial on this aspect.
The degree of variation in the structures that students built turned out to be significant. In initial experiments students were constrained to use one material so it would be simpler to analyse — most students did not originally appreciate this as an issue, showing a novice’s grasp of experimental design. On the other hand, variation in the structures built by different teams within a class was encouraged as a useful prompt for whole-group discussion.

The strategy of telling students that they had to design to achieve their own particular aims worked well. Their aims were as diverse as building a greenhouse; minimising temperature variations; making as hot/cold as possible. Most aimed to make a house comfortable for humans. A fairly wide variety of designs was used. The strategies students used in building their structures showed a range of effort. Some were straightforward applications of physics principles, eg: adding ceiling insulation layer. Others were more complex or original, eg: house built of double-layer walls with air gap; clear Perspex wall oriented to afternoon sun. Only a few design choices were questionable.

Student work shows use of physics knowledge that students had gained. Some final designs were informed by the first simple experiments, eg: finding that clear Perspex traps heat. Use of material of low thermal conductivity, and significant thickness, was informed by their measurements of conductivity, and what they knew of theory. They were able to apply the physics, eg: using triple layer of one material. Decisions about orientation of the structure, and choice of wall surfaces, eg: white and black walls to manage reflection and absorption of sunlight, showed some understanding of relevant theory.

Incidental learning occurred. With some students, thinking about the optimum orientation of their structure prompted discussion of seasonal variations in the path of the sun through the sky, so some more physics was learned.

Evidence of understanding occurred unexpectedly when students spontaneously identified from other students’ structures what their design aims had been (ie: they successfully interpreted the physics).

Asked to rate this activity as a learning experience, all staff involved agreed that the experiment is valuable (the group judging its quality as 4 on a scale of 5).

Conclusions
The aspects of this activity that worked particularly well were the semi-realism of the scenario, student ownership of experiments, and controlled variation in what students did through the design choices possible. These provided engagement, better motivating students to understand the physics involved, and a range of opportunities for learning, while being sustainable in terms of equipment and staffing requirements. Evidence of learning is seen in students successfully applying knowledge that they had gained – understanding of theory and/or results of preliminary experiments. This assessment of outcomes is paired with overwhelmingly positive evaluation by staff.

By doing this lab module in an introductory course, students are engaged in real scientific activity at the start of their university study. They are interested in their experiments. They
have to deal with problems that arise. They come across other interesting questions as they try to achieve their goal, and learn some more science in the process. Therefore the inquiry-based activity has been very effective in engaging students in science.

We plan to extend the experiment to include another biologically relevant situation involving heat transfer - the insulating characteristics of animals. In each possible experimental pathway, then, students would be aiming to regulate an internal temperature in their model structure (animal or building) exposed to a varying external environment. This project’s results have already been disseminated via the national Fellowship Forum, and presentations internal to UQ, both with positive audience reactions. With the further development outlined above, we expect to have something sufficiently original and worthwhile for presentation at science education conferences, and for publication in international journal(s).

Finally, we want to say that inquiry-based labs are more interesting and more challenging than recipe-based labs for everyone involved – the students, tutors and academic staff. The extra challenge is worth it.
Development of POGIL-style classroom activities for an introductory chemistry course (Adelaide University)

**University of Adelaide**
Dr Natalie Williamson, School of Chemistry & Physics  
A/Prof Greg Metha, School of Chemistry & Physics  
Dr David Huang, School of Chemistry & Physics  
A/Prof Simon Pyke, School of Chemistry & Physics  
Dr John Willison, School of Education (formerly of the Centre for Learning and Professional Development)

**Project Summary 2nd November, 2012**

**Introduction**

Level I Foundations of Chemistry IA (semester 1) and IB (semester 2) courses at the University of Adelaide are undertaken by students pursuing a wide variety of degree programs, many of which require a year of chemistry at first year level. As a consequence, many students who have never studied chemistry in high school enrol in these courses, which can have up to 350 students enrolled each semester. Prior to 2012, neither Foundations of Chemistry IA nor Foundations of Chemistry IB had SACE Stage 2 (Year 12) chemistry as a prerequisite, but assumed much of this knowledge, resulting in students who had never studied chemistry before (i.e. no Year 11 or 12 knowledge) having to come to terms with this unfamiliar course content very quickly. Some students thrived in this situation but others found it more difficult. For the latter group of students, the study of chemistry can be a roadblock preventing their progress through their chosen degree program.

The discipline of chemistry recognised that in the years to come, more and more students who have not studied chemistry at secondary school will be enrolling in degree programs that require a year of chemistry study. The discipline wished to maximise learning opportunities for these students by revising not only the content of the Foundations of chemistry courses, but also the way in which they are taught.

The combination of Foundations of Chemistry IA and IB will provide students with a good basis of chemistry knowledge that will enable them to continue their studies in level II courses not offered by the discipline of chemistry, but which may have first year chemistry as a prerequisite.

Course content for the new Foundations of Chemistry IA and IB now begins at an introductory level, rather than assuming any prior chemistry knowledge. Each semester-long course consists of four modules, with group-based Process Oriented Guided Inquiry Learning (POGIL)-style activities used to deliver the majority of the course content. Regular assessment through online tasks and short in-class tests provides students with continual feedback to guide and monitor their progress. It was anticipated that these group learning sessions would give students more of an opportunity to actively engage with the course content than the previous format provided.

Course content needed to be significantly revised, and in most cases completely rewritten, to accommodate the restructure of these courses, including the incorporation of group-
based learning activities.

A POGIL activity begins by providing students with some information, in the form of a paragraph or two of text, a diagram or a table, followed by guided inquiry questions that allow students to make their own connections and build understanding by doing.

The aim of this project was to develop POGIL-style activities in the area of introductory organic chemistry, with their construction guided by feedback from current chemistry students. Very few POGIL activities exist for introductory organic chemistry (much of what is already available is for second year-level college courses in the US and as such is aimed at too high a level for this course), so we wished to develop activities to cover subtopics such as systematic nomenclature, physical properties of organic compounds and functional groups for use in the semester 2 Foundations of Chemistry course.

**Approaches and analysis of results**

Development of three organic chemistry POGIL-style activities began in late 2011, covering the topics of proteins, physical properties of alkanes and introduction to alkenes and alkynes. A small-scale trial with first year students who had just completed Foundations of Chemistry studies was conducted in November, 2011. Students were introduced to the activities and the rationale behind their introduction and implementation, and were then asked to complete the activities in the same way as a student in class would. At the end of the session, students were asked to complete a survey, featuring both Likert-style and open-ended questions, in order to give their feedback on the activities. The response to the activities even in this early iteration was extremely positive, with 100% broad agreement for all Likert questions asked:

- The activities stimulated my interest in organic chemistry
- It was clear to me what to do in the activities
- The activities helped me to develop my thinking skills (e.g., problem-solving)
- I understand the concepts presented in these activities
- Completing these activities has given me more confidence in approaching assessment tasks in organic chemistry

Responses to the open-ended question “Overall, what was the best aspect of the activities and why?” included “You can share ideas and learn from each other”, “Student involvement and participation and engagement. Problem-solving skills” and “A student can read anything, but when it comes down to doing questions and testing that knowledge, as done in these worksheets, that’s where the real learning happens.”

Students in the November workshop also provided some constructive ideas on how to improve the activities, especially commenting on the need for the activities to be less text-focused. Based on this feedback, the activities were updated in early 2012 and then trialled again in April 2012 in a workshop session featuring a mixture of second year and postgraduate chemistry students. The structure of this workshop was the same as the one held in November, but in addition, a focus group was run following the workshop session to enable more time for conversation and general feedback. A paper survey similar to the one
used in the November workshop was provided to participants, who were asked to complete it to give their feedback on the activities. Once again, the responses were extremely positive, with 100% broad agreement for all Likert questions asked, which included the first four questions used in the November survey, with two additional questions: “There was a strong inquiry focus to the activities” and “The activities helped me better understand chemistry”. Responses to the open-ended question “Overall, what was the best aspect of the activities and why?” included “Interactive. Keeps students focused. Independent learning”, “They weren’t too long so I didn’t feel overwhelmed. There was a logical progression between parts”, “Learning by example/problem solving. Keeps you awake in lectures! Allows you to get a better grasp of the concepts by actually applying them.”

Further feedback on the structure and content of the activities was provided by participants in the April workshop, which was used to further refine the activities in preparation for their implementation into the semester 2 Foundations of Chemistry course in July/August 2012.

Discussion and conclusion

The use of workshops and a focus group to trial the activities were extremely beneficial. The students who attended the workshop sessions provided valuable feedback that gave us an insight into their thoughts about inquiry-based learning and also greatly assisted with refining the activities before their implementation. This feedback was especially useful in the development of the proteins activity: initially, this activity featured a very text-heavy introduction, providing students with a large amount of information that needed to be read before they could even begin to work their way through the questions that followed. Attendees in the first workshop picked up on this, and suggested that the activity be made “less wordy”. This advice was taken and the information at the start of the proteins activity was reduced from almost a full page of text to just under half a page. The other activities were also revised based on feedback from the first workshop, and were received favourably when trialled in their revised form in the second workshop.

The focus group held after the April workshop resulted in a wide-ranging discussion between participants. It was clear that these students wanted to use their perspective as senior chemistry students to enhance the activities. The focus group participants all recognised the need to incorporate interactivity in lectures, and were extremely supportive of the introduction of this style of learning into the new Foundations of chemistry courses, with one participant commenting “I wish my lectures were like that now”. Additional comments during the focus group session further supported the use of inquiry-based learning: “It definitely helps you to develop skills more than traditional lectures” and “What really helps with learning is that you are doing it yourself rather than the traditional where someone is telling you something and you take in one word out of every thirty.”

The group agreed that it would be beneficial if inquiry-based learning was introduced into Science (not just chemistry) courses at higher year levels; however, they stressed that beyond first year, it was important that inquiry-based learning be used to support traditional lectures (for example, in tutorials), rather than replace them entirely.

This project began with the relatively simple aim of obtaining students’ feedback in order to improve the teaching materials that we were preparing. This aim was certainly achieved; however, an unexpected side benefit was seeing the thoughtful nature with which the
Inquiry-oriented learning in science

Student volunteers approached this task in providing us with their views and ideas regarding not just the technical aspects of activity structure and content, but also the deeper concepts of how they approach their own learning, and the ways in which inquiry-based learning would be beneficial to them and to future students taking the course.
Inquiry-oriented Learning in Physics at Murdoch

Chris Creagh and David Parlevliet

School of Engineering and Information Technology, Physics and Energy, Murdoch University

At Murdoch University there are two first year physics mechanics units, one is algebra based, co-ordinated by David Parlevliet and the other is calculus based, co-ordinated by Chris Creagh. Both units have between 70 and 120 students in them, most of whom are not physics students. The continual challenge is to engage the non-physics students at an appropriate level while maintaining a high quality unit that extends the physics major students. One way of doing this is to make the units as student focused as possible. This allows students to achieve at a level they are comfortable with.

There are two traditional mathematical based assignments in each unit. The third assignment is based on students identifying physics in the real world, performing a self-developed proof of concept experiment and producing a scientific paper on the whole activity. There are multiple choice tests on the content in each unit and traditional labs that relate to the content. There are also tutorials which were originally intended to go over assignments but which have been more recently utilised for testing different ways of engaging students in the learning process.

Inquiry-oriented Learning (IOL) activities are the latest and probably the most successful of the initiatives we have been trailing in order to engage students in their own learning. Anecdotally the retention rate in the tutorials is better, there is good working noise during the activities, the students seem brighter and more likely to try an activity and the tutors seem to be enjoying themselves as well. So now we have a mix of activities in the tutorials consisting of the best of each of the past activities.

