More active lecture approaches in science and mathematics: Using expert cultural capital to drive change

Final report 2016

The University of Sydney

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www.activelearningscience.com
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List of acronyms used

ALIUS: Active Learning in University Science
ASELL: Advancing Science and Engineering through Laboratory Learning (current)
ASELL: Advancing Science by Enhancing Learning in the Laboratory (precursor)
ATN: Australian Technology Network
CCI: Chemistry Concept Inventory
ChemEd: Chemistry Education Research
FCI: Force Concept Inventory
FMCE: Force and Motion Concept Evaluation
Go8: Group of Eight
HoS: Head of School
IOL: Inquiry Oriented Learning
IRU: Innovative Research Universities
LASE: Lecture Activity and Student Engagement
MOOCs: Massive Open Online Courses
PF: Postdoctoral Fellow
POGIL: Process Oriented Guided Inquiry Learning
PRT: Peer Review of Teaching
RFS: Representational Fluency Survey
RUN: Regional Universities Network
SaMnet: Science and Mathematics network of Australian university educators
TCS: Thermal Concepts Survey
Executive summary

More active lecture approaches in science and mathematics:
Using expert cultural capital to drive change

March 2016
The University of Sydney
Professor Manjula Sharma 2013 National Teaching Fellow
Supported by Postdoctoral Fellow, Dr Helen Georgiou

There is a general feeling that lectures are falling out of fashion with university science educators. Strategies and rhetoric are appearing; where everything from small class teaching to online resources are being proposed in an effort to redeem universities from the potential damage done by associating themselves with the ‘traditional’ style of lectures. However, as with all stereotyping, there is a danger in making assumptions about what the lecture is and what it isn’t—and what it can and can’t be. Furthermore, while more flexible learning spaces are emerging, lecture theatres continue to be constructed. That suggests that lectures are ingrained both in practice and in institutional structures.

Expert Cultural Capital: Universities are places of research and teaching. They are ‘knowledge intensive’ organisations where knowledge is created and shared through a variety of mechanisms: from collaborative knowledge creation amongst research colleagues, to induction into bodies of knowledge in undergraduate programs using the infamous lectures as a prime vehicle of delivery. It is perhaps then ironic that in the area in which the two spheres of universities overlap; the research on teaching and learning, there exists a boundary preventing research findings from informing practice. In other words, the expertise within and across universities is rarely taken advantage of to improve teaching practices. Working within science and mathematics disciplines, this Fellowship is a campaign to create an exception to the rule. ‘Active learning’, a robust, research-based movement which improves student understanding and affect towards learning, is being increasingly adopted by university actors that hold cultural capital. Active learning appeals to academics because it encompass all modes of student learning bringing coherency to the teaching enterprise, and provides clarity to the espoused student-centred approaches educationalists strive for.

Strategy: The Fellowship utilised a three-pronged strategy, each associated with a type of academic identified by their role in the creation, sharing and use of knowledge about teaching and learning. The Fellowship uses the following terms with reference to Academics and their use of ‘active learning’ practices such as those who were actively using the practices (Engaged academics), those who were open to using these practices (Open-to-change academics) and those who were unacquainted with these practices (Unacquainted academics).

The figure below shows a typical university department with a few Engaged academics more that are Open-to-change and even more that are Unacquainted with the practices. For research on teaching and learning to inform practice and for the expert cultural capital to drive change, the knowledge sharing is vital. The Fellowship worked with the three groups
of academics in creating, sharing and using knowledge about teaching and learning in effective, efficient and a timely manner as captured below.

![Figure 14 Strategic connections, using expert cultural capital to drive change.](image)

The Fellowship involving 13 universities, 8 initial partners and 5 new partners;
- extracted themes which underpin effective achievements of ten engaged academics,
- involved 31 open academics in experimenting with efficient assessment of learning gains using concept inventories with 8000 students,
- and implemented a timely peer review of teaching program with 29 unacquainted academics utilising active learning.

The creation and sharing of knowledge is critical to ‘steering’ the three types of academics, not necessarily relative to one another, but all groups in certain directions, generating cultural shift in ways of thinking and enacting teaching and learning at the local level. The wider exchange of knowledge, akin to research, valued within knowledge intensive institutions, is facilitated through networks, regular gatherings and scholarly work in which the expert cultural capital is exchanged. This flow of knowledge between departments, disciplines and institutions draws on and drives systemic change.

**Recommendations:** With its focus on lectures, this Fellowship could be seen as both novel and controversial. As in many controversies, a way forward is through reframing the dilemma. In this spirit, the Fellowship found that the key challenge is the uptake of effective strategies. To hasten the uptake and for research on teaching and learning to inform practice, knowledge sharing needs to be effective, efficient and timely. Four recommendations emerge from the Fellowship activities.

In reframing the dilemma, the **first recommendation** for departments is to support engaged academics in the establishment, uptake and embedding of active learning approaches through internal structures identified as four themes-listed below-operating in concert to facilitate transformative levels of achievement with sustained change in teaching and learning practices.

1. For the university department to have one or more ‘champions’ engaged in evidence-based education; the creation and sharing of teaching and learning knowledge within and beyond the department in an effective manner.
2. For influential senior leadership within the university department of teaching and learning and mentoring of teaching and learning leaders.

3. For the university department to have a sufficient number of committed colleagues (critical mass) rallying around teaching and learning activities.

4. For the institution to have measures reflecting that their institution values teaching and learning and be committed to them.

The second recommendation is to enable the generation and garnering of evidence to support approaches such as active learning by coaching academics open to change.

The third recommendation is to guide unacquainted academics into adopting active learning approaches in the formative years of their careers through timely programs such as the Peer Review of Teaching program.

The fourth recommendation is to establish networks for sharing knowledge within and between departments and institutions.

Impact and Implications: Over 20 years, education experts have developed a number of successful active learning programs that are being selected for use in science and mathematics courses. Why are these being adopted sporadically rather than becoming the norm? The explicit knowledge sharing amongst the different types of academics has been missing. Clear guidelines for departments have been missing. This Fellowship, in recommendations, articulates guidelines which, if implemented, have the capability to shift the culture, not just for transforming the perceived (and real) limitations associated with the traditional lecture format, but for the entire teaching enterprise.

Resources at website: http://activelearningscience.com/
Table of contents

Acknowledgements ............................................................................................................................................ 3
List of acronyms used ....................................................................................................................................... 4
Executive summary ........................................................................................................................................... 5
Tables and figures ............................................................................................................................................. 10
Figures ........................................................................................................................................................... 11
Fellowship Context ......................................................................................................................................... 12
Fellowship Approach - The three-pronged strategy ....................................................................................... 14
Scope – Institutions and colleagues ................................................................................................................ 16
Strategy 1: Engaged (academics) .................................................................................................................... 17
  Context ......................................................................................................................................................... 17
  Approach ...................................................................................................................................................... 17
    The engaged participant and their pocket of excellence ........................................................................... 17
    Themes supporting the local pocket of excellence ............................................................................... 18
    A classification of the achievement of the pocket of excellence ...................................................... 19
  Outputs and findings ................................................................................................................................. 20
Strategy 2: Open-to-change (academics) ....................................................................................................... 24
  Context ......................................................................................................................................................... 24
  Approach ...................................................................................................................................................... 26
  Outputs and findings ................................................................................................................................. 28
    The individual misconceptions .......................................................................................................... 29
    The individual institution .................................................................................................................... 30
    Individual inventory across many institutions ............................................................................. 30
Strategy 3: Unacquainted (academics) ........................................................................................................... 33
  Context ......................................................................................................................................................... 33
  Approach ...................................................................................................................................................... 34
    Approaching and recruiting potential participants .......................................................................... 34
    Workshop meeting ............................................................................................................................... 35
    Observation (of the unacquainted participant) .................................................................................... 35
    Interview (of unacquainted participant) .............................................................................................. 36
    Observation (of unacquainted participant) ............................................................................................ 36
    Reflection (of unacquainted participant) – consisting of three parts ............................................. 37
    Data and analysis ................................................................................................................................... 38
  Outputs and Findings ................................................................................................................................. 38
    What way do they want to improve/develop? ..................................................................................... 39

More Active Learning Approaches in Lectures
What do early career lecturers think are the biggest barriers to giving good lectures? .................................................................40
What are their approaches to dealing with these barriers? ..................................41
Did the early career lecturers try active learning methods? .................................42
What where the substantive lessons learnt by them? ........................................42

Impact and recommendations ..............................................................................45
Recommendations .................................................................................................47
References .............................................................................................................48
Appendices ...........................................................................................................50
DVC-Education certification ..................................................................................57
Tables and figures

Tables

**Table 1:** The three groups of participants and their involvement with the Fellowship

**Table 2:** The engaged participants and their local pockets of excellence

**Table 3:** The timeframe for achievement of each pocket of excellence and the strength (qualitatively) of the themes underpinning the achievement

**Table 4:** The different first-year samples and how the concept inventories were administered. Some data sets were not analysed due to insufficient sample sizes.

**Table 5:** Results from administration of conceptual inventories

**Table 6:** Common and persistent misconceptions identified through inventories

**Table 7:** The PRT participants
Figures

**Figure 1:** The three groups of participants

**Figure 2:** The Engaged involved in “the communication and circulation of thought”, knowledge on teaching and learning in their departments.

**Figure 3:** Pre and post test scores for the CCI for institution I

**Figure 4:** Hake plots indicating course average normalised gains for different inventories from Hill, Sharma and Johnston (2015)

**Figure 5:** Hake plot for the Fellowship results from various conceptual inventories (Interactive plot at [http://activelearningscience.com/open/](http://activelearningscience.com/open/))

**Figure 6:** Internal connections and “the communication and circulation of thought” as the department seeks knowledge using a scholarly approach.

**Figure 7:** Overview of Peer Review of Teaching Program

**Figure 8:** A completed section of the PRT Reviewers tool

**Figure 9:** Two completed sections of the PRT Reviewers tool showing a change in teaching approach of the participant and a change in student engagement

**Figure 10:** How the Participants engaged with the PRT program

**Figure 11a:** Lecture activity as a proportion of the first sixty-minute observed lecture.

**Figure 11b:** Lecture activity as a proportion of the second sixty-minute observed lecture.

**Figure 12:** Level of student engagement for different types of lecture activity. Diagram produced by Dr Matthew Hill

**Figure 13:** Strategically connecting the groups through knowledge sharing which is effective, efficient and timely.

**Figure 14:** Strategic connections, using expert cultural capital to drive change
Fellowship Context

“The Lecture is Dead; long live the lecture!”