Some of the IOL tutorial activities were originally developed as labs for external students. In previous years external students were sent a kit of equipment to enable them to do their labs in their own home. This became unwieldy as the numbers of external students increased and the ability of the postal system to get packages to the students decreased. This necessitated creating experiments that students could do with equipment they could find around them i.e. they were the experimental designers. The latest experiment they have been asked to design is “Given that you have a refrigerator and an electric kettle find the specific heat of water”.

Other IOL tutorial activities were developed almost on the spot by just reworking the introduction to the activity. “Demonstrate the sharing of voltage across two resistors in series where one resistor has a variable resistance” becomes “Many circuit components are characterised by obtaining their IV curves. Design and build a circuit that can do this for a resistor and then a LED. Compare and contrast the two curves.”

We have also developed IOL activities for projectile motion and heat transfer in materials. These have been implemented in small group tutorials with some success. Although no formal survey on the experience has been conducted as yet, informal feedback from the tutors was very positive. Students reacted favourably and were more engaged during and
Inquiry-oriented learning in science

IOL can be applied outside of the tutorial and classroom for larger scale schools-on-campus activities. We have developed a workshop based on the concept of designing a solar powered mobile phone recharging station. Here small groups are given some materials including solar panels, multimeters and mirrors and asked to design a charging station from a design brief. Supporting materials are provided to help make sure people have the information they need to tackle the activity with confidence. The activity can be scaled to different groups with different backgrounds.

Once we had the basic concept of using IOL activities they started to pop up everywhere we felt students needed to engage more, lectures, on-line discussions and tutorials sometimes with only an hour’s notice. Our thought process became “The content is in the previously recorded lectures and in the text book so how do I provide the environment that gets students working with this material rather than passively sitting there waiting to be entertained?”

Even relatively simply IOL activities could be used in traditional lectures to improve audience engagement. Within General Physics towards the second half of second semester active learning and small inquiry-oriented activities (5min in length) were incorporated into the traditional lecture format. No formal survey on this was conducted, but anecdotally the audience came alive and the atmosphere in the lecture lifted. Students were more attentive and willing to engage in discussion and ask questions after these activities.

I have a sneaky feeling we are heading towards flipping the classroom. David has already made some short videos of experiments. Both of us have made them of lecture-demonstrations. I recorded my lectures (PowerPoint and audio) sitting in-front of my computer years ago which has given me room to make my real-time lectures more interactive. I think we are just waiting for a way to record mini lectures that looks semi-professional. We were supposed to get recording rooms this semester but they have been lost in the university reshuffle. It looks like we are going to have to work this one out for ourselves. Next year we start to move to a new and more flexible learning management system and a new lecture capture system which allows desktop editing. It cannot come soon enough. We can then seriously start to work on mixed modal learning and teaching in which IOL can play its significant part.

Where to next? More activities will be incorporated as we move towards a flipped classroom. The engagement and enthusiastic discussion that comes out of IOL activities gives students a good incentive to turn up to lectures and tutorials. Chris is applying for a National Teaching Fellowship that will combine the concept of IOL and the multiple representations an expert uses to communicate their understanding in a “Work It Out” sort of way. In other words we have not finished yet; watch this space!
Model building Approach to Optics (Flinders University)

Maria Parappilly
School of Chemical and Physical Sciences, Flinders University

Introduction
As a part of the ALTC Fellowship 2011 grant, we have implemented an interactive computer lab (3 hour lab session, week 10) in semester 2, 2012 where the students built simulation themselves and explored various aspects of geometric optics (building lenses in different shapes, making ray diagrams for lens combinations- bi concave, convex lenses themselves & learning theory behind it) using the Mathematica software. One of the simplest and most useful lens combinations is the astronomical telescope. This computer based lab was configured in such a way to allow students to work alone and to promote their independent learning. After this interactive lab, students performed a laboratory experiment where they built an astronomical telescope (week 12). To equip first year students with the concepts and skills required in designing an experiment, we trialled an Inquiry-based practical in Semester 2, 2012 as a part of this Fellowship grant and the SaMnet Project. The aim of this lab was to promote higher order thinking, creativity and learning. Studies (Etkina, Kareлина et al. 2010) reported that when students engaged in the design of experiments, they not only developed scientific abilities but use them without prompts and scaffolding on transfer tasks. One of the practical classes was changed from a ‘recipe’ format to an inquiry-based format (IB lab) that drives students to design and execute their own experiment.

The key question to evaluate the effectiveness of this new lab was: What are students’ attitudes and perceptions towards inquiry-based practicals compared to traditional, recipe-based practicals. Inquiry-based practical evaluation involved students completing an anonymous questionnaire. A survey instrument based on a semantic differential format was developed to gather students’ feedback. This survey instrument has been used previously in published studies (Chatterjee et al. 2009). We have obtained ethics approval (#5757 SBREC) for the data collection.

Approaches/Method
It is a common perception that traditional recipe based laboratory experiments are generally boring, non-interactive and non-engaging. Inquiry-based experiments are usually designed to introduce concepts compared to recipe based labs which are for the confirmation of concepts (Abraham 2011). We have implemented an Inquiry based lab on radioactivity for non-physics majors in semester 2, 2012. The students were given 5 traditional and then 1 IB lab. We encouraged students to acquire prior knowledge through literature, synthesize the information and then design their own experiment incorporating innovation and techniques. In the light of students’ feedback, we offered a set of lab activities to students to choose from. These activities were designed in such a way to explore and critically examine their new lab experience where students to take charge of their own learning and time management.

Two weeks before the delivery of the inquiry-based laboratory, a focus group was held to trial the laboratory. The formation of the focus group was put together by inviting students to participate via Flinders Learning Online (FLO) discussion forum. The focus group consisted of four students and was designed to assess how an inquiry-based laboratory might be
useful for students to investigate some of the principles they learn in the lectures rather than simply following a recipe to produce results and back up basic principles. The aim of this focus group meeting was to gauge their initial response to the experiments and to provide feedback as to how to better present the inquiry-based laboratories to all the students in the topic. To gauge students’ prior knowledge of radioactivity, we distributed a pre-lab questionnaire prior to the commencement of lab. Reading materials were given to help them acquire prior knowledge to design their own experiment incorporating innovation and experimental techniques. Four activities on radioactivity were posted on FLO for students to choose from.

Findings/Discussions
Evaluation of the inquiry based practical involved students completing a Semantic Differential Survey about their attitudes and perceptions towards IB labs (Chatterjee et al. 2009). 72% of students felt they had to do a lot of thinking and analyzing when doing the inquiry-based laboratory reports. Although only 36% of students preferred IB labs over recipe based labs, 55% of students believed that they learnt more with IB lab than recipe based lab (Parappilly et.al 2012).

Research statement 1 and 2 asked about students attitudes towards IB lab. Results indicate that 64% of students have a more positive attitude towards Inquiry based labs. For Statement 3 “It takes a smaller amount of effort to complete the inquiry-based laboratory reports”, 95.4% of the students rated it between 1 and 0, where such a range of scores defines broad agreement. They all agree that it takes larger amount of efforts to complete IB lab reports. The survey result for statement 3 could support the findings of (Laws et al. 1995) though we have not collected the data on gender basis. The analysis of the responses to statement 4 “I have to do a lot of thinking and analysing for doing the inquiry-based laboratory reports” is of particular interest to us, since it tested the effectiveness of inquiry based lab to promote higher order thinking skills. 72% students strongly agreed with the statement. This may be due to the guidance provided by the focus group of students or the design of pre-laboratory questions enhanced their thinking skills. Thinking Skills which is what we expect as these are not recipe based laboratories. These results are in agreement with (Etkina, Karelina et al. 2010). The survey response shows that while 54% students found inquiry based labs were fun to do, there is almost 46% disagreement with this statement. Responses to the statement “I would choose to do an inquiry-based laboratory over a recipe-based laboratory” show that 67% students prefer to have procedures included in the lab reports.

Future work
As a part of this project, we have implemented a computer based simulations lab (CBSL lab) on Geometric Optics in week 10, semester 2, 2012 and after that students performed a lab where they built as an astronomical telescope in week 12. All students were invited to complete a survey. We are still in the process of collating the data and analysing the survey results.
References


Introduction of inquiry-oriented activities into Biology of Animals: A first year unit at the University of Tasmania.

Dr Regina Magierowski and Dr Ashley Edwards,

School of Zoology, University of Tasmania

Introduction
The first year experience can be an overwhelming one for many reasons and early negative or boring experiences can result in reduced student engagement, motivation and retention. Our overall aim was to introduce hands-on inquiry-based exercises to a first year zoology unit to create a more positive and relevant learning environment for our students (Vernon and Blake 1993).

The unit selected was Biology of Animals (KZA 161) this unit provides an introduction to the scientific study of animals. Students are introduced to the characteristics of the major invertebrate and vertebrate phyla from the perspective of an evolutionary interpretation of diversity. Lectures in comparative animal physiology, with an emphasis on Australian examples, provide a functional basis for an understanding of animal adaptations. In 2012 there were 290 students enrolled in the unit. The student base was broad and diverse, including international and mature-aged students, incorporating service teaching into multiple degree programs including Biotechnology and Biomedical Research, Agricultural Science and Natural Environment and Wilderness Studies.

Student feedback on the unit through the UTAS formal process of unit evaluation (Student Evaluation of Teaching and Learning, SETL) is overwhelmingly positive. However, our own qualitative assessment of examination results suggest that students do have difficulty dealing with the quantity of information they need to learn, and in seeing the big picture amongst a wealth of detail. We thought this problem could be alleviated if the students had a better understanding of the ‘evolutionary story’ presented across the unit, i.e. if there were a greater emphasis on the evolution of animals from earliest to more recent rather than a ‘snap-shot’ approach to each taxon.

Our specific aims were to modify two existing practicals, the first critical practical of the semester and a flexible-learning practical on the Phylum Mollusca. Dr Regina Magierowski developed the practicals with assistance from Dr Ashley Edwards and mentoring from Prof. Sue Jones. Zoology’s laboratory manager Kate Hamilton was involved with developing and road testing new teaching materials and past and present PASS (Peer Assisted Study Sessions) tutors (Ben Haliwell, Ee Jon Yeoh and Bianca Deans) tested new teaching materials and provided feedback and fresh ideas. The students of KZA161 completed a feedback sheet and some participated in a focus group session with Assoc. Prof. Les Kirkup after completing their mollusc practical.

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Methods

Introduction of a self-paced activity to week 1.
Students were asked to access (online) an interactive application “Introduction to Microscopy” recently developed by Dr Fiona Bird and team from the Department of Zoology at La Trobe University. Once the students had completed the activities within the application they were asked to complete a small inquiry-orientated activity within the first-year zoology laboratory.

The activity achieved a number of aims:
1. Shifted much of the introductory material from their first practical (week 2) into week 1. This provided more time for inquiry-orientated activities in week 2.
2. Encouraged students to come into the first year laboratory and meet their practical coordinator (Regina Magierowski) in smaller groups.
3. Gave the students the opportunity to complete their first piece of practical work in a less intimidating environment.
4. The inquiry-orientated component of the activity encouraged the students to get hands-on and thinking in the first week of semester.

Redevelopment of Practical 1 (Week 2)
The aim of this re-development was to get students thinking/talking and excited about the evolutionary story about to unfold in lectures. Lectures were modified to include more in-depth coverage of the topics of natural selection and adaptation. These are important concepts to understand in this unit which covers the characteristics of the major invertebrate and vertebrate phyla from the perspective of an evolutionary interpretation of diversity.