The last several years have produced many an obituary for the university lecture, both by the academic as well as the popular press. In Australia, many universities have prioritised blended learning, some have embraced Massive Open Online Courses (MOOCs) (Macdonald, 2014) and one university has announced they will phase out lectures completely (Dodd, 2015). This sentiment assumes a particular structure and homogeneity in the mode; that is, that the modern lecture involves a straightforward didactic presentation of information delivered by a specialist in the field to a relatively large cohort of students. This is simply not a reflection of modern Australian universities. However, due to the complicated and abstract organisational structure of universities, it is not easy to assess the state and nature of teaching practices. University teaching is mainly facilitated implicitly through institutional and professional cultural cues, rather than explicitly outlined in procedures and documents. Furthermore, what appears to be a ‘traditional’ didactic lecture may be interactive and collaborative, while a supposedly interactive small group tutorial where students watch a video beforehand and the tutor provides an analysis may be extremely passive. For example, the basis of many MOOCs and Blended Learning environments is still a didactic lecture, albeit one that is presented as a recorded video, and yet these efforts are almost always presented as ‘innovative’ and ‘enterprising’ (Kovanović, Joksimović, Gašević, Siemens, & Hatala, 2015), when, in fact, they emulate transmissive lectures. In addition, the effectiveness of these relatively new modes is questionable (Hew & Cheung, 2014). On the other hand, time has ensured that the research on what makes a lecture effective is now quite substantial, and it may be the case that the issue is translating these research findings into practice. Considering the common ground shared by the different modes of university teaching, and across the disciplines, it is inevitable that the lessons learnt from this Fellowship will have consequences in a much wider context.

The Fellowship therefore chooses to retain the focus on lectures because it shares the belief of many others that the format is able to facilitate student learning as long as appropriate evidenced-based approaches are utilised, such as those falling under the umbrella of active learning. The lecture also has many other advantages such as encouraging the union of teaching with research, favourable economies of scale and capitalising on face-to-face communication, which includes non-verbal cues. It therefore relies on several firm assumptions about science lectures; that they remain the dominant form of teaching in higher education, that they are economical and efficient, and, when done correctly, can be effective. In the words of one of the early architects of the modern university:

“A University is a place ... whither students come from every quarter for every kind of knowledge; ... a place for the communication and circulation of thought ... It is the place to which a thousand schools make contributions; ... We must consult the living man and listen to his living voice, ... to adjust together the claims and relations of their respective subjects of investigation. Thus is created a pure and clear atmosphere of thought, which the student also breathes.”

One of three principles underpinning the modern university, articulated by the father of the modern university, Wilhelm von Humboldt, is the unity of research and teaching (Boulton & Lucas, 2008). In this unison, knowledge is created and shared through a variety of mechanisms: from collaborative knowledge creation between experts who hold cultural capital supporting postdoctoral research, to induction into bodies of knowledge in undergraduate programs. Knowledge is valued; the sharing of which provides novel intellectual insights. It is perhaps then ironic that with time, the intent articulated by the early founders has been eroded. While knowledge creation and sharing continues to underpin research, the research on teaching and learning is often not shared or simply ignored by practitioners in universities. This thus constrains the advancement of evidence-based approaches and prevents research findings in the realm of teaching and learning from informing practice. In teaching, the university loses the focus as ‘a place for the communication and circulation of thought’. The expertise within and across universities inherent amongst the teaching and learning cultural capital does not circulate and is therefore rarely taken advantage of to improve teaching practices. This Fellowship, working within science and mathematics disciplines, is a campaign to change this status quo.

“At this point, it is unethical to teach any other way”


‘Active learning’, a robust, research-based approach has garnered ample evidence, leaving no doubt, that the approach improves student understanding and affect towards learning (see, for example Deslauriers, Schelew, & Wieman, 2011; Georgiou & Sharma, 2015; Mazur, 2009). While those who hold cultural capital are increasingly adopting active learning approaches, the limited opportunities for the cultural capital to coalesce with colleagues ‘to adjust together the claims and relations of their respective subjects of investigation’ results in constrained uptake. Active learning appeals to academics because it encompass all modes of student learning bringing coherency to the teaching enterprise, and provides clarity to the espoused student-centred approaches that educationalists strive for. Hence, active learning, along with other research-based approaches, when adopted appropriately can provide a vehicle for transforming the entire teaching enterprise, not just lectures. The Fellowship focuses on the lecture, includes other modes of teaching and is hopeful to impact more widely. Despite the fact that such research-based approaches have made their imprint in the Australian context through endeavours such as those listed below, their presence is ad hoc, raising the question, why are these not the norm?

Active learning in Australia:


Active Learning in University Science (ALIUS)


Process Oriented Guided Inquiry Learning (POGIL) – [https://pogil.org/](https://pogil.org/)
Fellowship Approach - The three-pronged strategy

The Fellowship addresses the question of “How do we capitalise on the ‘expert cultural capital’ of those staff who are enthusiastic about more active approaches to teaching and learning in lectures with the intent of making lectures a valued, and valuable, learning event?”

The Fellowship’s main goal is therefore to illuminate and improve lecture practices through the focus on cultural capital. In other words, it involves observing and reporting on lecture practices across the country and engages with various cultural groups within the university to improve them.

The Fellowship specifically aimed to: identify good practices and further engage academics who are enthusiastic about more active approaches in lectures; develop and employ strategies to enlist hesitant academics who are open to change; and support those who are unacquainted with more active approaches in lectures. The Fellowship approached this through a three-pronged strategy that was enacted to suit these three distinct participant groups. Each strategy involved working with academics with distinct needs and therefore required different methods and produced unique outputs. These three strategies formed the overall project approach and are outlined below.

<table>
<thead>
<tr>
<th>Engaged</th>
<th>Open</th>
<th>Unacquainted</th>
</tr>
</thead>
</table>

The figure depicts a typical department with few engaged academics, more open-to-change and even more unacquainted. Each participant group is associated with a type of academic identified by their role in the creation, sharing and use of knowledge about teaching and learning. The Fellowship probed mechanisms for “communication and circulation of thought” amongst the groups.

The Fellowship acknowledges a hesitant group, ranging from the reticent to rather vocal, some of whom have participated in the open-to-change and a few others in the unacquainted groups.

Figure 1: The three groups of participants

Three distinct participant groups – shown in Figure 1 and described in Table 1 - were identified. It is these three groups that then shaped the three-pronged strategies described in the final column of Table 1: method of involvement.
Table 1: The three groups of participants and their involvement with the Fellowship

<table>
<thead>
<tr>
<th>Participant group</th>
<th>Description of participant group</th>
<th>Method of involvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engaged</td>
<td>Participants in this group were already effectively using active learning approaches in their lectures or were enacting active learning approaches in their departments as coordinators.</td>
<td>Structured interviews were conducted to understand the aspects that made their active learning efforts successful (Strategy 1)</td>
</tr>
<tr>
<td>Open</td>
<td>Participants in this group were open to improving or developing their lectures or the lectures/lecturers in their departments in the case of coordinators. They were often unsure of where to start and how to develop and manage successful teaching strategies.</td>
<td>Concept inventories were used to provide a means of determining impact of active learning programs and to induct participants into the scholarship of teaching and learning (Strategy 2).</td>
</tr>
<tr>
<td>Unacquainted</td>
<td>Participants in this group were unacquainted with educational research or the formal study of pedagogy. They were interested in improving their teaching but not aware of what this might involve or what success may look like.</td>
<td>A Peer Review of Teaching program was implemented to guide early career lecturers through active learning techniques suited to science lectures (Strategy 3).</td>
</tr>
</tbody>
</table>

The hesitant group

There are also a group of academics not explicitly captured here, the group that was hesitant in engaging with the Fellowship, and indeed, does not generally engage with these kinds of projects or efforts at all. This group was of particular interest to the Fellowship as it is this group that is the key to enacting meaningful, lasting cultural change. As part of strategy 2, a few were included in communications becoming aware of the processes involved in experimenting with concept inventories. As part of strategy 3, a small number of otherwise ‘hesitant’ academics participated in the Peer Review of Teaching program, which brought them into contact with pedagogical specialists (the cultural capital), and other enthusiastic lecturers. The section reporting on strategy 3 identifies the importance a program such as this one provides for the visibility of the teaching professional development process for these individuals. Furthermore, strategy 1 identifies the importance of a ‘critical mass’ in improving the reputation of teaching and in enacting change in lecture practices. Once this is achieved, even the most hesitant could be drawn in.
Scope – Institutions and colleagues

The participating institutions and colleagues came on board following through on their Letters of Support, took part after initial contact with the Fellow, as well as after the Fellowship gathered some momentum. Ultimately, thirteen institutions took part with some engaging with more than one strategy. Of the 13 institutions, six were leading research-focused (Group of Eight, Go8) universities from four states, two were leading-technology focused (Australian Technology Network, ATN) from two states, two innovative research-focused (Innovative Research Universities, IRU) from two states, one regional (Regional University Network, RUN) and two with no affiliation from two different states. Thus, the Fellowship is comprehensive, with participants from across the country and from different types of universities, capturing a diverse student and staff population.

With respect to the three different strategies, six unique universities participated as the engaged group, ten took part as the open-to-change group and one university participated as the unacquainted group. Within each participant group, several individual colleagues participated; sometimes this included more than one from each university. Descriptions of participants are elaborated on in the respective sections. In terms of disciplines, Physics and Chemistry were most represented, possibly due to the stronger contacts already existing between the Fellow (who is in a School of Physics) and the Schools of Physics and Chemistry at these various universities. It is also the case that both Physics and Chemistry have quite distinct and developed discipline based education research fields.

Following advice from the Fellow’s critical friend, the initial contact involved a structured invitation (see Appendix A) that was sent to Associate Deans Learning and Teaching (or equivalent) and/or colleagues from the eight institutions that had provided Letters of Support for the Fellowship. Over extensive discussions, the approach was customised to suit the needs of the participants at each institution, giving rise to the methods through which the Fellowship would engage the sector as shown in Table 1. Through disciplinary networks and the Science and Mathematics network of Australian university educators (SaMnet), five additional institutions came on board after the Fellowship had commenced. Appendix B shows a list of participating institutions. Due to human ethics committee requirements, identities have been protected throughout this report where data are presented. The codes used in the report therefore consistently refer to a unique university but are in a different order to that in Appendix B.

For the different types of participants involved in each strategy, different ways of keeping in touch, providing feedback and finalising the Fellowship were utilised. While the most frequent communication was via email, contact was also maintained via Skype, face-to-face meetings and informal meetings during conferences. In some cases, presentations at institutions have occurred and will continue as some efforts continue into the future.

The context, approach, and outputs and findings resulting from each of the three strategies are provided in the following three subsections. Following this is a consolidated summary of evidence about the overall impact and recommendations for future efforts.
Strategy 1: Engaged (academics)

Context

It is commonly agreed in the higher education context that teaching comes second to research. The tension between teaching and research more often than not results in academics striving to be research productive and investing less in teaching (Hattie & Marsh, 1996). And yet, there are local pockets where academics continue to excel in teaching.

What are those in these local pockets doing right? How did they manage to pull it off? In university science and mathematics, where the lecture is still a predominant method through which full-time academics engage in teaching, efforts to improve teaching often centre on active learning methods or student centred philosophies (Freeman et al., 2014). These methods and philosophies, although originating in an educational research community, are often implemented by an individual or group of individuals in science and mathematics who are engaged with driving change, resulting in the local pockets of excellence. These pockets of excellence and leadership capacity can be referred to as having ‘cultural capital’. However, the way in which such cultural capital operates and is effective is not well understood. In the absence of this understanding and despite having university-wide teaching support, the dissemination and uptake of active learning initiatives locally remains constrained.