Having students gain basic microscope skills through a self-paced activity in week 1 rather than during formal practical time freed up space in the first formal practical class (week 2) to implement an inquiry-orientated activity on freshwater invertebrates. This activity added a little fun to their first practical session and covered important concepts like natural selection and adaptation. The practical included a number of challenging questions that encouraged the students to think about diversity within this interesting group of organisms and how this practical would help them to understand the differences among the major animal groupings covered in the unit.

Redevelopment of an existing flexible practical on the molluscs (week 8)
We redeveloped an existing flexible learning practical on the phylum Mollusca to make it more inquiry-orientated. During the redevelopment we held a focus group session with past students and PASS leaders to discuss implementing inquiry-orientated activities into this practical. The aim was to test some of our ideas on this group. The group also came up with some great suggestions that were then incorporated into the practical.

To help us gauge the success of our redevelopments the students were asked to complete a short survey after they completed this practical. Les Kirkup visited this week and led a focus session with a small group of students to further gauge their response and feedback to the new practical.
Other activities

- The grant allowed us to purchase new display material (e.g. prepared slides and animal specimens) and technologies for the 1st year laboratory.
- Regina and Ashley contributed to staff meetings in Zoology on implementing other inquiry-orientated activities into zoology units.
- We added an inquiry-orientated component to our demonstrator training workshop.
- Regina has begun developing an existing osmosis practical in a zoology foundation unit to make it more inquiry-orientated.

Analysis

Student feedback in 2012 through the UTAS formal process of unit evaluation (Student Evaluation of Teaching and Learning, SETL) was again very positive (scores on average were >4 out of 5). We can also report that in comparison to 2011 student retention was proportionally higher and there was a clear improvement in final results.

Les Kirkup reported that focus group of students (9 students) spoke extremely positively about the flexible mollusc practical, concluding that the students had fun, engaged deeply and learnt more in comparison to more traditional practicals. He also reported that the students enjoyed the challenge of this practical and while it made them nervous they enjoyed the introduction to experimental design. This was encouraging as one of the particular challenges for redeveloping this unit was how to incorporate inquiry-orientated activities into a unit that has no experiments. We decided that we could help the students develop the skills necessary to participate in inquiry-orientated activities by focusing our redevelopments on flexible learning, group participation and the basics of experimental design (students were encouraged to form hypotheses and think about how they could design experiments to test these).

The survey conducted after the mollusc practical was completed by 119 students and was therefore more representative of the overall class response to the practical. Common responses among students included:

- They liked the flexible nature of the prac (no time pressure and opportunity to work in groups) and the opportunity to be creative and make decisions independent of teaching staff.
- They didn’t like the reduced opportunity for feedback and reassurance from demonstrators and some needed more detailed descriptions of what that had to do.

Conclusions

Overall the developments to KZA161 were successful and appeared to get students enthused, thinking and participating right from week one. Incorporating inquiry orientated activities encouraged the students to think independently and helped them to understand the big picture in this unit. Student retention in this unit was proportionally higher in 2012 than 2011 and we saw an improvement in final results. We believe that this was due in part
to the developments we made to improve links between the lectures and practicals, the incorporation of an evolutionary narrative and because the incorporation of inquiry-orientated activities fostered a friendly atmosphere where students felt comfortable approaching teaching staff and asking questions.

To further improve the first year experience we need to continue to develop the practicals in this unit and think more about how we can give students the skills to be independent and more confident in their own abilities. Our first job will be to address some of student’s concerns about the new mollusc practical. While most students enjoyed this practical there was a clear need for additional guidance about what they needed to do and for additional teaching staff to provide feedback and help keep them on track.

This first step was encouraging and we plan to continue to look for opportunities to incorporate inquiry-orientated learning into other zoology units.
Experiences in Inquiry: Exploring the experiences of coordinators, tutors and students involved inquiry-oriented laboratories in science (University of Queensland)

Dr Kirsten Zimbardi and Dr Kay Colthorpe
School of Biomedical Science, Faculty of Science, University of Queensland.

In 2007, a review of the Bachelor of Science (BSc) program at the University of Queensland (UQ) led to recommendations for a revised curriculum which actively engages students in research-like and inquiry-oriented experiences throughout their entire undergraduate degree. To achieve this goal, during 2008-2011 we designed and implemented a series of vertically-integrated inquiry-oriented practical curricula across the Biomedical Science major (enrolling 900 students per semester in 1st year, to 220 students per semester in 3rd year). These practical curricula were designed so that students would work with increasing autonomy and ownership of their research projects, to develop increasingly advanced skills in scientific investigation and communication, using the framework of Willison and O’Regan (2007). Students undertaking the first iteration of these three vertically integrated courses reported learning gains in each of these areas, as well as course content, as a result of participating in the inquiry-oriented curricula and completing the associated practical assessment tasks (Zimbardi et al. submitted).

In 2009, we interviewed a sample of course coordinators (n=5), tutors (n=12) and students (n=15) involved in the biomedical science courses during their transformation from traditional, prescribed (‘recipe-based’) laboratory classes to inquiry-oriented classes with varying degrees of openness. As part of the ALTC Fellowship Funded Activities (AFFA) of ALTC Fellow Assoc Prof Les Kirkup, we identified key themes from these interviews and developed a series of narrative vignettes documenting the experiences of these participants in their own language. These three perspectives provide valuable insights on 1) the process of designing and implementing inquiry-oriented laboratory classes, 2) the changing facilitation roles experienced by tutors, and, 3) the experiences students have in traditional-prescribed and inquiry-oriented laboratory classes. In addition, during 2012, undergraduate science students undertaking one of the inquiry-oriented classes were invited to participate in focus group interviews. The outcomes of these interviews were compared the student narrative vignettes and used to revise the vignettes where required. Full versions of these narratives are available at www.kzimbardi.pbworks.com

Student experiences of the transition to inquiry-oriented curricula described in the interviews, and thus the narratives developed from them, clearly indicated that different students experience the curricula and its impact on learning in different ways. Specifically, it appears that regardless of how open the curricula design was, the degree of autonomy experienced by the students was more dependent on the degree of leeway provided by a tutor to a student during the implementation of the inquiry-oriented class, and the prior experiences of the student with inquiry-oriented projects. These experiences subsequently determine the degree to which students feel responsible for the planning of experiments and interpretation of experimental findings, which ultimately influences the degree to which students believe they are gaining experience in developing skills such as critical thinking.
Tutors generally perceived a shift in their roles with the transformation from recipe-based curricula to inquiry-oriented curricula. Firstly, tutors found that inquiry classes were more fun to teach. In inquiry-oriented classes, tutors saw their major role as facilitating learning by encouraging students to think about the scientific process and about the findings, expressing this as guiding the students to learn rather than demonstrating. Tutors also highlighted that inquiry classes gave students the opportunity to understand the perspective of the scientist.

In designing and implementing the inquiry-oriented curricula, coordinators described several key features that they saw as essential to success. These included enabling students to make their own decisions about which topics to explore and which experiments to perform. Coordinators also highlighted that the desired learning outcomes differed between inquiry and recipe-based classes. Where the latter were useful for teaching specific content and technical skills, inquiry classes allowed students to learn these aspects and additionally to develop their understanding of the processes, thinking and communication relevant to their science disciplines. One important distinction coordinators made between inquiry and recipe-based curricula concerned the role of the tutors, and the impact this distinction had on tutor training. While tutor training for recipe-based classes focused on content knowledge and process, for inquiry-oriented classes, tutor training was directed at how tutors interacted with students, and how to mark and give feedback on the more open-ended assessment tasks that focused on experimental design and interpretation of experimental findings in relation to scientific literature. Although some coordinators raised concerns over scalability of inquiry-oriented curricula, they also testified to successfully implementing inquiry-oriented curricula for cohorts over 800 students.

Furthermore, each of the three stakeholder groups interviewed gave insights into the ways in which inquiry curricula foster critical thinking and problem solving skills. Across all of these stakeholder groups, this theme of learning outcomes resulting from inquiry-oriented laboratory practicals mapped consistently to the LTAS Threshold Learning Outcome (TLO) for Inquiry and Problem Solving, TLO 3 (Jones et al 2011). Extracts of interviews from each of the stakeholder groups mapped against TLO 3 are provided below (table 1), highlighting the close connections between aspects of the inquiry curricula and the development of critical thinking skills in science.


Table 1. Mapping of quotations from each stakeholder group against each of the components of TLO3 - Critically analyse and solve scientific problems by:

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<td>There was nothing really that was similar to what we were doing in our prac – no-one had thought of it and there was nothing online. So we had to find articles of just similar things. We researched articles on oil spills, but we were picking up Ping-Pong balls which was very different. We used similar concepts derived from oil spills – not the detergent obviously, or the foam, just the net and found that we could use this.</td>
<td>For inquiry the students have to think. They have to go to the journals and they have to study about the past and then apply their knowledge in the prac.</td>
<td>In the inquiry style the students look at literature. They talk to each other. They talk to the tutors as much as they can. And their tutors are told to give them strategies with which to perhaps answer their question. Often they can explore something that may not necessarily be correct. But they’re exploring it - the experimental approach that they are taking is valid and robust and their ideas can be validated on their results.</td>
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3.1 gathering, synthesising and critically evaluating information from a range of sources

3.2 designing and planning an investigation

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<td>Because you gain an understanding because you have to think about it. You’re forced to design an experiment, and so like in the act of designing an experiment you basically, you have to know at least something about how the concept works to design an experiment, otherwise you’re just going to design rubbish. So when it comes to designing an experiment you end up thinking about what the end result might be, then you start hypothesizing for yourself.</td>
<td>With inquiry, students get to design their own experiment and decide which path they would like to go down. For the first half an hour of a prac they’ll sit there and discuss what they would like to do and they discuss various underlying mechanisms and “Would it be good to do this and this? Or that and that?” There’s a lot interaction. Peer-to-peer and also asking questions of me – whether they’re going in the right direction or whether their hypothesis is correct.</td>
<td>The inquiry style means students are given some kind of background detail, and then have to make some decisions themselves about what they’re going to do. The fun part about is that there is no defined answer, so any answer is okay.</td>
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3.3 selecting and applying practical and/or theoretical techniques or tools in order to conduct an investigation

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<td>My first year biology courses included both recipe based and inquiry based prac. The inquiry pracs I found to be more challenging, interesting and engaging. I liked that they gave me some freedom to design a hypotheses and the experiment myself. I’ve done plenty of pracs where I’ve just not really understood what’s going on, I’ve just gone like ding, ding, ding, ding, ding, ding, product.</td>
<td>As a tutor, I’m there to just guide them and steer them in the right direction. So I get them to talk about, think about what they are going to do and I listen to what they’re discussing. I help to guide their discussions and thinking by asking questions, giving some tips and help them think of how they can improve their ideas or make the experiment better and steer them in the right direction. The most important thing is to listen to what they have to say first, see what they’ve come up with first. Then you give them the tools to go and find out for themselves.</td>
<td>They engage with the information in an active way. After they have decided what they’re going to do, they have to work through the experimental design itself, linking a hypothesis with your methods, making sure the actual methods will test the hypothesis, controlling for human variability, plus the actual practical skills of being able to hook up a toad or taking measurements from a human. And it’s through this whole process of them doing and then receiving feedback that they learn; and then repeating the task in a similar setting, a different theory or a different context.</td>
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3.4 collecting, accurately recording, interpreting and drawing conclusions from scientific data

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<td>At the end of the day though in both types of prac you come knowing the same stuff, with increased knowledge because you still have to discuss why the results appeared the way they did which happens in both.</td>
<td>Where they really learn, is when they don’t get the answers that they think they would and there is a gap. And then they have to go and try and explain that by logically going through things from A to B. They might not know all of the answers by the end of the prac but they can do some more research and find what others think as well.</td>
<td>I also love it when they get unexpected results. It is much easier to get the reasoning coming through when they get unexpected results. The more difficult ones are when it’s exactly what they thought it was going to be, and it’s in the text book, and it’s clear. And they don’t get the same depth. The more complex and unstructured the problem, the more reasoning we get out of them.</td>
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looking outside of the usual human error stuff and see that even if you did it all perfectly it can still fail and it could be down to a conceptual error.