In this section of the report, strategies employed by those in these pockets of excellence are distilled from interviews of individuals engaged in the introduction and sustainability of active learning initiatives. The objective was to examine cases where cultural capital exists already and examine what enabled their influence on teaching practices in the local pockets of excellence.

Approach

The engaged participant and their pocket of excellence

An hour-long structured interview was conducted with each engaged participant. The interview was in the form of an informal discussion with the Postdoctoral Fellow (PF) taking notes on a laptop, the Fellow taking handwritten notes and the engaged participant reflecting on their experiences. The subjects of the interview were the active learning teaching technique utilised by the interviewee and what enabled the acceptance of the technique. Using the probes in the interview template shown in Appendix C, the interview attempted to probe the “what” and the “how” of their achievements, highlighting the successes associated with these pockets of excellence.

The two sets of notes were cross-checked within 48 hours of the interview and a summary forwarded to the interviewee to validate within a week. In general, only minor technical details were changed by the interviewee.

Table 2 presents the local pockets of excellence involved in this Fellowship and summarises salient information pertaining to them and the engaged participant(s) from that pocket.
### Table 2: The engaged participants and their local pockets of excellence

<table>
<thead>
<tr>
<th>University Code, Discipline area</th>
<th>Interviewee – engaged participant</th>
<th>The pocket of excellence</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Maths Chemistry</td>
<td>Senior Lecturer, Year Coordinator, national leader</td>
<td>Altering the lecture/tutorial structure such that tutorials involved controlled small group interactive sessions and lectures were freer for active learning activities. Persistence has resulted in gradual acceptance and adoption beyond the initiator across the year level.</td>
</tr>
<tr>
<td></td>
<td>Senior Lecturer, doing chemistry research and Year Coordination</td>
<td>Gradual changes since 2000 focused on content alignment, capitalising on space changes and based on good practice resulting in greater than 80% student participation in face-to-face activities across the year level.</td>
</tr>
<tr>
<td>B Biology Physics</td>
<td>Senior Lecturer, educational innovator with national recognition and institutional standing</td>
<td>A slow ‘Evolution’ of the Biology courses, which included the introduction of an e-textbook, expectation for students to prepare, tracking of students and non-standard assessment across year level. Culture of excellence around teaching associated roles.</td>
</tr>
<tr>
<td></td>
<td>Professional Officer, educational innovator with substantive standing in the national community</td>
<td>The building of new lab spaces to facilitate lecturing in the ‘studio-teaching’ format (flat spaces, no lecturer out the front) and supporting academics in changing curricula and practices to realise the potential of these spaces with impact across the School.</td>
</tr>
<tr>
<td>C Chemistry</td>
<td>Lecturer, Year Coordinator who regularly participates in national projects</td>
<td>The systematic introduction of research-based, small group, active learning strategies in large lectures for a cohort and subsequently to other cohorts.</td>
</tr>
<tr>
<td>D Biology Chemistry</td>
<td>Annually contracted Lecturer supporting innovative Year Coordinator in reform</td>
<td>The introduction of a range of innovative strategies in large cohorts, from classroom response systems in lectures, pre-lab videos, popular online discussion forum to student generated questions. Predominantly in one course.</td>
</tr>
<tr>
<td>E Chemistry</td>
<td>Professor, innovator, internationally recognised science education researcher and educator</td>
<td>The introduction of simulations and active learning strategies in large cohorts. Difficulty persuading colleagues to take on ideas. Issues with multiple campus environments. Innovations are not embedded within programs.</td>
</tr>
<tr>
<td>F Physics Chemistry</td>
<td>Early Career Lecturer, Year Coordinator seeking to develop in an education focused role</td>
<td>The systematic introduction of online support and small group problem solving classes. The trialling of active learning in lectures. Students have homework booklets, and video solutions are posted online. First year teaching and learning rejuvenation.</td>
</tr>
<tr>
<td>Chemistry</td>
<td>Early Career Lecturer, doing chemistry research and Year Coordination</td>
<td>The systematic introduction of online quizzes associated with lectures. Plans to overhaul first year course to flipped model.</td>
</tr>
</tbody>
</table>

### Themes supporting the local pocket of excellence

The analysis was iterative with tentative themes extracted after three interviews; these themes were consolidated as more interviews were completed. After the first three interviews, possible answers to the “what” and the “how” of their achievements were
extracted. The possible answers were compared across these three interviews, generating four themes around things that either inhibit or enable local pockets of excellence. In subsequent interviews, these themes were probed to determine if they were critical contributors to the effectiveness of the local pockets of excellence.

The themes were refined iteratively as more interviews were completed based on (1) prominent ideas underpinning the theme, (2) ideas that resonated with other interviewees, (3) divergent or contradictory ideas, and (4) local subtleties surrounding the theme. Finally, the themes were re-checked against the data recorded on the template for each interviewee to ascertain how often the themes emerged and how strong they were in the case of each engaged participant (presented in the Output and Findings in Table 3). That is, for each interview, categories of strong, medium and weak were assigned to the themes to indicate qualitatively the extent to which a strategy was helpful in achieving a successful local pocket of excellence.

A classification of the achievement of the pocket of excellence

In seven cases, extra interactions occurred - observations, site visits and discussions with others in the department. For those established and recognised in the broader community, discussions with colleagues beyond the department were also held to obtain an historical perspective and current status of the development of the pocket of excellence. These data were collapsed to obtain a qualitative sense of the ‘achievement’. This assessment employed the following characterisation:

‘Transformative’ means the teaching environment has been significantly overhauled. The processes may have been evolutionary but when the final is compared with what existed earlier, there has been dramatic change. The transformation included philosophies, materials, resources and structure of teaching format (labs/tutorials/lectures). The transformation has changed student and staff expectations and practices.

‘Gradual’ means that the teaching and learning has been evolving over time. Changes have crept into the materials, resources and some aspects of the structure of teaching format (labs/tutorials/lectures). The transformation has changed student expectations and practices. While some staff practices have changed, others can continue as before. With time, more staff are engaging and changing approaches.

‘Escalating’ means one or more aspects of the materials, resources and structure of teaching format (labs/tutorials/lectures) have changed recently. A new philosophy is being embraced. Change has been initiated with plans to continue into the future. Student and staff expectations and practices are changing.

‘No traction’ means one or more aspects of teaching have been changed but the change was confined to one course or lecturer who has been struggling to convince others to change practices. Again, ‘no traction’ refers to no traction with others aside from the single lecturer or course where the initial change occurred.
Outputs and findings

Four key themes emerged from analysis of the interviews in which the engaged participant discussed their efforts in introducing and sustaining their pocket of excellence. These themes, with illustrative quotes, are as follows:

1. Existence of a champion who is engaged in evidence-based education, who is contributing locally and is connected with like-minded others outside their university.

This manifested itself in the interviewee’s engagement with evidence-based ways of demonstrating excellence in teaching and their confidence in taking action and connecting with others.

F: Chemistry; “The notion of ‘experimenting’ with new methods of teaching, using research based pedagogies, gathering data and utilising evidence for decision making is important. Basically, collecting baseline data so I can undertake ‘educational experiments’. Next year, when I trial Flipped lectures, I can compare with the baseline data. I like innovating, inquiring and trying new ‘things’, which have a sound educational basis. I do not prefer radical change. Strategy is to ask colleagues what they do not like about teaching, than make changes to solve their problems. Not to necessarily advocate change for the sake of change.”

2. Influence of local senior leadership and mentoring

This manifested in the approach of the Head of School (HoS)/Department, the ways in which they triggered and/or intervened in teaching and learning with a focus on pedagogy rather than content.

B: Physics; “Change was already in the pipeline due to a change in Dean … we ‘bid’ for better space. A working group including HoS was formed. HoS was very strong in his vision to capitalise on this change; if it is to happen, it should be ‘different’ and ‘radical’, not just a minor upgrade. Research was conducted in relation to existing models. The link to this model came initially from an academic on the working group. External feedback was sought in terms of the draft proposal. Overall, HoS provided the vision and the working group nutted out the possibilities, with feedback provided by external contacts. … After this decision had been made, the others in the group took a more hands off approach. HoS pushes for even more change and is happy/comfortable to takes risks. He is willing to be guided by others who are committed to change. For example, he was quite happy to be ‘pushed around’ when [redacted] suggested the introduction of ‘Clickers’ in the first year labs. So, not just directing innovation, responds to being directed as well.”

3. Existence of a sufficient number of committed colleagues within a School/Department to provide a critical mass and time investment in pedagogical initiatives.

This ranged from a team of professional and academic staff (sometimes including postgraduate students) systematically invested in teaching and learning, to teams who could be assembled as needed supporting a core teaching and learning team. Both of these
extremes are illustrated in the quotes below. The key facet was that a team would pull their weight and work in concert on a consistent mission.

B: Biology; “This involves a unique structure whereby a core of ~25 sessional staff (post-grads included but not honours) share teaching load and responsibilities. This differs from a larger, transient cohort of casual post-graduates who might usually have this responsibility. It ensures a specialism in this area, and ongoing opportunities for mentorship among the teaching team, a pool of expertise, with the obvious ‘disadvantage’ of perhaps not involving as many post-graduates in the teaching as possible. … Underperforming or uninvested members are let go and marking or teaching not up to standard is professionally developed. There are an additional two academic education focused one-year associate lecturer positions. The group contact hours amounts to about 6 full-time salaries. Since Biology is a profitable course, even with teaching salaries/resources, there are funds ‘left over’. … At a School level, [redacted] is the director of education. [redacted] is the head/director of the 1st year educational committee. … [redacted] is the Deputy Head of School, a valued researcher in a senior role who manages workload/coordination etc. [redacted] ties teaching and learning strongly to school goals and is also a head mentor. Educational committee and honours coordinator (and others) meet every month to discuss innovation and logistics.”

F: Physics: “I have a supportive Head of School. I have complete authority to run the operation. I have administrative support and am working towards having a Physics graduate with pedagogical/technological skills join core team. They are 0.5 time but I am trying to make it a full time Level A appointment. It is important to have support staff who have pedagogical as well as physics knowledge so they can handle online forums etc. I have good core group of four academics interested and involved.”

4. Evidence that the institution values teaching and learning

The interviewee could provide instances of when they or their work seemed to have been noticed and highlighted within the institution as well as the interviewee revealing insights into the role of teaching achievements in career progression.

C: Chemistry: “The School is open to new ideas, with good interaction between staff. The School must support this kind of work. Teaching intensive option must exist. I find it easy to get funding to go to science education conferences. ChemEd is advertised. We have a particular course which is mandatory for everyone enrolled in science. It covers writing skills, including interviewing an active researcher who could be a ChemEd researcher. I can see a pathway in Scholarship of Teaching and Learning including grants in teaching and learning, publications. I am co-supervising a student in Chem Ed. My original intellectual contributions are through curriculum renewal and innovation. Evaluation, reflection, implementing good practices from literature and other places is key to career trajectory.”

These themes summarise the nature of efforts of the engaged participant within their pocket of excellence. The strength of each of the themes (the extent to which they were related to achieving a successful local pocket) were ascertained from the interviews. The results are shown in Table 3. The timeframe for the achievement of the pocket of excellence is shown in the last column of Table 3.
Table 3: The timeframe for achievement of each pocket of excellence and the strength (qualitatively) of the themes underpinning the achievement

<table>
<thead>
<tr>
<th>Discipline area</th>
<th>1 Champion</th>
<th>2 Senior leadership</th>
<th>3 Critical mass</th>
<th>4 Value</th>
<th>Achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: Maths</td>
<td>Strong</td>
<td>Medium</td>
<td>Strong</td>
<td>Strong</td>
<td>Transformative: over 10 years</td>
</tr>
<tr>
<td>A: Chemistry</td>
<td>Weak</td>
<td>Medium</td>
<td>Medium</td>
<td>Weak</td>
<td>Gradual: over several years</td>
</tr>
<tr>
<td>B: Biology</td>
<td>Strong</td>
<td>Strong</td>
<td>Strong</td>
<td>Strong</td>
<td>Transformative: over 7 years</td>
</tr>
<tr>
<td>B: Physics</td>
<td>Strong</td>
<td>Strong</td>
<td>Strong</td>
<td>Strong</td>
<td>Transformative: over 5 years</td>
</tr>
<tr>
<td>C: Chemistry</td>
<td>Strong</td>
<td>Strong</td>
<td>Strong</td>
<td>Strong</td>
<td>Transformative: over 3 years</td>
</tr>
<tr>
<td>D: Biology</td>
<td>Strong</td>
<td>Weak</td>
<td>Weak</td>
<td>Weak</td>
<td>No traction: 2 years work, likely to reverse</td>
</tr>
<tr>
<td>E: Chemistry</td>
<td>Strong</td>
<td>Weak</td>
<td>Weak</td>
<td>Weak</td>
<td>No traction: 20 years of work with minimal impact in department</td>
</tr>
<tr>
<td>F: Physics</td>
<td>Strong</td>
<td>Medium</td>
<td>Strong</td>
<td>Medium</td>
<td>Escalating: within 2 years</td>
</tr>
<tr>
<td>F: Chemistry</td>
<td>Strong</td>
<td>Strong</td>
<td>Strong</td>
<td>Strong</td>
<td>Escalating: within 2 years</td>
</tr>
</tbody>
</table>

The achievement indicated by the terms transformative, gradual and escalating are associated with cultural change within the department. This change could be seen as a result of measures that were either implicit - as the engaged participant went about improving their own practices and influencing others within a context with themes supporting change, or explicit - driven by the engaged participant with an intent to improve teaching and learning, thereby escalating change. The level of achievement indicated by ‘no traction’ tended to have three weak themes (from the four columns listed). Active learning approaches utilised by the engaged participant had minimal impact beyond the participant.

From this analysis, the Fellowship concludes that the reinforcement or interplay among these themes has been important in assessing what it is about the local pockets of excellence that facilitates their achievements in transforming teaching and learning. By identifying these themes, the Fellowship helps departments identify where resources would be most usefully directed and under what conditions active learning programs can flourish.

Given that the themes emerged from data, it is worthy to review the themes from the perspective of the visionaries of the modern university. Wilhelm von Humboldt’s focus on the unity of research and teaching is reflected in themes 1 and 3. Central to theme 1 is the cultural capital engaging with research on teaching and interacting with others outside their department, as well as collaborating with their departmental ‘critical mass’ to implement research based teaching (theme 3). Clarity and purposeful departmental leadership prioritising the champion as the teaching knowledge expert as well as seeking evidence...
based practices in the teaching in their department is reflected in theme 2. Finally, theme 4 is structural with the senior institutional leadership valuing and rewarding the contributions to the advancement of teaching through evidence based approaches. Coherently, the resultant is “the communication and circulation of thought”, knowledge on teaching and learning in the knowledge intensive University, as articulated by Newman captured by Figure 2.

**Figure 2:** The Engaged involved in “the communication and circulation of thought”, knowledge on teaching and learning in their departments.

At a fundamental level, the Fellowship contributes to understandings of how and what enables individuals or groups of individuals to enact change by adopting methods and philosophies originating in the research community and resulting in local pockets of excellence. This Fellowship therefore helps illuminate the nature of cultural change in university teaching of science and mathematics. These findings will be shared with Associate Deans, Head of Departments and through academic publication and presentation in an effort to communicate key features of successful change programs and make explicit the institutional and professional cues embedded in the higher education context.
Strategy 2: Open-to-change (academics)

Context

Evaluation of active learning strategies occurs predominantly through the use of concept inventories in physics education research. It is these concept inventories that helped galvanise the finding that active learning strategies are far superior to ‘traditional’ lecturing with the recommendation that they should be implemented more broadly in science teaching at the undergraduate level (Freeman et al., 2014).

Concept inventories are conceptual, often multiple-choice surveys that contain material that is fundamental to the discipline (as opposed to mathematical or specific/technical knowledge). They are based on common misconceptions that have been progressively documented over 30 years (Driver, Guesne & Tiberghien, 1985). The misconceptions are minutely probed during the development of the survey. The misconceptions are consistent across many samples, found to persist with ‘traditional’ instruction and are associated with deepening understanding of the discipline. These concept inventories are given in a pre- and post-test format. A change in concept inventory scores measures a ‘change in the way that students understand the world scientifically’, with consequent implications for curriculum and teaching practices.

Concept inventories have been developed for a range of subject matter. Those used in this Fellowship have been validated and tested for reliability with hundreds of students. Furthermore, they have been utilised to demonstrate that active learning approaches are associated with learning gains evident in student scores on the concept inventories.

There is an attempt to keep the concept inventories ‘secure’, and since they are not associated with high stake testing, they are not as susceptible to misuse. Consequently, concept inventories form a reasonably good basis of obtaining a measure of whether teaching is effective and ascertaining if changes to the teaching program are making a difference.

The use of concept inventories does not occur without criticism. Critics suggest student understanding is trivialised by the assignment of numerical marks and that such inventories could never accurately represent a students’ comprehensive understanding at all times. They also argue that such concept inventories cannot provide sufficient detail for perfecting the teaching environment.

However, the use of these inventories persists for a number of reasons, three of which are important in this context.

- The first is that they offer a way of comparing across years, student bodies and locations (including internationally), as the inventories have been tested to assure that they validly and reliably reveal common misconceptions despite diverse settings.
- The second is that they track cohort understandings rather than individual ones.
• The third is that they provide the practitioner open to change with a tool with which to participate in the scholarship of teaching and learning, connecting with evidence-based education.

The advantages of inducting participants who are open to change into evidence-based education are manifold. Participants open to change will benefit from exposure to reported practices as well as involvement in the logistics of how to contribute to further understandings of active learning approaches. Engaging with participants open to change therefore offers the possibility of building cultural capital within their institution. The Fellowship’s objective, then, was to provide opportunities to participants open to change to experiment with implementing concept inventories, supporting and inducting them into evidence based education, and providing an entry into the scholarship of teaching and learning.

There were five main inventories used with participants open to change:

**Thermal concepts survey (TCS)** - A survey based on concepts in thermal physics, which may be administered in part (15 questions) or in full (35 questions). Topics covered include heat, temperature, thermal processes (Wattanakasiwich, Talaeb, Sharma, & Johnston, 2013). The use of TCS demonstrating learning gains with active learning, including an analysis of lecture time spent on interactivity, can be found in Georgiou and Sharma (2015).

**Force and Motion Concept Evaluation (FMCE)** - A 43-question survey based on concepts in mechanics. Topics covered include Newton’s laws, energy and momentum, as well as general kinematics (Thornton & Sokoloff, 1998). The use of FMCE demonstrating learning gains with Interactive Lecture Demonstrations as a form of active learning is in Sharma et al. (2010).

**Force Concept Inventory (FCI)** - A 30-question survey based on force concepts. Topics include Newton’s laws and kinematics (Hestenes, Wells, & Swackhamer, 1992). The use of FCI demonstrating learning gains with active learning is in Hake (1998). With a sample of 6,000 students, this paper establishes the low, medium and high gain areas; the higher the gain, the more interactive the teaching.

**Representational Fluency Survey (RFS)** - A seven-question, three-tiered survey based on scientific representational fluency in Physics. Questions do not require pre-requisite knowledge of physics concepts. Topics include understanding and interpreting graphs, words and equations used in science (Hill, Sharma, O’Byrne, & Airey, 2014). The use of RFS demonstrating both conceptual and representational learning gains with online pre lecture modules is in Hill, Sharma, & Johnson, (2015).

**Chemistry Concept Inventory (CCI)** - A 22-question survey based on concepts in Chemistry. Topics covered include the transformation of matter, energetics, and representations in Chemistry including formulae and equations as well as micro- and macroscopic considerations and the relationships between them (Mulford & Robinson, 2002). The use of an adaptation of the CCI demonstrating learning gains with active learning (Predict, Observe, Explain) is shown in Costu, Ayas, & Niaz (2010).
Approach

The participants open to change had one of the following interests:

- They were in contact with the Fellow for guidance with pursuing science education research within their local contexts
- They were newly appointed course coordinators or had responsibilities in first-year science units
- They were specifically requested, or required, to participate in educational research practices as part of their role (e.g., a teaching-focused appointment).

They looked to the Fellowship as an avenue to advance their interest. After initial contact, an individualised program was developed for each participant that included a follow up email, a face-to-face or Skype meeting, and the delivery of a physical or electronic package containing the inventories. The participant was schooled in the specific methods of administration of these inventories, and time was spent setting up the administrative process such that it may be replicated with ease for any subsequent re-runs. The intent was to make the implementation of the inventory not onerous. Most data were collected in 2014, although three institutions offered historical data as well.

A summary of the various approaches can be found in Table 4. The analysis of the results was performed completely on our end, with a solution available for participants in the way of a fully functional Excel template, should they wish to perform a basic analysis in the future. Results were offered to the participants in a digestible format (Appendix D) and in many cases meetings were held to discuss the significance of the results and the way forward.

Table 4: The different first-year samples and how the concept inventories were administered. Some data sets were not analysed due to insufficient sample sizes.