The future for our project is to further identify and describe these different experiences so that we can determine what specific aspects of inquiry design or implementation relate to these experiences. Our ongoing work is focused on, and beginning to elucidate, the key elements of inquiry design that support the development of critical thinking. Information from the interviews and the narratives developed from them during this project has been used to inform iterations of each of the courses, allowing us to continue to maintain and improve the inquiry curricula over time.

Acknowledgements
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Development and evaluation of inquiry based laboratory experiences for students in the capstone Instrumental Analysis subject, CHM320, (Charles Sturt University)

Charles Sturt University Chemistry Teaching Team.

Introduction
Our involvement in the project has been the introduction of inquiry based laboratory experiences for students in our third year analytical chemistry subjects as part of their Bachelor of Science (Analytical Chemistry) degree. Historically these subjects have run as a single one year subject; however, 2012 is the first year the subject is being offered in a new sequence of two single semester subjects – CHM323 (Instrumental Analysis 1) and CHM324 (Instrumental Analysis 2). The changes and rewrites of the subject topics for this new two subject format provided a perfect opportunity to make substantive changes in the format for the laboratory experience. Students in these subjects study by distance, and complete their practical experiences at intensive four day residential schools.

Our aim was to give students a better understanding of analytical instrumentation and what is required for their optimisation along with a taste of instrument trouble shooting. More broadly we hoped to develop students’ skills in problem solving and analytical thinking using inquiry based approaches.

Approaches and analysis of results
We have trialled the activities on CHM323 and CHM324 students only. The expectation is that as we instructors become more experienced and comfortable with such laboratory methods we will expand such inquiry methods into the laboratory experiences for our other chemistry subjects.

In our application we indicated we would introduce inquiry laboratory experiences into our second semester Instrumental Analysis 2 subject (CHM324). In fact we moved such changes forward into CHM323 in the first semester as a trial experience for both the students and the instructors.

The CHM323 students had a ‘traditional’ prac experience as we have done in the past for about ¼ of the four day residential school. The instructors for the subject, Dr. Howitt and Dr. Doran, have, through conversations with Drs. Ryan, Prenzler, and Bedgood have changed the remainder of the pracs to inquiry based labs. As an example, there is an experiment analysing caffeine in beverages that compares liquid chromatography techniques with derivative UV-Vis techniques. In the past students have been told what to do and asked to compare their results from the different techniques. This year students were referred to a scientific paper and asked to make decisions about which analysis technique to use for their samples. Essentially students needed to do the legwork to decide what and how to conduct their experiments.
Assessment methods for the introduction of inquiry based pracs involved student questionnaires/evaluations, and instructor personal reflections. Student responses to evaluations for CHM323 can be summarised as follows:

- self directed pracs are more challenging but 50% of students preferred this style of prac compared to a more traditional approach
- time was highlighted as an issue
- students requested more initial direction in preparing for an inquiry based prac and also assistance in how to interpret and report their results since the report writing style for an inquiry prac differs to the standard lab report to which they are more accustomed.
- students enjoyed working in pairs on the inquiry based prac and enjoyed the flexibility in determining their laboratory and instrumental approach; “self directed pracs help me to learn better as I know why I’m doing things”

Instructors for CHM323 also reflected that time was an issue; students required significant time in order to decide their approach. It was also necessary for the Instructor to ask a series of leading questions to ensure students considered issues such as replication, solvent blanks, safety requirements etc. One Instructor noted that “there is a fine line between guiding and directing” and both instructors agreed that that students were much more comfortable with the “usual style” of prac whereby a clear set of instructions are provided. On the whole, the reports for this exercise were not as well done as for the other practical where their instructions were more clearly laid out. The comparative part of the activity was not well done and no student commented on changes they might have made to the sample preparation method. One Instructor noted that “if the students were more familiar with this style of activity from classes in earlier years they would have handled the reports better, but the level of complexity in the analysis combined with being unfamiliar with inquiry style practicals resulted in them taking a superficial or incomplete approach to reporting their experiments.”

Lessons learnt in our trials in CHM323 were carefully considered for the incorporation of inquiry based pracs in CHM324. In this subject Dr Prenzler, in consultation with Dr. Bedgood, has revised the chromatography experiment to put the onus on students to think carefully about what instrument conditions and parameters are appropriate for reasonable results (please see attached information provided to students before res.school as an advance organiser.)

Based on feedback from CHM323, students were given more direction to prepare for the inquiry based prac in CHM324, namely “Optimisation of a Chromatographic Method for the Analysis of Phenolic Antioxidants in Red Wine”. Students were given information regarding the material provided to them in the lab, and a starting point (eg isocratic elution using a specified mobile phase) from which they could plan their optimisation experiments. Students were given a pre-lab exercise to document their optimisation plan and assessment points were allocated to this task. The students were required to submit their written plan to Dr Prenzler prior to the commencement of the residential school and were advised that...
their report for the inquiry based prac would be marked differently compared to the traditional directed prac.

Student feedback for this experiment was positive and, as expected, was more successfully received than the first implementation of an inquiry based prac in CHM323; most likely this is attributed to student experience and students commented that this style of prac should be introduced in second year rather than being “thrown in at the deep end in third year”. Students felt they had adequate time and enjoyed discussing their optimisation strategies with the Instructor. Students enjoyed optimising and troubleshooting the instrument; “the ability to fault find and experiment on the (instrument) rather than just performing an experiment” was highlighted as something that worked well for the inquiry based prac. This was precisely our goal in that we wanted students to develop a deeper fundamental understanding of instrument functions and processes (moving away from the instrument as a magic black box).

The instructor for the optimisation prac was a casual employee with expertise in chromatography. He noted that students found the pre-lab plan challenging since they have had no previous experience in instrumental optimisation and recommended that a few more hints could be given to students to assist them. He thought the instrument (liquid chromatograph) could be broken down into component sections (eg instrument injector; column/separation; detector) to encourage students to consider the breadth of optimisation options and better understand the functioning of the instrument.

Reflections and conclusion
Student feedback indicates that despite students finding inquiry based pracs to be more challenging, they are clearly of great learning value. As a direct result the Chemistry Teaching Team needs to continue to refine our approach to implementing inquiry based pracs and introduce students to this style of prac as early as possible; in their first year would be wonderful however this is challenging due to large student numbers and limited Instructor support. At this point we are focusing on our second and third year subjects and one of our team members has plans to change the laboratory experience in her second year organic chemistry subject to incorporate inquiry based pracs as a result of this project. The pracs in our second year analytical chemistry subject, which are part inquiry based, will also be reviewed in light of this project.

Working collegially towards student centred learning has been of significant value to both students and instructors alike. The Chemistry Teaching Team will continue to work together to ensure the best possible learning outcomes for our students; we have no doubt that inquiry based approaches will feature heavily in our future learning and teaching strategies.
Introducing inquiry-oriented learning at the University of New England to increase engagement of students with different interests and aspirations

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Approaches and Methods – adapting the fundamentals of cardiac conduction practical

Prior to the University of New England’s involvement in the “Inquiry-oriented learning in science” project, the Toad heart and ECG practical in the PSIO210 Introductory Physiology I unit had comprised a classical formulaic practical where students followed a rigid set of instructions, obtained data and then interpreted their results. In 2012, the main curricular learning outcome was unchanged, which was to develop an understanding of the electrical activity of the heart and its control. The basic method to be used in the practical was also retained involving measuring the ECG and using a toad heart to measure force and rate of contraction under various conditions. The ECG and heart rate were measured using standard limb leads and the force of cardiac contraction via a hook attached from the single ventricle to a force transducer. Raw data was obtained and interpreted using the Powerlab and Chart software.

The major difference that was introduced this year was the aim to improve student engagement and interest in practicals by challenging them to think more deeply about the relevance of the practical to their chosen degree/career pathway and to try to increase the fun element in the practical. These goals had to be accomplished in a single practical. Therefore, to achieve our aims within the one 3-hour session, each activity was given a title and a small light-hearted but relevant blurb was added which gave an example of the relevance of each experiment. Examples included “the importance of environment”, “balancing your minerals” and “becoming a cardiac surgeon”. The first of these examined the effects of temperature (hot and cold Ringers solution) in relation to controlling the spread of cane toads in Australia; the second was placed in the context of diet, either human or livestock, and the last challenged the students to think of how different drugs could be used to change heart rate and force of contraction during an open heart operation. In addition to these preambles, a number of pre-measurement and post-measurement questions were added which required the students to attempt to think about and hypothesise as to what their results might be and then to comment upon what they found. The practical finished with a tutorial which continued the themes of providing context to all students and reflection on the experiment outcomes but also included explanations and reinforcement of the learning objectives.

The new practical was evaluated in two ways. Human ethics approval was obtained from the University of New England to survey the students during the practical and to conduct a focus group after the practical was concluded. Although Associate Professor Roberts and Dr King were critically involved in designing the questions for the survey, both this and the focus group were conducted by people unconnected to the assessment of PSIO210. The
survey contained 12 questions which students responded to using a 5-point likert scale ranging from strongly disagree to strongly agree and two additional questions where students could comment on the best aspects of the practical and make suggestions for its improvement. The questions covered topics such as the accompanying lectures; the practical instructions; the use of inquiry in the practical; timing; learning experience and whether the students had enjoyed the activity. The focus group was conducted and analysed by Associate Professor Kirkup who subsequently reported on his findings.

Data Analysis – Evidence of increased engagement
A total of 39 students filled in the surveys. Sixty-seven percent agreed that the practical had given them a chance to think for themselves, whilst 76% and 62% respectively agreed that the lectures had helped them understand the fundamentals of cardiac conduction and that the practical had connected well with the lecture material. The two other questions where more students agreed with the question compared to any other option were that the practical was interesting and a preference for more detailed instructions. There was only one question where students more strongly disagreed or disagreed compared to the neutral and more positive options, which concerned the amount of time devoted to completing the practical’s activities. Students were neutral about whether this practical had increased their confidence for completing further practicals in their courses. Of the 29 students who gave an answer about the best aspects of the practical, 20 made specific reference to either the “hands on” nature of the practical or the ability to carry out a practical activity and see things for themselves. Constructive suggestions for improvement included a pre-practical tutorial; increased use of demonstrations and to consider splitting the practical over two sessions.