<table>
<thead>
<tr>
<th>University Code, Courses</th>
<th>Inventory</th>
<th>When collected</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: No concept inventory data collected</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B: Physics</td>
<td>FCI</td>
<td>S1: 2012-2014</td>
<td>Pre- and Post-collected at institution (online) as part of course and provided to us for analysis purposes</td>
</tr>
<tr>
<td>B: Concept inventory not carried out in Biology</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C: Chemistry</td>
<td>CCI</td>
<td>S1: 2014</td>
<td>Pre- and Post-administered online (Survey Monkey).</td>
</tr>
<tr>
<td>D: Physics</td>
<td>FMCE</td>
<td>S1: 2014</td>
<td>Both Pre- and Post- administered in first lab and final lecture, pen and paper</td>
</tr>
<tr>
<td>D: Physics</td>
<td>FMCE- 47</td>
<td>S1: 2014</td>
<td>Pre-administered in first lecture (pen and paper) and post-administered online (Survey Monkey)</td>
</tr>
<tr>
<td>D: Chemistry</td>
<td>CCI</td>
<td>Summer School 2013</td>
<td>Pre- and Post-administered in lectures, pen and paper</td>
</tr>
<tr>
<td>D: Chemistry</td>
<td>CCI</td>
<td>S1: 2014</td>
<td>Pre- and Post-administered in first and final lab sessions, pen</td>
</tr>
</tbody>
</table>
### Table 1: Administration of Pre- and Post-concept Inventory

<table>
<thead>
<tr>
<th>Subject</th>
<th>Inventory Type</th>
<th>Semester</th>
<th>Administration Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>D: Physics</td>
<td>TCS</td>
<td>2011-2012</td>
<td>Pre- and Post-administered in first lab session and final lecture, pen and paper</td>
</tr>
<tr>
<td>D: Concept inventory not carried out in Biology</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E: No concept inventory data collected</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F: Chemistry</td>
<td>CCI</td>
<td>S1: 2014</td>
<td>Pre- and Post-administered online within institution (Moodle)</td>
</tr>
<tr>
<td>F: Physics</td>
<td>TCS</td>
<td>S1: 2014</td>
<td>Pre- and Post-administered in first and final lectures, pen and paper</td>
</tr>
<tr>
<td>G: Chemistry</td>
<td>CCI</td>
<td>S1: 2014</td>
<td>Pre- and Post-administered in first and final lab sessions on pen and paper</td>
</tr>
<tr>
<td>H: Chemistry</td>
<td>CCI</td>
<td>S1: 2014</td>
<td>Pre- and Post-online (Survey Monkey). Sample size not sufficient</td>
</tr>
<tr>
<td>H: Physics</td>
<td>FMCE</td>
<td>S1: 2014</td>
<td>Pre- and Post-administered in first and final lab sessions on pen and paper</td>
</tr>
<tr>
<td>H: Physics</td>
<td>FMCE</td>
<td>S1: 2014</td>
<td>Pre- and Post-administered in first and final lab sessions on pen and paper. Sample size not sufficient.</td>
</tr>
<tr>
<td>I: Chemistry</td>
<td>CCI</td>
<td>S1: 2014</td>
<td>Pre- and Post-administered in first and final lab sessions on pen and paper</td>
</tr>
<tr>
<td>I: Physics</td>
<td>FMCE</td>
<td>S1: 2014</td>
<td>Pre-administered on pen and paper, post- not administered.</td>
</tr>
<tr>
<td>J: Physics</td>
<td>FMCE</td>
<td>S1: 2014</td>
<td>Pre- and Post-collected at institution (online) as part of course and provided to us for analysis purposes</td>
</tr>
<tr>
<td>K: Chemistry</td>
<td>CCI</td>
<td>online</td>
<td>S1: 2014</td>
</tr>
<tr>
<td>L: Chemistry</td>
<td>CCI</td>
<td>S1: 2014</td>
<td>Pre- and Post-administered online (Survey Monkey). Insufficient sample size.</td>
</tr>
</tbody>
</table>

In total, 12 separate courses were analysed with 17 individual sample groups, as some institutions administered the surveys to different cohorts.

The analysis included input from an undergraduate research student, Mr Xing Wang, which consisted of:

- Reducing data using standard procedures, e.g., removing those which had selected only one option throughout the inventory and those that had completed half or less of the inventory.
- Calculating mean and standard deviation for both pre- and post-tests.
- Identifying those who had completed both pre- and post-tests, i.e. generating matched data.
- Calculating course average normalised gain using matched data based on Hake (1998):
Post test class average – pre test class average

\[
\frac{\text{total possible} – \text{pre test class average}}{\text{pre test class average}}
\]

- calculating effect size (Preacher & Kelley, 2011):

\[
\text{Difference in group means} \over \text{Variability of groups}
\]

## Outputs and findings

The results are summarised in Table 5 using the measures of: sample size; mean and standard deviation for both pre- and post-tests; course average normalised gain (Hake, 1998); and effect size (Preacher & Kelley, 2011) to measure conceptual change.

**Table 5:** Results from administration of conceptual inventories

<table>
<thead>
<tr>
<th>University</th>
<th>Concept Inventory*</th>
<th>Pre-test mean %</th>
<th>Pre-test mean</th>
<th>Pre-test st. dev.</th>
<th>Pre-N</th>
<th>Post-test mean</th>
<th>Post-test st. dev.</th>
<th>Post-N</th>
<th>Both-N</th>
<th>Gain</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>CCI</td>
<td>35.8</td>
<td>7.67</td>
<td>3.72</td>
<td>497</td>
<td>10.18</td>
<td>3.68</td>
<td>304</td>
<td>261</td>
<td>0.16</td>
<td>0.62</td>
</tr>
<tr>
<td>C</td>
<td>CCI</td>
<td>57.9</td>
<td>11.8</td>
<td>4.31</td>
<td>90</td>
<td>11.35</td>
<td>4.67</td>
<td>57</td>
<td>26</td>
<td>-0.01</td>
<td>-0.016</td>
</tr>
<tr>
<td>F</td>
<td>CCI-A</td>
<td>63.5</td>
<td>13.32</td>
<td>4.54</td>
<td>117</td>
<td>13.21</td>
<td>4.91</td>
<td>96</td>
<td>32</td>
<td>0.10</td>
<td>0.19</td>
</tr>
<tr>
<td>F</td>
<td>CCI-B</td>
<td>65.1</td>
<td>15.26</td>
<td>7.37</td>
<td>127</td>
<td>14.39</td>
<td>4.28</td>
<td>113</td>
<td>37</td>
<td>0.13</td>
<td>0.24</td>
</tr>
<tr>
<td>D</td>
<td>CCI</td>
<td>62.2</td>
<td>12.52</td>
<td>4.29</td>
<td>571</td>
<td>11.47</td>
<td>4.24</td>
<td>165</td>
<td>49</td>
<td>-0.06</td>
<td>-0.11</td>
</tr>
<tr>
<td>G</td>
<td>CCI</td>
<td>44.0</td>
<td>9.58</td>
<td>3.73</td>
<td>817</td>
<td>10.19</td>
<td>3.90</td>
<td>742</td>
<td>608</td>
<td>0.06</td>
<td>0.19</td>
</tr>
<tr>
<td>H</td>
<td>FMCE</td>
<td>35.1</td>
<td>13.99</td>
<td>10.79</td>
<td>200</td>
<td>14.83</td>
<td>11.46</td>
<td>135</td>
<td>84</td>
<td>0.04</td>
<td>0.09</td>
</tr>
<tr>
<td>D</td>
<td>FMCE-A</td>
<td>30.2</td>
<td>10.50</td>
<td>8.82</td>
<td>175</td>
<td>18.6</td>
<td>11.51</td>
<td>15</td>
<td>10</td>
<td>0.28</td>
<td>0.71</td>
</tr>
<tr>
<td>D</td>
<td>FMCE-B</td>
<td>44.2</td>
<td>18.58</td>
<td>11.34</td>
<td>595</td>
<td>23.68</td>
<td>12.40</td>
<td>533</td>
<td>424</td>
<td>0.19</td>
<td>0.41</td>
</tr>
<tr>
<td>J</td>
<td>FMCE</td>
<td>50.9</td>
<td>244</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>RFS</td>
<td>44.8</td>
<td>8.76</td>
<td>3.76</td>
<td>422</td>
<td>11.42</td>
<td>3.79</td>
<td>625</td>
<td>460</td>
<td>0.25</td>
<td>0.67</td>
</tr>
<tr>
<td>F</td>
<td>TCS</td>
<td>57.0</td>
<td>8.80</td>
<td>2.60</td>
<td>1022</td>
<td>10.42/18.08†</td>
<td>2.80/4.78†</td>
<td>724</td>
<td>560</td>
<td>0.23</td>
<td>0.61</td>
</tr>
<tr>
<td>D</td>
<td>TCS-A</td>
<td>58.6</td>
<td>9.38</td>
<td>2.70</td>
<td>55</td>
<td>11.25/19.36†</td>
<td>2.31/3.97†</td>
<td>55</td>
<td>55</td>
<td>0.28</td>
<td>0.69</td>
</tr>
<tr>
<td>D</td>
<td>TCS-C</td>
<td>54.5</td>
<td>8.72</td>
<td>3.41</td>
<td>60</td>
<td>11.21/18.96†</td>
<td>2.20/4.14†</td>
<td>60</td>
<td>60</td>
<td>0.34</td>
<td>0.73</td>
</tr>
<tr>
<td>D</td>
<td>TCS-B</td>
<td>59.9</td>
<td>9.59</td>
<td>3.53</td>
<td>34</td>
<td>12.17/20.72†</td>
<td>2.18/4.31†</td>
<td>34</td>
<td>34</td>
<td>0.4</td>
<td>0.73</td>
</tr>
<tr>
<td>D</td>
<td>TCS-D</td>
<td>59.3</td>
<td>9.48</td>
<td>2.53</td>
<td>63</td>
<td>11.22/19.23†</td>
<td>2.17/3.74†</td>
<td>63</td>
<td>63</td>
<td>0.27</td>
<td>0.69</td>
</tr>
<tr>
<td>B</td>
<td>FCI-A</td>
<td>69.6</td>
<td>20.86</td>
<td>6.51</td>
<td>286</td>
<td>23.56</td>
<td>5.72</td>
<td>286</td>
<td>286</td>
<td>0.31</td>
<td>0.43</td>
</tr>
<tr>
<td>B</td>
<td>FCI-B</td>
<td>75.3</td>
<td>21.80</td>
<td>5.84</td>
<td>234</td>
<td>23.20</td>
<td>5.80</td>
<td>234</td>
<td>234</td>
<td>0.05</td>
<td>0.07</td>
</tr>
<tr>
<td>B</td>
<td>FCI-C</td>
<td>76.4</td>
<td>22.9</td>
<td>5.78</td>
<td>342</td>
<td>24.3</td>
<td>5.09</td>
<td>342</td>
<td>342</td>
<td>0.19</td>
<td>0.23</td>
</tr>
<tr>
<td>B</td>
<td>FCI-D</td>
<td>40.3</td>
<td>12.1</td>
<td>6.21</td>
<td>202</td>
<td>15.7</td>
<td>6.6</td>
<td>202</td>
<td>202</td>
<td>0.20</td>
<td>0.58</td>
</tr>
</tbody>
</table>

Note: some data missing

*Suffixes denote different streams within courses or different years of inventory administration

† Two values are shown as the TCS had two parts. Part I was given (/16) as the Pre-test and parts I and II were given as the Post-test (/35).
A total of around 8,000 students provided inventory responses, making this a significant sample size. The analysis yielded several interesting and useful findings and has scope for more examination. Summarised here are three findings capturing the different aspects of the study: the individual misconception; the apparent effects or context of the individual institution; and the patterns in individual inventories across many institutions.

The individual misconceptions

As with the extensive literature on misconceptions in science, this study revealed that students, even at university level, still have difficulty understanding basic concepts and these misunderstandings remain even after completing their courses.

Table 6 shows, from three of the conceptual inventories used, the question that was answered most poorly and showed the least improvement after students had completing their courses. Questions have been altered slightly for brevity.

Table 6: Common and persistent misconceptions identified through inventories

<table>
<thead>
<tr>
<th>Inventory</th>
<th>Question</th>
<th>Correct answer</th>
<th>Most popular alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q14: CCI</td>
<td>What is the approximate number of carbon atoms it would take placed next to each other to make a line that would cross this dot:  •</td>
<td>30 000 000</td>
<td>6.02 x 10^{23}</td>
</tr>
<tr>
<td></td>
<td>a. 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>b. 200</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>c. 30,000,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>d. 6.02 x 10^{23}</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q6: FMCE</td>
<td>The sled is slowing down at a steady rate and has an acceleration to the right. Which force would account for this motion?</td>
<td>The force is toward the right and is of constant strength (magnitude)</td>
<td>The force is toward the right and is decreasing in strength (magnitude)</td>
</tr>
<tr>
<td>Q9: TCS</td>
<td>How does the gas pressure change?</td>
<td>No change</td>
<td>Increase</td>
</tr>
<tr>
<td></td>
<td>a. Increase</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>b. Decrease</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>c. No change</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

These questions are based on concepts that are considered fundamental assumed knowledge at the undergraduate level. Therefore, misunderstandings of these kinds of concepts, if unchecked, may cause conceptual difficulties to compound in further study (Georgiou, Sharma, O’Byrne, & McInnes, 2009). Participants open to change can therefore use concept inventories to diagnose such common and persistent learning difficulties and develop strategies to improve student learning, that of their own students and those of their colleagues.
The individual institution

At the institutional level, the inventory results may be used to compare the effect of the teaching program on students’ conceptual understanding. The 'normalised gain' and 'effect size' measurements provide some information about student improvement. Figure 3 shows pre- and post-test scores for each individual question of a particular first-year Chemistry course at institution I.

![Figure 3: Pre and post test scores for the CCI for institution I](image)

This particular course had pre-tests scores amongst the lowest but showed the highest course average normalised gain and effect size. This administration of the conceptual inventory shows the significant improvement between pre- and post-test implementation of the Chemistry Concept Inventory for this course at this institution and may be used by the participant open to change to investigate the effectiveness of certain pedagogies or teaching programs or justify their efficacy.

Individual inventory across many institutions

Lastly, the large data set may be used as a database to establish a baseline, just as the FCI was used in the Hake study cited earlier (1998). There, several thousand data points on the national level were used to delineate ‘low’, ‘medium’ and ‘high’ gain areas (see Figure 4a, which is called a ‘Hake plot’). The data provide a direct connection between the use of active learning approaches and a shift toward higher course average normalised gains. This insight is likely the most powerful lesson from the use of a particular inventory across many institutions. The second lesson is around ‘value and return on investment’; what do we expect as a reasonable course average normalised gain on a particular inventory when active learning approaches have been utilised?
The data points gathered by the participants open to change have been used to initiate a database in the Australian context and chart a ‘Hake plot’, which is a graph of course average normalised gains verses pre-test scores. The low, medium and high areas of Hake (1998) are separated by diagonal lines as shown in all the graphs in Figure 4.

More data is needed to establish whether the diagonal lines in the Hake study for the US apply for the Australian context, and if they need to be shifted for the other inventories. Despite the fact that more work needs to be done, what is clear is that the course average normalised gain shifting in one way indicates improved conceptual understanding on a particular inventory. At the very least, this inchoate graph allows one to compare with others who have improved course average normalised gains using a particular concept inventory (Figure 5).
The approach used for participants open to change therefore centred on an induction or assistance in involvement with evidence based education, which would lead toward building cultural capital within their institution. Those participants were given opportunities to experiment with scholarly assessment of active learning techniques that had been implemented or will be in the future. This engagement was achieved with the deployment of conceptual inventories. The deployment was intimately supported by the Fellow and RA. It provided the participants open to change with a number of tools, including a way to diagnose persistent misconceptions, a way to track student learning in a course, or courses using pre- and post-tests across groups or years and a way to display institutional success in the context of other Australian and international universities.

The most significant outcome in terms of the Fellowship’s goal of driving change through cultural capital for this strategy is therefore empowering the academic to develop a scholarly approach to evaluating student learning outcomes in the context of changes in curriculum and pedagogy. This allows the academic to have confidence in these changes and connects the academic to the wider research community. Such outcomes make it more likely that appropriate and successful changes will be made and retained. Figure 6 illustrates the departments connections empowered through this reliance on scholarly approach driven by seeking knowledge.

Figure 5: Hake plot for the Fellowship results from various conceptual inventories (Interactive plot at http://activelearningscience.com/open/)

Figure 6: Internal connections and “the communication and circulation of thought” as the department seeks knowledge using a scholarly approach.
Strategy 3: Unacquainted (academics)

Context

While research careers are supported through mentors in closely-knit research groups, early career lecturers often participate only in university-wide graduate programs to support their teaching. Necessarily, such programs provide a sound grounding in overarching teaching and learning matters from learning objectives to assessment and scholarly inquiry to student centred learning. They often pay limited attention to the very public, and often confronting, lectures. In contrast, what the early career lecturer needs most and immediate help with is the lecture. Furthermore, adequately supporting early career lecturers in their high-risk lectures establishes enduring habits, such as reflective practices and the capacity to experiment with active learning methods that serve the students, the academic and the establishment well.

Although the previous strategies involved a number of diverse universities across Australia, strategy 3 focused on an implementation in only one university.

Assisting the unacquainted participants, these early career lecturers, with strategic formal development of teaching practices provides them with confidence to consider interacting with their seniors who have more cultural capital, particularly those endeavouring to initiate or sustain active learning approaches. In this respect, this approach involved a comprehensive effort with the unacquainted early career lecturers at one university. It involved the development and deployment of a type of mentoring program, the Peer Review of Teaching (PRT) program. The program was designed to support lecturers in taking a ‘first step’ into formally developing their lecture practices.

Familiarity with the culture around teaching and a clear understanding of the local context (staff and students) led to the following questions:

1. Why would early career lecturers take time out to think about their teaching, and in what way do they want to improve/develop?
2. What do early career lecturers think are the biggest barriers in giving good lectures, and what are their approaches to dealing with these barriers?
3. Did the early career lecturers try active learning methods, and what were the substantive lessons learnt by them?

To probe these questions, the PRT program was designed with three aims:

- To expose lecturers to different strategies and techniques that may be useful in their own teaching
- To scaffold reflection, development and dissemination of teaching practices by engaging participants in a persistent, supportive conversation
- To provide measures by which lecturers may describe contributions in teaching more concretely for use in professional development/promotion.
The objective was to facilitate the unacquainted participants’ understanding and utilisation of active learning approaches, enabling them to consider and use different approaches and be reflective in their teaching.

**Approach**

The structure of the PRT program was amalgamated from structures of existing programs, including instances of such programs in other Australian universities (Harris, Farrell, Bell, Devlin, & James, 2008). Appendix E outlines the timeline of the program. Figure 7 shows keys elements of the program.

![Figure 7: Overview of Peer Review of Teaching Program](image)

**Approaching and recruiting potential participants**

The process of recruiting unacquainted participants was carefully considered, planned and implemented. The backing of the Dean of Science was employed to give the program credence. Following that, buy-in from the Teaching & Learning Coordinators within the Schools of the Faculty was straightforward.

Since there exists diversity in the traditions and operational structure of each School, approaching and recruiting staff to participate from each School was customised for the needs of the particular School. A call customised for each School went out from the Teaching and Learning Coordinator within that School. The call was sent to 20 academics and, of those, 14 participated. A general call also went out at the whole School level attracting an additional 15 participants. Seven of the participants were required to participate as part of a compulsory University-wide training program for new staff. In total, there were 29 participants, as summarised in Table 7.
### Table 7: The PRT participants

<table>
<thead>
<tr>
<th>School/Faculty</th>
<th>Number of Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemistry</td>
<td>6</td>
</tr>
<tr>
<td>Mathematics and Statistics</td>
<td>5</td>
</tr>
<tr>
<td>Molecular Biosciences</td>
<td>1</td>
</tr>
<tr>
<td>Physics</td>
<td>9</td>
</tr>
<tr>
<td>Engineering</td>
<td>2</td>
</tr>
<tr>
<td>Biology</td>
<td>5</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
</tr>
</tbody>
</table>

### Workshop meeting

The first official part of the PRT program was a workshop during which the unacquainted participants were: given an introduction; asked to outline their objectives for the upcoming observations; and provided logistical information (timetables/classes taught, etc). Some justification and guidance for setting objectives was provided, and some ideas about active learning and how to recognise some potential measurable outcomes were shared. Central activities were two, 20-minute, small group discussions followed by whole-group discussion on the following questions:

1. When observing the teaching of others (or consider your own teaching), think of a technique that was successful/unsuccessful. How did you know that the technique was successful?
2. When would you like to focus on improving in your lectures (what are your objectives)? How will you know if you have improved (what can you measure)?

For the second discussion question, the unacquainted participants documented their personal responses in the ‘Objectives and Indicators’ sheet (Figure (i) from Appendix F). The sheet was collected and used as a prompt for persistent supportive conversations and as a reflective tool to chart a path such that the participants could see that they were developing, refining and progressing their ideas. The participant had set broad objectives as well as one objective specifying an active learning technique that they would try.

Participants were separated into two groups. One was allocated to the Fellow, and the other group was allocated to the RA. Only the RA and Fellow observed the participants (rather than peer observations) and held the interviews and reflections.

### Observation (of the unacquainted participant)

The observations involved either the Fellow or the RA sitting in the back of a lecture theatre and recording on the PRT Reviewer’s tool (Figure (ii) of Appendix F) what students (by visually scanning) and the participant were doing. Figure 8 shows a section of the tool, with notes made by the RA indicating the activities of the lecture and level of engagement of the students.
Interview (of unacquainted participant)

The interview focused on what the unacquainted participant had tried to do from the Objectives and Indicators’ sheet that they had completed in the workshop. They focused on broad objectives as well as the one specific active learning technique. Did they feel that they had achieved what they set out to do? What were the barriers, and what could they do differently? They were prompted to be self-reflective.

The underlying notion was to instil the idea that it was OK to try new ideas and be innovative in their teaching. The Fellow gave their feedback and perspectives on the lecture and relayed what the students had been doing during the scans. The observations explicitly referenced the objectives stated by the participants and used measures agreed upon before the observation had occurred. The participant was prompted to refine the active learning technique or select an active learning technique they would attempt in the next observed lecture, which could be the next lecture or weeks away.

Observation (of unacquainted participant)

The same procedure was used in this follow-up observation as in the initial observation of the participant. Figure 9 shows sections from PRT Reviewer’s tool from two observations of the same participant indicating changes in teaching approach. This participant had utilised worksheets in the second observed lecture. In this case, the ‘after’ showed a higher level of student engagement (more engaged in discussion, fewer on devices and high quality discussion).
Figure 9: Two completed sections of the PRT Reviewers tool showing a change in teaching approach of the participant and a change in student engagement

**Reflection (of unacquainted participant) – consisting of three parts**

One part of the process of reflection of the participant was an interview, which was much the same format as the earlier interview. The second was the PRT colloquium. The PRT colloquium was a teaching forum designed to reflect on the experiences gained through the PRT program. It involved a debrief of the program, followed by presentations by three participants. These participants discussed their objectives, how the objectives were met, what they had learnt, and the way forward that they perceived. A critical aspect was sharing
experiences and bolstering confidence that it was okay to try new ideas and be innovative in their teaching.