The clearest indication that we had achieved our objective of addressing the students’ specific areas of interest was obtained from the report on the focus group involving 12 students. The participants included 8 BSc students (mainly majoring in animal science), 2 Bachelor of Pharmacy students, 1 Bachelor of Exercise and Sports Science and 1 Master of Agriculture student. With one exception all of the students had clear career aspirations including veterinary science, pharmacy, animal nutrition and research. These diverse and widespread career aspirations notwithstanding, quoting from the executive summary compiled by Associate Professor Kirkup, “PSIO210 students on May 9, 2012 were clear – this practical did address their area of interest well. The key goal of the activity, as articulated by UNE academics was demonstrably achieved.” Students further stated that the practical was ‘very’ relevant to their career aspirations, course and general interest. This was attributed to a “deeper engagement and level of thinking”. In agreement with the survey results, students expressed enjoyment of the practical (variety, relevance, unique nature and working hands on) and went on to speak positively about “UNE science students are prided on their practical experience”.

There was also evidence from the focus group that this practical and, in particular, the concluding tutorial had increased their learning experience. Students suggested that the tutorial had helped reinforce the main principles and concepts and as evidence of increased reflection about their overall learning experience suggested that a similar tutorial be introduced into other practicals. Other evidence of improved engagement and higher order learning came from the support voiced about the value of inquiry learning and experimental
design and to the correct placement of this within undergraduate and postgraduate studies. The advantage of the flexibility within the practical for meeting differences in student learning techniques was also apparent and appreciated from their reactions to expected/unexpected results. When the experiment gave the expected results the students learnt from the hands on experience, when the results were unexpected learning was achieved through the tutorial.

Discussions/reflections/conclusion
It was clear that the students had enjoyed this practical and had wanted it to be retained in the curriculum. Some modifications may however stimulate a higher level of achievement. This may involve reducing the practical content so that the greater amount of time available allows for deeper thinking and improving the practical manual to provide clearer instructions about each activity. The modified fundamentals of cardiac conduction practical was a first investigation into the potential introduction of inquiry based learning into science teaching at UNE. Our main finding was that this approach does enable us to increase engagement of all students regardless of their widely differing interests. This suggests that further work should be conducted scoping the feasibility of extending inquiry-oriented learning into other units that cater for divergent student interests. As a foundation in a second year introductory unit, it also provides a platform onto which further inquiry-oriented practicals could be scaffolded into the third year curriculum where students begin to design their own experiments to answer specific questions or tackle specific career related scenarios. In conclusion, the involvement of UNE in the inquiry-oriented learning project has been wholly beneficial from a perspective of student engagement and as a driver towards modern, innovative and successful teaching practices.
Creating a bank of inquiry-oriented resources for large first year classes in Chemistry (Flinders University)

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The aim of this project was to create an inquiry-oriented resource bank to assist students in building confidence in their abilities to deal with fundamental concepts of chemistry. This resource bank was focussed on meeting students from large and increasingly diverse first year chemistry classes around key areas of chemistry, where reinforcement, further elaboration and practise would be beneficial. Inquiry-oriented activities were chosen with the aim of encouraging the students to take control of and gain enthusiasm for their own learning, and to foster interactions with peers around key areas of chemistry. The issue of many students lacking in confidence in their abilities with core chemical concepts has been made clear to both students and staff through a Key Competency testing program which has run at Flinders University since 2006. Identifying these areas has afforded opportunities to increase academic support for our first year students, and strategies including conversations between academic staff and individual students around key areas identified by the test, opportunities to reassess Key Competencies and ‘drop-in’ tutorials which are student directed and extend beyond key areas have become part of our first year chemistry topics. The ‘drop-in’ tutorials provide an ideal opportunity (location, time etc.) to have activities available for use by willing students (attendance is voluntary) with some academic support and encouragement available if needed. The resource bank of activities will enhance the opportunities for consolidation, investigation and extension of students understanding of and confidence with key chemical concepts. These activities will be available to the students in the “drop-in” tutorial room for either group or individual use.

2012 saw an abnormally large increase in the number of students in our Introduction to chemistry topic (an increase of more than 30% over the previous year). These extra students had serious implications on my time for this project and I found I was not able to develop activities in the timeframe expected. Several activities involving writing and interpreting chemical formulae and balancing reactions, along with activities involving oxidation numbers and balancing redox equations are currently being developed but have not yet been trialled. In week 1 of semester 2, 2012, 25 students transitioning from Introduction to Chemistry to the higher level Chemistry 1 worked through a ‘POGIL type’ (Process Oriented Guided Inquiry) activity covering two areas (basics of acid – base chemistry and ways of representing organic structures). This activity was designed to assist the students to bridge the gap into the higher level chemistry topic and be confident in their abilities. A short feedback survey at the end of the workshop assessed the student experience. The students reported increased confidence with their ability to cope with the more challenging topic and an easing of their trepidation about the standard required. They were also able to interact with peers studying at least two common topics and start friendships and find study partners that in some cases continued after the session. The session was held in the ‘drop-in’ tutorial room which some of them had not attended before and many then continued to attend. The need for more activities such as these which along with improving concept
understanding will hopefully lead to group discussions and/or peer mentoring is clear. Students show independence in even attending voluntary sessions and hopefully this independence and confidence in their own learning abilities will be fostered through completion of these inquiry based activities. Discussions with students have shown they would be keen to undertake these types of activities and also willing to be involved in groups such as focus groups to evaluate the activities and evaluation of performance in assessment tasks. So more activities are needed to trial and evaluate their impact. The potential benefits of this resource bank of activities has been recognised not only by Assoc. Prof. Les Kirkup in his support of this as an AFFA but also within Flinders University by funding of a DVA’s transition/retention program grant. This centres on the development of the ‘drop-in’ tutorial room into a modern first year ‘learning space’ where a range of activities and resources will be made available to assist first year students in both chemistry and physics both academically and with their transition to University study. Financial support for this project includes funding to employ a project officer to assist in the development of the resource bank started with the AFFA project (now encompassing both chemistry and physics), and also to develop extension activities to encourage engagement with the disciplines beyond the core material of the disciplines. The School of Chemical and Physical Sciences is supporting this idea by the provision of two large tutorial rooms for the use of first year students, and providing staff to encourage and assist student learning and foster enthusiasm for science.

Being part of the AFFA Initiative has provided several valuable opportunities. Firstly the opportunity to be mentored by an experienced and passionate science educator in Les Kirkup who has been always keen to support our endeavours enthusiastically has been brilliant. Secondly being part of a national network of inquiry based science education researchers (facilitated by Les) with a range of discipline specific interests but common goals, and the opportunity to hear about the research endeavours within the group and to discuss our projects together particularly at the inquiry day in September 2012 was extremely encouraging and informative. The interest shown by those outside my University was encouraging personally. The fact that someone outside the my own institution was sufficiently interested in my education based research project to support it both through mentoring and financially, has helped to raise the profile of my work within my own school. This has been particularly helpful as during the course of this project I have transferred into an education focussed role at here at Flinders University and have recently been appointed as Director of First Year Studies for the School of Chemical and Physical Sciences. Being part of the AFFA initiative has led to many contacts, particularly with Les Kirkup which will continue to be productive into the future. It has also provided a useful stepping stone to both encourage and enable me to apply for further funding which will result in a valuable resource for first year students in chemistry and physics at Flinders University.

Appendix C: Findings from student focus groups

Main author: Andrea Mears

Here we unpack some of the general findings obtained across all the focus groups. Representative quotes from students are included where they assist to bring emphasis to an important point or issue.

Students prefer inquiry more than traditional activities even if their personal experience of inquiry has not been positive.

Inquiry style activities are understood by students to be hands-on learning activities, where students have greater ownership and are able to “wonder why”. Inquiry activities are seen as engaging, interesting, interactive, building confidence, challenging and promoting a real understanding of the content.

Students value inquiry activities more highly than traditional recipe-based activities particularly because they allow students the time to explore and learn in an environment that they prefer and in which they are encouraged to think for themselves, achieving a deeper learning.

Students that had a positive inquiry-activity experience had fun, engaged deeply and learnt more than they had in traditional activities. Interestingly these students spoke emotionally rather than rationally about the experience and attributed their learning to feelings. When these students were asked about the effect of the activity they spoke of deep emotional and long-lasting effects.

For many students the activity while enjoyable was stressful and these competing emotions defined the experience for these students. Stress was primarily due to a lack of understanding of the material/content, lack of time and workload pressures. Despite the stress students across all focus groups agreed the activity discussed was preferable to more traditional activities as a way of engaging and learning.

As students progress through their degree so will the level of inquiry.

For all participants this was the first major inquiry activity they had undertaken in their degree. Students spoke of elements of inquiry in other experiments/activities but this was the first with a greater inquiry focus.

First-year students believe universities intentionally seek to progress students to more inquiry-focused activities throughout their degree. Students want to make that progression and engage with science in a more interactive and deeper way, a way “closer to what we will be doing in the future”. Students had a strong awareness of their own learning and accordingly believe that as their knowledge, understanding and confidence develop so will the level of challenge they are presented with. Inquiry is seen as a means through which they are able to consolidate and improve upon their existing knowledge.

For second-year students approximately half believed this inquiry activity was the start of things to come. The activity provided a stepping stone, building on what had been learnt in first year and an introduction to what will be a step up in third year. The remaining second-
year students believed this activity was in isolation and believe that universities should introduce inquiry activities more widely. Having said that many students warned of ‘economy versus effort’. Often inquiry activities require greater effort and if the reward is a small percentage of marks than it may not be worth the effort particularly if such activities are widely introduced.

Postgraduate students were very positive about the introduction of inquiry activities and complementary to academics in trying to change what “you could tell had been the same way for 40 years”. They believe the university has a role to introduce similar activities throughout the degree experience.

**Inquiry is more fun, interesting, challenging and has a valuable real-world relevance**
For all students these activities were one of the best and most interesting students had done. This high level of interest was crucial to the success of the activities which students attributed to a deeper engagement which in turn resulted in greater confidence, level of thinking, learning, skills and an understanding of the relevance of real research.

The activities were seen as interesting as they were unique, hands on, had a real-world application and were relevant to student career aspirations, course and general interest. “It is why we do science in the first place”.

**A stressful experience of inquiry was reported when students lacked an understanding of the content, lacked the time to complete the activity and felt workload pressure.**
Despite student enjoyment, interest in the course material and an appreciation of the value of inquiry learning, many students had a less than positive experience with the inquiry activity they participated in.

**Why?**
Regardless of the year the activity was introduced and the location of the university three core themes emerged throughout the focus groups as to why:

**Lack of understanding**: The main reason students reported being stressed or struggling with the activity or experiment was that they believed they had a lack of content knowledge, an inability to link pieces of knowledge together and lacked the capacity to form a coherent block of understanding.

Students acknowledge that science, in laboratories in particular, is “applied so what they tell you in the lecture you have to apply it to your prac”; students went on to say “but they don’t really clarify. The bridge is missing.”

Many students talked about the inability to make connections between the experiment/activity and their learning or skill development. Interestingly second-year students were confident that they would consolidate the content and learning objectives in their own time and make positive connections between the experiment and their development. By way of contrast, first-year students did not believe they had the time or forum in which to gain this knowledge and make the necessary linkages. First-year students were overwhelmed by their lack of understanding.
Lack of time: Another key issue contributing to stress was the lack of time to complete the activity or experiment. This lack of time meant students were on autopilot, unable to consolidate and understand the material and unable to make connections to the learning objectives. Many students felt the lack of time, the inability to review the experiment/activity in detail at the beginning and the end and inadequate demonstrator/tutor assistance left them confused.

Pressure for marks: An additional theme, the pressure for marks, emerged through the conversations. Students felt the pressure for marks across all their subjects, and this experiment/activity added to this pressure. While this was not widely held concern, for those who did feel the pressure, it was a deeply held concern. Students spoke about the balance between “economy and effort” and having to complete “a lot of work worth only a few per cent”.