The third part of the reflection process was the observation of others’ lectures. Participants were required to perform two observations of others’ lectures. These observations were intended to expose the unacquainted participants to different lecture topics, styles, sizes, problems, etc. The justification is that lecturers do not often get to observe others’ lectures, and when they do, they are rarely in other schools or departments.

To control some factors, the other lectures were carefully selected by the RA and Fellow, such that one could observe active learning approaches being utilised or the lectures received good reviews from students. Spectacular mesmerising lectures were avoided, as it is difficult to cherry pick simple ideas from such lectures to try in one’s own lectures, particularly as a novice.

The participants were given the LASE tool to complete when partaking in these observations (Figure (iii) of Appendix F). The LASE tool is the result of the PF’s doctoral thesis (Georgiou, 2014). The main purpose of the tool is to draw the observer’s attention to otherwise invisible or difficult to see aspects of the lecture, such as what students are doing and what their engagement is like during different lecture activities. Participants were asked to return these forms to the RA and Fellow. There was also an unintended knock-on effect where the lecturers requested that they themselves provide ‘observable’ lectures so as to gain systematic feedback. An email is included from a Head of School to illustrate:

Hi [redacted]

Sure, no problem. All I ask is that observers give me feedback comments and suggestions

[redacted]

Data and analysis

The ongoing interactions resulted in a rich and diverse set of templates and field notes maintained by the RA and Fellow. These were analysed using codings triangulated to extract consistent, robust themes. An undergraduate research student, Ms Amanda Ling, interviewed five lecturers (see Appendix G for interview questions) and coded their lecture recordings, thereby consolidating the themes.

Outputs and Findings

The findings are presented according to the questions stated in the Context section above.

Why would early career lecturers take time out to think about their teaching?

The following four themes emerged in the order of how committed the participants said they were to these themes, with the most committed reason first. The numbers indicate how many of respondents ascribed to these themes.

- The unacquainted participant genuinely wanted to improve students’ learning and engagement. (ALL)
• The unacquainted participant could not get help in other ways or wanted to complement other help (15).
• The unacquainted participant wanted to improve career prospects. (3)
• The unacquainted participant was required to take part. (7)

Considering the second point, some Schools already have a mentor scheme set up with the brief of observing and providing feedback independent of the PRT program. However, this application of the PRT program revealed that there were eight cases of no such activity occurring despite mentors being set up within a School. There were six cases of good interaction with mentors within a School in parallel with the PRT. In the case where the school’s mentor scheme appeared to work, there was a structure for the mentoring and staff time committed to enable the mentoring. The key point here is that, for any program to work, there needs to be a structure and staff time committed to enable the program to deliver to its potential.

What way do they want to improve/develop?

This section unpacks the first theme from above into three ways in which the participants sought to develop – a focus on students, material, and/or engagement. Quotes from two data sets are presented here, Objectives and Indicators sheets to set the scene, followed by a quote from an interview to elaborate.

The first is a student focus, the lecturer seeks to understand students and their learning:

“To get students more involved with Socrative.”
“Ensure students are understanding the information.”
“I want to be interactive and engage students and I don’t know how to do it. As a first time lecturer I don’t know how long to wait, whether chatter is good or bad. I don’t know how to interpret class behaviour. I need to know if I am on the right track.”

The second is a material focus, the lecturer seeks to reorganise the material:

“Going through material without hurrying things up”
“Can I tailor the material better to motivate
“I had never thought that I should think about how I lecture in this way. I always think about the content and spend time organising demos, examples and what I am going to say when - pacing is difficult.”

The third is an engagement focus, the lecturer seeks ways and techniques to keep students’ attention:

“Try to get them more *engaged* so they wouldn’t fall asleep”
“To *engage* all students equally in lectures”
“I was taught in a transmission mode which made me uncomfortable. ... I have used worksheets which made me rearrange content. Half of the content was integrated into discussions on worksheet questions ... very important ... rather than stating as a fact.”
What do early career lecturers think are the biggest barriers to giving good lectures?

The predominant barrier is that of time, time constraints outside the lecture and within the lecture. Outside the lecture, there is the need to find the time to explore and integrate alternate, active learning methods into the lecture.

“Time is always a problem especially because I’m meant to be doing research.”

“Yeah, so research, research students, post-docs who are working in our group, travel commitments related to research and related to grants.”

To save time creating new slides, slides are passed on. In some cases, there is the freedom to change slides, while in others the slides cannot be changed to maintain consistency between parallel lecture streams.

“First time lecturing large 1st years. I have received help and materials from someone who is regarded as a good lecturer and is teaching the other streams. I am aware that students are not following derivations and I don’t know why are included in lectures. ... It is too high a risk to change and I don’t know what to change ... and how to change.”

Within the lecture, there is a sense of responsibility to cover most content so that students do not miss out. This constraint raises the challenge of juggling time within the lecture.

“If you’re putting something new into your lecture, you’ve got to find something to take out as well.”

“Every lecture we do worksheets which takes almost 15 minutes or 20 minutes. Then you’re lecturing and in [my course] I used to do a lot of demonstrations so I had, like, 19 lectures. 18 lectures I had 5 to 6 experiments, so every week I was doing an experiment in the class itself that takes another 5-10 minutes. So, to make sure that you run Socrative as well and knowing that more or less that Socrative will also take 10 minutes...”

With limited knowledge and understanding of alternate active teaching methods, the participants often were not aware of what was available and how to make appropriate choices to best serve their discipline and students.

“Oh no. I didn’t even know that existed. So it was entirely a new thing.”

“I guess when I first sort of looked, started learning about, um, all these different techniques that are coming in, there was a bit of a feeling of well, you know, I didn’t have any of those, I got through fine, why do you suddenly need all of these extra things.”

“Because nobody else was running Socrative so there was no firsthand information on what sort of questions should go or what should be the complexity of that.”
Finally, there is the realisation that there is an inherent lack of student interest and effort, which is unsettling to the lecturers.

“So, this class is the sort of weaker, less interested students and that’s more challenging because they’re not really interested to begin with... Like, we only had like 60 or 70% of the students do the assignments.”

“It also comes out when you’re trying to have a conversation with them and nobody responds, or you just get the same two people answering all the questions.”

What are their approaches to dealing with these barriers?

As discussed earlier, most participants volunteered for this program; only 7 were required to do the program. In general, the feeling was that it was difficult to know where to turn or what to do as assistance was, either, too temporary (one-offs), too targeted (help with a specific demonstration or concept), or too general (help with teaching philosophies and theories).

These statements are reinforced when considering engagement with the PRT program. Figure 10 shows that of the 29 participants, 12 exceeded expectations (went beyond the requirements of the program), nine achieved the outcomes (completed all requirements of the program), and the remainder (eight) engaged in one or more aspects of the program. The majority of participants therefore voluntarily either completed or went beyond the scope of the program to engage with this targeted teaching and learning development.

![Pie chart showing participant engagement]

**Figure 10:** How the Participants engaged with the PRT program
Did the early career lecturers try active learning methods?

Lecture recordings for the first and second observed lectures were analysed for five participants. The second observed lecture occurred after feedback and advice was provided on the first observed lecture. Figure 11a shows the first lecture, and 11b shows the second lecture, presented proportionately, as percentages of a sixty-minute period. The participants are referred to as P1, P2, and so on.

![Figure 11a: Lecture activity as a proportion of the first sixty-minute observed lecture.](image1)

![Figure 11b: Lecture activity as a proportion of the second sixty-minute observed lecture.](image2)

Transmission style lecturing is the predominant lecture activity occurring in both lectures for all lecturers. The interactive style has increased between the two lectures. The amount of interactivity plus use of demonstrations increased, almost doubled, from the first observed lecture to the second observed lecture. This was a phenomenon observed with all of the five early career lecturers included in this analysis.

What where the substantive lessons learnt by them?

Perhaps, the first most substantive lesson that seemed to be learnt by the unacquainted participants was that, if they wanted to engage students, they needed to introduce ways of teaching other than transmission for the entire lecture. This meant attempting to keep student attention by introducing variety into their lecturing strategy.
Figure 12: Level of student engagement for different types of lecture activity. Diagram produced by Dr Matthew Hill

Figure 12 shows what variety can look like, where T is transmission, I is interactive, A is administration, D is demonstrations, and W is worksheets (see Georgiou and Sharma (2015) for further description). However, there is no magic formula; the lecturer needs to craft the teaching to suit the content (such as formula rich, classifications, conceptual). Additionally, the background of the cohort of students and often factors, like the time of day, need to be taken into account as well.

The second substantive lesson was that student learning was difficult to ascertain directly from a lecture. Consequently, observed student engagement acted as a proxy for learning. The way to craft their lectures for both student engagement and learning was an objective that all the unacquainted participants submitted on their ‘Objectives and Indicators’ sheet. The hope was that this observation and reflection process enabled them to realise that they needed to utilise active learning approaches. This process was supported by the ongoing persistent conversations between the participants and the Fellow.

Other lessons learnt that are directly applicable to lectures include:

- Active learning approaches meant student interaction; allowing students to be ‘active’ (not lecturing) results in noise and a sense of being out of control. What mattered was that students were engaged and more likely to be learning.
- Active learning approaches necessitated rearranging content, leaving content out and focusing on particular problematic ideas, such as those identified through conceptual inventories, and specific technical ideas with demonstrations and applications.
• Active learning approaches meant letting go of the sense of responsibility to cover all content, to teach, and to let students take responsibility for their learning. To create this expectation and atmosphere is a critical part of active learning approaches.

• Active learning approaches meant creating expectations and an atmosphere conducive to the variety shown in Figure 9. That meant being comfortable with and having strategies for dealing with divergent pathways and, in cases, not completing what was planned for the lecture.

• Active learning approaches are a mechanism or pathway to student centred learning – they operationalise student centred learning.

Finally, active learning, its methods and philosophies originate in the research community, and they are incumbent with the jargon of educational research. If appropriate assistance is available in deciphering and applying these concepts and strategies, then implementation is feasible. This assistance, in the case of the PRT was provided by the cultural capital within the institution by the RA and Fellow, see Figure 13.

A key feature, which attracted and made the unacquainted connect with the RA and Fellow, was that the RA and Fellow and the participants shared a science background. Hence, the active learning approaches were grounded in common experiences, and the educational jargon was unpacked within a common language around science.

The unacquainted were initially hesitant to try something without support in their lectures, which are a very public and high-risk activity. Many voiced in the first workshop that current practices are not ideal, but they did not know any better. They had inherited PowerPoints from an established lecturer. They knew aspects were not working, but they would not risk changing. The lack of support in lectures they noted was very scary.

However, the unacquainted participants were very actively thinking about improvements, and they seemed eager to spend time to improve lectures. They were willing to change, which is why they participated in the PRT in the first place. They appeared to need help with identifying whether an implementation was successful (objectives and outcomes). They seemed unable to ascertain and interpret student behaviour without the structured assistance that the PRT offered. They do not get appropriate feedback about their in-class style, and there are no persistent conversations in which reflections can occur. The PRT provided this avenue.

Figure 13: Strategically connecting the groups through knowledge sharing which is effective, efficient and timely.
Impact and recommendations

The Fellowship utilised a three-pronged strategy to effect change in undergraduate science lectures. This effort necessarily needed to encompass all teaching in order to ultimately impact on lectures.