Well-supported inquiry activities are demonstrably successful creating strong student attachment
Students who spoke positively about the activities/experiments, their learning and their experience were very confident in their understanding and continually spoke about the activity in terms of ‘more’: more interesting, with more freedom, more absorbing and required more thinking. Quite simply it came together for these students, and they reported feeling confident, enthusiastic and inquisitive.

When these students were asked about the effect of the modules they spoke of deep emotional and long-lasting effects. The success of the activity cannot be attributed to any specific criteria but rather to the overall design and execution of the experiment/activity that combined to create strong student attachment and ownership.

The key elements students suggested that are required to effectively support the introduction of inquiry activities are sufficient time, supportive demonstrators, real-world relevance, useful background or manuals and coordination between the material presented in lectures, tutorials and practicals.

Students often linked the level of understanding in the material to whether or not they had completed Year 12 in that discipline. The most confident students had completed HSC in the relevant discipline. Students who did not complete Year 12 in the discipline reported struggling in the course. Some students who did have Year 12 in the relevant discipline did report to be struggling however they stated they would be in a worse position without the Year 12 background.

First-year students are less keen on inquiry-oriented activities than later-stage students.
All students acknowledge the value of inquiry, but first-year students were not enthusiastic about inquiry activities in their first semester at university.

“At this level we are looking for information from our pracs, not planning them.” Students were clear in that “right now” they needed firm direction and a greater understanding of the content and concepts. In first year inquiry is confusing, and they would prefer “someone
Inquiry-oriented learning in science

up front to walk you through it. I know that is like spoon-feeding, but sometimes you need that and get something out of it. I needed it explained; I would have got a lot more out of it like that.” Further there is a general belief, particularly from first-year students, that inquiry is “better for smarter and more motivated students” who have the ability and will make the choice to take advantage of the opportunity that inquiry offers.

Senior students reiterated this theme and again, while valuing inquiry, they do not think first-year students would take advantage of the “opportunity” that inquiry offers. Senior students are concerned that inquiry activities are not appropriate for first-year students as these students don’t have:

- the basic skills necessary to complete the activities and the numbers of first-year students without these skills is growing
- the confidence to engage in inquiry activities, i.e. to make connections and ask “why”
- an expectation of interactive learning. Students expect to be spoon-fed and if their experience does not match their expectation students may not engage and learn
- the motivation to learn as their motivation is to pass

Interestingly while senior students are concerned the activities may not achieve their intended learning outcomes, they believe the activities should be introduced in the first year, in fact it is the role of the university to do so.

**Students believe undertaking inquiry activities builds confidence, requires more thinking, and allows a deeper understanding and skill set to develop.**

Confidence was the elephant in the room. While groups only discussed confidence when specifically asked, it was clear that a student’s confidence or self-belief was the perspective through which comments were made.

Students who were confident when they commenced the inquiry activity engaged and thought more deeply; this in turn led to greater confidence, understanding and skills. Conversely students who were not as confident entering activities reported experiencing stress and difficulties with the activity and failed to gain significant learning or personal development outcomes.

**Keep these activities and introduce more of them**

All students in all groups when asked if the inquiry activity should be maintained said YES. The majority suggested improvements should be made.

All students valued inquiry as a method of learning and more inquiry activities, that are well supported, should be introduced across the degree experience.

Inquiry is seen as of most value in second year allowing students to build on and challenge their knowledge. Consequently for the majority of first-year students the lack the understanding, time and workload pressures means inquiry is of less value.
Regardless of when and how inquiry is introduced, to maximise learning through inquiry the following recommendations were suggested by students as the key factors to consider.

**Recommendations**

**Allow more time and simplify the activity/experiment:** Activities should be achievable within the time and the more complicated steps removed (particularly when newly introduced). Many groups suggested running the activity over several weeks. “Cut this prac in half and run it over two weeks.”

**Create a positive learning environment:** Students want demonstrators to facilitate learning and create a positive environment by providing the necessary support, advice and information. The lack of effective demonstrator assistance was a widespread and deeply held concern. Students would like more demonstrators “even if third years” and for demonstrators to “definitely do a demonstration” at the beginning of the prac, provide constructive background and assistance and “not just answer a question with a question”.

**Group discussions to be included and made meaningful:** Not all students who took part in the focus group sessions participated in a group discussion during or at the end of an activity. Those that did spoke very highly of its value, and all of those that didn’t recommended it be introduced as a way of consolidating learning.

**Improve student understanding. Suggestions include:**

- Provide greater content linkages between lectures, tutorials, workshops and practicals.
- Use lectures and tutorials to explain concepts explored in practicals and why things happen.
- Provide questions in preliminary work that assist with the understanding of content.
- Allow for facilitated peer discussions in practicals and tutorials.
- Ensure lectures with content relevant to the practicals are given before practicals.
- Review tutorials to place a greater emphasis on linking the theory and the practical application of the theory for students.

**Greater real-world application and contact with researchers:** Real-world context stimulates student enthusiasm and helps link students to their learning and skill development. Placing students in direct contact with researchers stimulates enthusiasm and helps cement learning even further.
Appendix D: Inquiry workshop and a representative workshop report

The essence of the activity at the core of the workshop involved developing an experimental approach to establishing which of two types of sticky tapes was the ‘best’. More specifically, workshop participants were asked to establish to the satisfaction of the CEO of a company which brand of sticky tape (that sold by Office Works or that made by the CEO’s company), was the stickier of the two tapes.

In advance of carrying out the experiment and in order to increase engagement in the experiment, the participants’ attention was drawn to a couple of (likely) little known facts about sticky tape: 1) That the 2010 Nobel prize winners had used sticky tape to isolate graphene, and 2) that by unpeeling sticky tape, you can generate X-rays.

Early in the workshop I indicated that it would essentially consist of two parts as follows:

Part 1
The participants were asked:

• to be ‘students’ and undertake an inquiry-type activity
• report on aspects of the activity
• refine their methods and provide evidence to support their conclusions
• communicate their findings to other participants.

Part 2
They were then asked to:

• probe the activity from a different perspective
• unpack the educational value/challenges of the activity
• examine the role of demonstrators and the challenges they face in supporting students engaged in the activity
• explore how the activity might support the development of valued graduate attributes/capabilities.
You work for a company that produces a sticky tape (Tape X). The Executive Officer of the company approaches you with a tape she has just purchased at OfficeWorks. OfficeWorks claim the tape they sell has better adhesive qualities than any other brand on the market.

Your Executive Officer wants to know the truth of the matter: Which is better? Tape X or the OfficeWorks tape?

### Background to the experiment

You are given the task of determining which tape is the better of the two by carrying out a ‘stickiness’ test on a sample of each tape.

You must report back your findings to the Executive Officer. It is important that you are able to describe and defend your methods, your data and any subsequent analysis and conclusions.

The key question is how well (if at all) are you able to discriminate between the stickiness of the two tapes?

### In this workshop...

- What learning opportunities do inquiry-type activities offer students?
- What challenges do demonstrators/tutors face in supporting students carrying out inquiry-type activities?
- In what ways might you assess what students had learned and can do as a result of engaging in such activities?

### Getting out of a sticky situation

**Learning experiences**

- Developing an experimental procedure
- Quantifying variability
- Refining the procedure to reduce variability
- Reporting the procedure and findings to the class

### How has sticky tape contributed to the advancement of science?

Nobel Prize in Physics for 2010 goes to Andre Geim and Konstantin Novoselov of the University of Manchester for their groundbreaking experiments regarding the two-dimensional material graphene.

### The Challenge

You are given the task of determining which tape is the better of the two by carrying out a ‘stickiness’ test on a sample of each tape.

You must report back your findings to the Executive Officer. It is important that you are able to describe and defend your methods, your data and any subsequent analysis and conclusions.

The key question is how well (if at all) are you able to discriminate between the stickiness of the two tapes?
Les Kirkup’s feedback/reflections: ANU workshop (on 11th April 2012)

Overview
Many thanks to everyone for participating in the workshop and for buying into being a student again.

My sense was that the workshop was well received and that the essence of inquiry based/oriented learning did emerge. Those elements (that I believe are transferable to the lab-based experiences you may design for your students) are that students: engage with questions that have no predetermined answer; develop and implement approaches to address those questions; work to refine their approaches in order to enhance their method/the quality of the data; gather evidence and formulate and communicate explanation/conclusions based on that evidence.

A particular focus of the hands-on component of this workshop was to design and carry out an experiment that would assist in discriminating the performance of two commercially available products (sticky tapes) in order to advise an imaginary Executive Officer which of the products was best. The issue of the looseness of the description of what constituted ‘best’ (provided by me at the start of the workshop) was explored in the discussion at the end of the workshop.

An issue of context and student reaction
The question was raised as to how students would react to the experiment. There were mixed feelings expressed by workshop participants about the context in which the experiment was placed. Some felt that students would be motivated by having a real-world issue to explore, others felt the context was too contrived.

There was some support for the notion that students would react positively to the inquiry elements of the experiment, though it could provoke concern (perhaps among ‘good’ students) and frustration at not knowing what to do in order to get maximum/full marks – as there doesn’t seem to be a right answer. Students who had been very successful doing lab. work up to this point (say at school) might wonder exactly what they would need do to score 100 per cent on this experiment. It was also suggested that some students might patiently wait until they were told what to do, rather than work something out for themselves.

Another issue that emerged related to how the experiment was introduced. I gave a general context-setting introduction, then showed the equipment available and indicated (by demonstration and through a diagram) how this equipment could be used. I think that there was consensus that I was too directed at this point and that I could have stated the aim of the experiment then left it to the ‘students’ to work out a way to discriminate the products for themselves. By being too directed I was impairing the opportunity for students to be creative and truly develop their own approach and solution to the problem.
Challenges for the demonstrator and possible improvements

Some discussion surrounded how the purpose of the experiment was expressed and how I related that to the participants during the session. I gave the following advice during the introduction and in the documentation:

*You are given the task of determining which tape is the better of the two by carrying out a stickiness test on a sample of each tape.*

At later stages I emphasised the importance of finding out which of the two tapes was ‘best’, without referring consistently to what ‘best’ means in this context (eg students might subsequently focus on the strength of the tape rather than on its adhesive qualities). It is important (and I think is very relevant to advice given to instructors/demonstrators who might look after such an experiment) that they are consistent when explaining the aim of the experiment. From my viewpoint, I was hoping that the issue would emerge of how you would decide which tape is most sticky and was pleased that it did.

What you find out and are prepared to defend relies heavily of what you set yourself to do in the first place (and experiments like this, where you have to develop your own definition put quite a lot of responsibility onto the student). An excellent point was made that the experiment deserved another general discussion session on defining exactly what it is that we are trying to determine and to clarify that before any design is attempted. This might fit before the ‘playing period’ (where participants get to explore, for example, how fast the tape peels under certain conditions).

Another matter that was raised was that of the learning objectives and how they could have been more clearly stated.

Demonstrators could be stressed by not being able to anticipate what was going to happen in the lab (owing to the open-ended nature of the experiment) and they could be uncomfortable with freedom that comes with open-ended labs. It would be easy to turn this experiment (even inadvertently) into a recipe-based experiment, especially if the demonstrators had seen many approaches adopted and made their own judgment as to which was best/most efficient/easiest to perform, etc – it could be hard to keep quiet and let the students pursue their own directions.

References/resources

If you’d like to know more about the ALTC Fellowship on inquiry that supported the workshop, please go to <www.iolinscience.com.au/>

Here are some references/resources that you might find useful if you are interested in incorporating more inquiry into your curriculum.


Comments from the feedback sheets included:

**The best aspects of the workshop for me were:**

<table>
<thead>
<tr>
<th>Participant</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>The hands-on experiment together with the in-depth discussion about the learning approach</td>
</tr>
<tr>
<td>B</td>
<td>Discussion after experiments – what is expected of students – what are the things I was to achieve with my course/lecture/how do I engage students</td>
</tr>
<tr>
<td>C</td>
<td>An open experiment to express the point</td>
</tr>
<tr>
<td>D</td>
<td>Watching everyone’s positive interaction with the experiment</td>
</tr>
<tr>
<td>E</td>
<td>Group discussions and debate – combining teachers from a variety of backgrounds</td>
</tr>
<tr>
<td>F</td>
<td>Doing the experiment and thinking from the students’ points of view. Hearing the responses of the undergraduate students attending the workshop</td>
</tr>
<tr>
<td>G</td>
<td>Thinking about the difference between learning about something and learning through something! And thinking about what students might understand if we say we’re going to assess them on being creative</td>
</tr>
<tr>
<td>H</td>
<td>Very practical hands-on approach</td>
</tr>
<tr>
<td>I</td>
<td>Opportunity to perform experiment and then discuss</td>
</tr>
<tr>
<td>J</td>
<td>A new idea to push students a bit further</td>
</tr>
<tr>
<td>K</td>
<td>Reflecting on how students react to open ended activities and how the words you say as instructors influence their behaviour in ways you don’t anticipate</td>
</tr>
<tr>
<td>L</td>
<td>New approaches/comments from the group discussion</td>
</tr>
<tr>
<td>M</td>
<td>The chance to discuss relationships between problems definition/outcomes a demonstrators wants and how that relates to the student experience</td>
</tr>
<tr>
<td>N</td>
<td>Discussion</td>
</tr>
<tr>
<td>O</td>
<td>The nature of the discussion. A very rich mix of lab-based disciplines and views on teaching in lab-based environments</td>
</tr>
</tbody>
</table>

**Suggested improvements to workshop**

<table>
<thead>
<tr>
<th>Participant</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>N/A</td>
</tr>
<tr>
<td>B</td>
<td>[No response]</td>
</tr>
<tr>
<td>C</td>
<td>Set more goals of the workshop and explain why we’re doing the sticky tape experiment</td>
</tr>
<tr>
<td>D</td>
<td>All good</td>
</tr>
<tr>
<td>E</td>
<td>Perhaps a non-physics lab/questions/exercise. Physics is often a more structured subject</td>
</tr>
<tr>
<td>F</td>
<td>Not provide <em>any</em> guidance or gear on the table – make sure things are available around the room</td>
</tr>
<tr>
<td>G</td>
<td>Spend time thinking about demonstrators</td>
</tr>
<tr>
<td>H</td>
<td>Structure the educational aspect a bit more</td>
</tr>
<tr>
<td>I</td>
<td>A bit more about how you design open ended labs</td>
</tr>
<tr>
<td>J</td>
<td>Nothing—thought it was great</td>
</tr>
<tr>
<td>K</td>
<td>[No response]</td>
</tr>
</tbody>
</table>
Here are a few photos, which I hope will assist you to reflect on what you did in the workshop, and the value of the experience.

**Summary of discussion of factors affecting peel off time**

- What factors affect the peeling of the tape? 
  - Surface texture
  - Force applied to tape (by weight)
  - Length of tape (affect peel off time)
  - Starting angle at which force is applied
  - How tape is fixed to card
  - How hard tape is pressed to surface
  - Tape contamination (due to touching)
  - Room conditions (eg. temp & humidity)
  - Motion of weight
  - Width of tape
  - How long tape has been down before applying force

- Adhesive left behind on table
- How sticky tape is attached to card
- Surface cleanliness
Participants in action I

Participants in action II
Snap shot of discussion of the educational aspects of the activity that took place on completion of experiment.

Finally...
Many thanks for inviting me to lead the workshop. I very much enjoyed being involved and hope that some aspects of the inquiry-oriented workshop or its philosophy is something you can apply or adapt.

I welcome any comments you have on the workshop, or on my feedback/reflections that appear above.

Les Kirkup
16 April 2012
Appendix E: CUUII experiment developed and evaluated using the ARK


Les Kirkup
13 November 2012

Executive summary

Summary
UTS and CSIRO are co-developing scalable inquiry-type activities that transform the practice of teaching and learning especially in large enrolment first-year classes. In doing this we are realising the UTS Model of Learning by creating opportunities for students to engage in practice-oriented, research-integrated learning.

This report describes an Inspiring Research (IR) activity being co-developed by UTS and CSIRO featuring organic solar cells, which has been trialled and reviewed by demonstrators and students. The IR activity has been developed to the stage where it can be rolled out to large enrolment first-year science classes.

This report contains evidence that the IR activity:

- successfully introduces students to research of national significance being undertaken by CSIRO and UTS;
- has been well received by students and academics. The activity is viewed as engaging, with strong real-world relevance;
- connects students directly to processes of research through the opportunity to examine the performance of research-derived devices (in this case, organic solar cells). More specifically, students: engage with a question that has no predetermined answer (what is the efficiency of an organic solar cell?); develop and implement approaches to address the question and work to refine their approaches in order to enhance their methods/the quality of the evidence they gather;
- encourages students to formulate and communicate explanations/conclusions based on the evidence they have gathered.
- can be carried out using equipment routinely found in an undergraduate laboratory which points to activity’s sustainability and scalability;
**Preamble**
Engaging students in the processes of research and inquiry in contexts of national significance stimulates learning and promises to enhance student engagement and graduate capabilities. A goal of the CSIRO-University Undergraduate Inquiry Initiative (CUUII) is to transform the practice of teaching and learning by co-developing inquiry-type activities with CSIRO that connect students, in a practical way, to research of national importance. The activity described here is essentially a proof of concept that shows, by means of a specific example, how activities can be designed, trialled, reviewed.

This report describes an Inspiring Research (IR) activity co-developed by CSIRO and UTS which introduces first year university students to an area of strategic national importance, namely the development of technology that exploits renewable energy. The activity is derived from work being carried out by Dr Scott Watkins who currently leads the CSIRO’s research stream on Organic Photovoltaics.

**Into the curriculum**
It is intended that the activity, once trialled and refined, will be introduced into the undergraduate curriculum in 2013 for two first year subjects at UTS, namely Physical Aspects of Nature (with a total of approximately 600 students over two semesters) and Foundations of Physics (with approximately 150 students in the Autumn semester of 2013). Changes will be made to the lectures in both these subjects in 2013 so that students are prepared for the activity in advance of going into the laboratory.

The framework shown in figure 1 (next page) is being used for the development and trialling of the activity, which has been successfully used to develop other lab-based activities.
The IR activity, in which students explore and compare the performance of conventional and organic solar cells, was trialled at the end of October 2012 by first-year and senior-year students and also laboratory demonstrators. An anonymous survey was administered to the participants of the trial in order to assess the level of engagement with the activity and to assist in identifying issues that need to be addressed before the activity went ‘live’ with hundreds of students. Dr Scott Watkins of CSIRO prepared a short video on the background to the work on organic solar cells and the current challenges. The video was shown as part of the trial in order to set the activity in context.

Review of the activity by independent academics from Murdoch University
Academics who had no involvement in the design of the activity, but who are interested in adapting the activity for use in their own subjects were asked to comment on the activity and to complete a short survey. Comments by independent academics included
Academic A

*Depending on the student’s background I think the two week setup could work well. The first week gets them thinking in the right direction – and maybe picking up a few hands on skills with multimeters and Excel if they haven’t encountered them before.*

*The second week would be great as an extension of these concepts. By using extra mirrors the students can see how solar concentrators function. If they were also measuring both current and voltage they would be able to observe that the intensity effects current in the cell to a greater extent than the voltage. Conversely if they were measuring temperature at the same time (and in an independent experiment) they might come to some conclusions as to some real world limits on the system – ie why cooling is so important in solar concentrator systems.*

*The temperature aspect could also be related back to the performance of roof top arrays and why although people think they will perform better on a sunny summers day, a clear winters day will produce a higher power output.*

Academic B

*I think the [teaching materials] are excellent.*

*They do seem to assume that the students are school leavers and read everything that you ask them to read and then act on that information. In my experience this is not often the case. I don’t think there is much you can do about that though.*

*If students are working in groups it is possible for one student to say and do very little. You have not provided any moderating influence based on peer assessment of how much work each student has done.*

*All of the design skills depend on how much the tutor lets them get on with it or guides their thinking in the design phase.*

Academic B also completed Survey B of the ARK which is a review of the notes given to students.

**Response to the IR activity by participants who trialled the activity on 29 October 2012**

The activity was trialled by four first-year students, three third-year students and three demonstrators. Figures 2, 4 and 5 show photographs taken during the trial. Les Kirkup acted as the demonstrator. The participants, working in pairs, were asked to take on the role of students. The trial was of 2.5 hours duration, which matches the time real students would spend on the activity. Participants were rewarded for their attendance with complementary movie tickets.
Fig 2: Les Kirkup introduces the activity

Fig 3: Scott Watkins describes CSIRO research

Fig 4: Students carrying out the activity

Fig 5: Students reporting on the activity

Participants were asked to rate the activity as a learning experience. The figure below summarises the responses.

![Pie chart showing as a learning experience: very valuable 80%, worthwhile 10%, outstanding 10%]

Fig 6: Students’ rating of the activity as a learning experience.
Participants were asked to complete a survey to explore their reaction to the experiment. The participants responded on a Likert scale (where the range of responses to a statement are from ‘strongly agree’ to ‘strongly disagree’).

![Fig 7: Student responses to student survey](image)

Overall the response to the experiment was very positive as can be seen by Figure 7 (above).

Responses to the question ‘What are the strengths of the activity?’ included:

**Participant B**

*Requires [students] to make simple but important measurements. Encourages students to think about how to calculate efficiency. It is interesting and applicable to the real world*

**Participant G**

*It connects the experiment to the current world and its growing importance in society – makes it more relevant – more creative learning*
Participant J
relevant context-renewable energy increasingly important, use of new equipment, prework and context useful – liked the little introductory lecture at the beginning

Responses to the question: In what way(s) could this experiment be improved?

Participant B
Include a circuit diagram, [otherwise] students might have difficulty setting up

Participant G
I felt pressed for time and was somewhat confused due to not planning my experiment. More time to think may be of value.

Participant J
I think it would be quite difficult for first years. It may be worth splitting into 2 labs or going more slowly through the experiment. Make sure they know how to graph on Excel – would be hard to calculate and draw a graph of so many points manually

Feedback from Teaching-and-Learning Experts who attended the Trial
The trial was also observed by two teaching-and-learning experts, Katrina Waite (from the Institute for Media and Learning at UTS) and Stephanie Beames (from the Faculty of Science at UTS), who took no direct part in the trial other than to observe what was happening. Their independent perspectives contributed significantly to the critical review of the experiment.

The observers:

- Agreed that there was strong engagement by the participants and that the relevance to society and sustainability was manifest;
- Expressed concern that quite a long time elapsed before the participants actually began the hands on part of the experiment and, when they did, some participants had difficulty connecting up the equipment;
- Agreed that the context (renewable energy) was as appealing and the video by Scott Watkins was excellent for setting the scene and reinforcing the research pedigree of the experiment;
- Suggested that the photographs in the notes for students could have been clearer;
- Indicated that more questions could have been included in the pre-work (for example the students could be asked to look for information on how much power was needed to run certain devices, such as an iPhone and iPod, as this would have assisted in relating the power output of the solar cells to what they could be used for);
- Raised the general issue of acoustics in the laboratory, i.e. it was often difficult to hear what the participants were saying when they gave their short presentations;
• Suggested a more detailed discussion at the end of the activity, drawing together what each group had found would have assisted in bringing the activity to closure;
• Remarked that there was clear collaboration within each student pair.

Les Kirkup’s reflections on the activity
The experiment worked well with good student engagement. All students had done the pre-work, so I did not need to spend much time on it. This situation is probably unrepresentative of what would happen in practice when the experiment is rolled out to hundreds of students, and so more time would need to be allocated to covering pre-work to assure that students are well prepared for the activity.

The students were rushed towards the end, and I believe there is merit in making this a two-week activity (this was also suggested by one of the participants).

Week one would be fairly prescriptive so that students could become skilled in making basic measurements. Week two would be open-ended such that they could explore some specific factor affecting the power out of the cells or the efficiency. Pre-work for week two could require students to develop a plan for the experiment. There was some confusion about connecting up the solar cells and selecting the settings on the digital voltmeter (DVM). I believe stepping the students through the set up in front of the whole class early would address this.

In summary
This was a successful trial of an IR activity that exposed students to cutting edge research of national significance and gave them an opportunity to engage practically in the process of inquiry. The topic chosen for the IR activity was appealing and engaging. Organic solar cells provided by CSIRO and the video created by Scott Watkins successfully connected first-year students to important research happening nationally to which both CSIRO and the University of Technology, Sydney are contributing. The resources required are such that this activity could be rolled out to many hundreds of students (the only limitation being the sustained availability of the organic solar cells).
## Appendix F: Keynotes and presentations

The work of the fellowship was extensively presented across Australia and overseas. Given here are details of the when, where, what and who of those presentations.

<table>
<thead>
<tr>
<th>Date</th>
<th>Presentation title, Location (city only)</th>
<th>Hosted by</th>
<th>Brief description of the purpose of the presentation</th>
<th>Number of participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>8th June 2011</td>
<td>Inquiry-oriented learning in the undergraduate science laboratory: Brisbane</td>
<td>University of Queensland</td>
<td>Explore initiatives designed to better reflect the processes that scientists adopt when undertaking experimental work.</td>
<td>35</td>
</tr>
<tr>
<td>2nd August 2011</td>
<td>The undergraduate science laboratory: what is it good for?: Brisbane</td>
<td>QUT</td>
<td>Explore initiatives designed to better reflect the processes that scientists adopt when undertaking experimental work.</td>
<td>25</td>
</tr>
<tr>
<td>28th/29th September 2011</td>
<td>Realising the Teaching-Research nexus at first year: Sydney</td>
<td>Informa</td>
<td>Examining potential benefits in connecting first year students to research and how those connections can be made.</td>
<td>50</td>
</tr>
<tr>
<td>5th October 2011</td>
<td>Changing practice towards IOL: Harrisonburg, US</td>
<td>James Madison University</td>
<td>Describe processes to facilitate, and in some cases stimulate, change towards inquiry-oriented learning in science.</td>
<td>20</td>
</tr>
<tr>
<td>11th October 2011</td>
<td>Changing practice towards IOL: Purdue, US</td>
<td>Purdue University</td>
<td>Describe processes to facilitate, and in some cases stimulate, change towards inquiry-oriented learning in science.</td>
<td>30</td>
</tr>
<tr>
<td>25th October 2011</td>
<td>Changing practice towards IOL: Hull, UK</td>
<td>Hull University</td>
<td>Describe processes to facilitate, and in some cases stimulate, change towards inquiry-oriented learning in science.</td>
<td>12</td>
</tr>
<tr>
<td>27th October 2011</td>
<td>Inquiry-oriented learning: What is it and how do we make it happen: Lismore</td>
<td>SCU</td>
<td>Presentation included examples of embedding IOL into the undergraduate curriculum in first year, large enrolment, STEM units.</td>
<td>2 (remotely, via Elluminate)</td>
</tr>
<tr>
<td>23rd November 2011</td>
<td>Realising the Teaching-Research nexus (keynote at Festival of Learning): Adelaide</td>
<td>Adelaide University</td>
<td>Examining potential benefits in connecting first year students to research and how those connections can be made.</td>
<td>120</td>
</tr>
<tr>
<td>24th February 2012</td>
<td>Inquiry-oriented learning: Definitions, drivers, and dissemination: Melbourne</td>
<td>Monash University</td>
<td>To talk to education developers and science academics about fostering changes in the science curriculum towards IOL and to emphasise the timely nature of this fellowship program.</td>
<td>30</td>
</tr>
<tr>
<td>29th February 2012</td>
<td>Inquiry-oriented learning: Definitions, drivers, and dissemination: Perth</td>
<td>Curtin University</td>
<td>Similar to above, with many more science academics in attendance.</td>
<td>25</td>
</tr>
<tr>
<td>1st March 2012</td>
<td>The undergraduate science laboratory: what is it good for?: Perth</td>
<td>Murdoch University</td>
<td>General presentation about the role of the lab in the science curriculum, and in particular the place of IOL in that curriculum.</td>
<td>20</td>
</tr>
<tr>
<td>26th April 2012</td>
<td>Service teaching for diverse needs and futures: Hobart</td>
<td>University of Tasmania</td>
<td>Examining experiences of identifying and addressing issues of student engagement in physics service subjects, drawing on insights gained through ALTC funded fellowships</td>
<td>15</td>
</tr>
<tr>
<td>15th May</td>
<td>A fellowship Unpacked: Sydney</td>
<td>Office for Learning and Teaching</td>
<td>Background to the fellowship, current work, planned and unplanned activities. Future prospects of the fellowship</td>
<td>11</td>
</tr>
<tr>
<td>Date</td>
<td>Event Description</td>
<td>Location</td>
<td>Details</td>
<td></td>
</tr>
<tr>
<td>------------</td>
<td>------------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------</td>
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<td></td>
</tr>
<tr>
<td>17th May 2012</td>
<td>Research-integrated learning and the student experience (keynote at the VC’s Learning and Teaching Showcase): Sydney</td>
<td>University of Technology, Sydney</td>
<td>Linking teaching and research from first year onwards is promoted as a means of preparing students for unpredictable and diverse futures, and arguing that to make it happen we need ‘Student focused, research-active, education-savvy academics’.</td>
<td></td>
</tr>
<tr>
<td>25th May 2012</td>
<td>Changing practice towards inquiry-oriented learning: How do we make it happen?: Melbourne</td>
<td>Melbourne University</td>
<td>Describe the processes the fellowship is adopting to stimulate and facilitate change in Australian universities.</td>
<td></td>
</tr>
<tr>
<td>29th May 2012</td>
<td>The Research-Teaching Nexus: who does it benefit?: Dunedin, New Zealand</td>
<td>University of Otago</td>
<td>Linking teaching and research from first year onwards is promoted as a means of preparing students for unpredictable and diverse futures.</td>
<td></td>
</tr>
<tr>
<td>30th May 2012</td>
<td>Changing practice towards inquiry-oriented learning: how do we make it happen?: Palmerston North, New Zealand</td>
<td>Massey University</td>
<td>Describe the processes the fellowship is adopting to stimulate and facilitate change in Australian universities.</td>
<td></td>
</tr>
<tr>
<td>1st June 2012</td>
<td>Inquiry-oriented learning: What is it and how do we make it happen?: Hamilton, New Zealand</td>
<td>University of Waikato</td>
<td>Describe the processes the fellowship is adopting to stimulate and facilitate change in Australian universities.</td>
<td></td>
</tr>
<tr>
<td>19th July 2012</td>
<td>The CSIRO-University Undergraduate Inquiry Initiative: Sydney</td>
<td>ACDS conference</td>
<td>The genesis of the CUUII initiative and its current status were explored as well as the role National Teaching and Learning Centre can play in progressing, supporting and expanding this initiative.</td>
<td></td>
</tr>
<tr>
<td>8th August 2012</td>
<td>Embedding Research into the Undergraduate Curriculum: Why do it?: Sydney</td>
<td>University of Technology, Sydney Law Faculty</td>
<td>The presentation explored, with the aid of examples, how involving undergraduates in research and inquiry can invigorate teaching and research to the benefit of all stakeholders.</td>
<td></td>
</tr>
<tr>
<td>19th September 2012</td>
<td>University of Technology, Sydney and CSIRO initiative readies our 2016 researchers: Sydney</td>
<td>University of Technology, Sydney Science</td>
<td>I described a recent initiative with CSIRO to co-develop ‘inquiry in-context’ activities, drawing on CSIRO/University of Technology, Sydney research in order to engage first-year science students in practical, meaningful and sustained ways with scientific issues of national significance being researched by CSIRO and University of Technology, Sydney.</td>
<td></td>
</tr>
<tr>
<td>20th September 2012</td>
<td>Inquiry-oriented activities in the undergraduate science laboratory: Sydney</td>
<td>Sydney University</td>
<td>Described processes to facilitate, and in some cases stimulate, change towards inquiry-oriented learning in science.</td>
<td></td>
</tr>
<tr>
<td>25th September 2012</td>
<td>Inquiry in Context: Sydney</td>
<td>University of Technology, Sydney fellowship Forum</td>
<td>This presentation explored: national drivers causing a reconsideration of learning science through inquiry in the undergraduate curriculum; why the portents are favourable for the mainstreaming of inquiry in the undergraduate curriculum and touched on some key issues such as the use of technology to support learning through inquiry.</td>
<td></td>
</tr>
<tr>
<td>Date</td>
<td>Title</td>
<td>Location</td>
<td>Description</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>27th Sept</td>
<td>Scientific inquiry in the undergraduate curriculum: challenges and benefits in the new age of standards: Sydney</td>
<td>ACSME plenary, University of Sydney</td>
<td>This presentation explored the benefits to student learning of developing and embedding scientific inquiry into the science curriculum and brings a focus to the challenges of assessing the attendant learning outcomes.</td>
<td></td>
</tr>
<tr>
<td>12th Dec</td>
<td>Preparing demonstrators to facilitate learning in inquiry-oriented practicals: Sydney</td>
<td>AIP Congress, UNSW</td>
<td>In this paper I reported an innovation in the professional development of demonstrators that focuses on the student perspective in order to enhance demonstrators’ capacity to support learning in inquiry-oriented practicals.</td>
<td></td>
</tr>
</tbody>
</table>
Les Kirkup’s fellowship is a landmark in the re-invigoration of tertiary teaching and learning in science. It has long been felt that science has suffered in the estimation of students because its teaching has failed reflect its character as an activity of discovery, embracing curiosity, creativity and independent thinking challenged by evidence. Many individuals have felt this keenly, tried to change their own teaching, and put forward their good ideas to other likeminded tertiary science teachers. Nevertheless mainstream science teaching has remained unaffected.

Les’ fellowship has engaged the mainstream and created a national profile for inquiry oriented learning in science that provides a platform for its expansion. He has achieved this by operating at an organizational rather than an individual level, working with science faculties and their teaching and learning leaders directly, through workshops and activities that engage their own ideas and practices. It is, if you like, faculty sponsored professional development that role models the very inquiry oriented learning approach that Les is seeking to promote.

The fellowship is commendable for the breadth of ideas and approaches that it took up in the effort to promote science as a real discovery activity rather than a rarified academic one. One notable aspect is the connection made with CSIRO. One hopes that this will continue to develop a strong connection between real world science and science teaching in universities.

Professor John Rice
Executive Director
Australian Council of Deans of Science
February 2013