The first strategy drew on themes that underpin pockets of excellence in teaching and learning. The themes include input and support from Heads of Departments, School and Deans but also involve a critical mass of colleagues on board and a general culture of support. The effort supported some change and in doing so identified specific actions can be taken to further sustain and grow pockets of excellence as well as to generate more pockets of excellence.

The second strategy employed concept inventories to teach lecturers about the extent to which a particular investment – i.e., a particularly change to how they lecture - is effective. The impact can be seen in the dissemination of evidence-based approaches to university science education. The concept inventory represents a way through which we can evidence the shift in student learning sector wide.

The third strategy was embodied in a Peer Review of Teaching Program for early career lecturers. The program provided a system of support for academics (for lecturing) that develops conversations about teaching and learning and aids dissemination of effective teaching practices and strategies by bridging a gap between research and practice in undergraduate science education.

Lessons learned from the implementation of these strategies lead to an overarching finding - that active learning approaches are measurably beneficial and therefore worthwhile in Australian university science and mathematics lectures.

In all three strategies, the use of active learning approaches (which include a long string of programs including Workshop Tutorials, IOL, ASELL, ALIUS and POGIL) provide student engagement and measurably effective learning. Why have these programs not been taken up more widely? One reason illustrated here is that active learning approaches require effort, which could be directed toward research, and are somewhat uncomfortable or unnatural for lecturers.

The Fellowship’s activities, it is hoped, will steer the ship toward further investment in active learning, irrespective of the individual program. Progress can be made by: capitalising on the expert cultural capital of the engaged academics, such as those identified in this work. Engaged academics are already investing in active learning. One also needs to work with those open to change, who are interested to figure out if their investments are improving student learning. Further, one needs to support the unacquainted, who are aware they need to adopt different approaches but do not know what to do and how to do it.

The number of participants deeply involved in this Fellowship campaign suggests the effort’s impact - ten engaged academics directly providing interviews, 31 academics open to change directly involved in concept inventories, and 29 unacquainted involved in the PRT. Others have been involved at various stages, aware of Fellowship, and providing data. More still
will be engaged through the sharing of results in conferences and in journal publications. In total, 13 institutions took part.

In each participant group, we worked with, we found enthusiastic, passionate and successful lecturers eager to share their experience and develop their practice. In creating a bespoke, three-pronged strategy, we were able to capitalize on these qualities to yield powerful and inspiring results. Although the approaches are not straightforward and do not neatly fit into the organisational structure of the university, this Fellowship effort shows that investment in cultural capital can be implemented, supported, sustainable, and productive.

A critical element is prioritising the creation and sharing of knowledge in the knowledge intensive university: aligning with the visionaries who conceptualised the modern university, “the communication and circulation of thought” and the unity of research and teaching. Of course, for research on teaching and learning to inform practice, the knowledge sharing needs to be effective, efficient and timely. Figure 14 captures the essence of the creation and sharing of knowledge.

Figure 14: Strategic connections, using expert cultural capital to drive change.
Recommendations

The **first recommendation** for departments is to support engaged academics in the establishment, uptake and embedding of active learning approaches through internal structures identified as four themes—listed below—operating in concert to facilitate transformative levels of achievement with sustained change in teaching and learning practices.

1. For the department to have one or more ‘champions’ engaged in evidence-based education; the creation and sharing of teaching and learning knowledge within and beyond the department in an effective manner.
2. For influential senior leadership within the department of teaching and learning and mentoring of teaching and learning leaders.
3. For the department to have a sufficient number of committed colleagues (critical mass) rallying around teaching and learning activities.
4. For the institution to have measures reflecting that their institution values teaching and learning and be committed to them.

The **second recommendation** is to enable the generation and garnering of evidence to support approaches such as active learning by coaching academics open to change.

The **third recommendation** is to guide the unacquainted into adopting active learning approaches in the formative years of their careers through timely programs such as the Peer Review of Teaching program.

The **fourth recommendation** is to establish networks for sharing knowledge within and between departments and institutions.
References


Harris, K.-L., Farrell, K., Bell, M., Devlin, M., & James, R. (2008). Peer review of teaching in Australian higher education: A handbook to support institutions in developing and embedding effective policies and practices Centre for the Study of Higher Education.


Appendices

Appendix A Invitation for participation based on critical friend discussions:

Dear Participant,

Thank you for supporting my OLT National Teaching Fellowship. I have had a casual chat with you and have been busy since then trying to map out how best to proceed. I have had an in-depth meeting with my critical friend. She strongly recommended that I develop a structure and try to operate within this structure. This will optimise the benefits to the colleagues I work with and my Fellowship. Helen Georgiou, my PhD student, will be working with me as a postdoctoral fellow. She has just submitted her PhD thesis which is focused on interactivity in lectures. So here is the structure.

There will be 3 phases reflecting 2 types of activities on the ground:

Phase 1: The main objective in this Phase will involve the development of a research-based teaching program focusing on lectures that aligns with the institution’s strategic direction.

Phase 2: The objectives of this phase will be to determine if newly implemented programs (such Peer Instruction, Active Learning or Flipped Lectures) are achieving their aims, and, if not, what may be done to assist the progress of the program.

Phase 3: The objectives of this phase are to assess established programs and encourage faculty to report findings to the wider community, both within the University and in research.

I have emailed colleagues from other universities regarding the phases and anticipate developing plans for local activity in the coming weeks. I will touch base with you in January/February to obtain feedback.

I would love your input at any stage. Just let me know.

Looking forward to this adventure.

Have a fab weekend

Cheers

manju
**Appendix B: List of institutions and departments in a different order to tables in report**

<table>
<thead>
<tr>
<th>Institution</th>
<th>Involvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>The University of Sydney</td>
<td>Involved at the outset: Provided Letters of Support</td>
</tr>
<tr>
<td>University of Western Sydney</td>
<td></td>
</tr>
<tr>
<td>University of Technology Sydney</td>
<td></td>
</tr>
<tr>
<td>Monash University</td>
<td></td>
</tr>
<tr>
<td>The University of Melbourne</td>
<td></td>
</tr>
<tr>
<td>La Trobe University</td>
<td></td>
</tr>
<tr>
<td>University of Canberra</td>
<td></td>
</tr>
<tr>
<td>Australian National University</td>
<td></td>
</tr>
<tr>
<td>Curtin University</td>
<td>New partners</td>
</tr>
<tr>
<td>Flinders University</td>
<td></td>
</tr>
<tr>
<td>University of New South Wales</td>
<td></td>
</tr>
<tr>
<td>University of Adelaide</td>
<td></td>
</tr>
<tr>
<td>The University of New England</td>
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</table>
**Appendix C: Interview Template for strategy 1 Engaged**

<table>
<thead>
<tr>
<th>Background</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Institution</strong></td>
<td><strong>Meeting</strong></td>
</tr>
<tr>
<td><strong>Course(s)/subject</strong></td>
<td><strong>Staff</strong></td>
</tr>
<tr>
<td><strong>Pre/post testing?</strong></td>
<td><strong>Post-test details</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Course</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Labs</strong></td>
<td><strong>Tutorials</strong></td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td>Eg assignments, projects</td>
</tr>
<tr>
<td><strong>Lectures</strong></td>
<td></td>
</tr>
</tbody>
</table>

| Student demographic | **Staff involved** |

<table>
<thead>
<tr>
<th>Change</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Introduction of change (why, who)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Challenges/hurdles</strong></td>
<td><strong>Strengths</strong></td>
</tr>
</tbody>
</table>

**What do you want/need out of the Fellowship? What can we offer? (What have we already offered)**

| Other |  |
Appendix D: Feedback for strategy 2 Open

CONCEPTUAL SURVEY REPORT

Overview

<table>
<thead>
<tr>
<th></th>
<th>Pre/16</th>
<th>Post/16</th>
<th>Post/36</th>
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<tbody>
<tr>
<td>N</td>
<td>1033</td>
<td>737</td>
<td>537</td>
</tr>
<tr>
<td>Mean</td>
<td>9.54</td>
<td>11.26</td>
<td>19.88</td>
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<tr>
<td>StDev</td>
<td>2.81</td>
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<tr>
<td>Gain</td>
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</tbody>
</table>

Individual questions

How do we compare?

Yellow star indicates gain measurement to 3.5. Blue stars are a similar Australian university. Red squares are from an international sample.
Appendix E: Timeline of development of Peer Review of Teaching Program

- (Late 2013) Research and Development
- Approval from key (teaching) Associate Dean and Dean in Faculty of Science
- Dissemination of information to other Associate Deans
- Approval to accredit program as part of P&P
- First workshop with 7 participants (March)
- Recruitment (unique to each school) occurring through various channels
- Negotiation for recruitment of possible participants with T&L committee members
- (March 2014) Presentation to T&L committee members after recommendation from Dean
- First and subsequent observations with first-round participants
- Second workshop with x participants (*)
- First and subsequent observations with second round participants
- Final colloquium
- Summary meetings with participants
- Repeat in second semester
### Appendix F: Forms for Peer Review of Teaching Program

#### (i) Objectives and Indicators sheet

<table>
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<th>Name</th>
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</tbody>
</table>

#### (ii) PRT Reviewers tool

**Peer Review of Teaching: Reviewers Form**

**LASE (Lecture Activity and Student Engagement)** protocol for observing lecture practice

<table>
<thead>
<tr>
<th>Background Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observed</td>
</tr>
<tr>
<td>Observation</td>
</tr>
<tr>
<td>Location</td>
</tr>
</tbody>
</table>

**Number of students:**

<table>
<thead>
<tr>
<th>20-50</th>
<th>51-100</th>
<th>101-200</th>
<th>201-500</th>
<th>501-900</th>
<th>other</th>
</tr>
</thead>
</table>

**Objectives:**

- [ ] 

**Achieved:**

- [ ] 

**Overall notes and summary:**

- [ ] 

**Real lecture duration:**

- [ ]

**During the Lecture**

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Activity</th>
<th>Objectives, Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Lecture Activity and Student Engagement**

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Activity</th>
<th>Student engagement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes on lecture:**

- [ ]

**PRT Reviewers tool**

- [ ]

**(iii) LASE**

**LASE (Lecture Activity and Student Engagement)** protocol for observing lecture practice

<table>
<thead>
<tr>
<th>Background Information</th>
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</thead>
<tbody>
<tr>
<td>Observed</td>
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<tr>
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<tr>
<td>Location</td>
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<th>other</th>
</tr>
</thead>
</table>

**Objectives:**

- [ ] 

**Achieved:**

- [ ] 

**Overall notes and summary:**

- [ ] 

**Real lecture duration:**

- [ ]

**During the Lecture**

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Activity</th>
<th>Objectives, Indicators</th>
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</thead>
<tbody>
<tr>
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</tbody>
</table>

**Lecture Activity and Student Engagement**

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Activity</th>
<th>Student engagement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes on lecture:**

- [ ]
Appendix G: Interview questions for Participants of PRT program

Thank you for participating in my research. I’m Amanda, a first year student from the ANU doing a Bachelor of Philosophy (Honours) degree. This interview is a part of my assessed research project, and I hope that it will inform my understanding of the experiences of early career lecturers. It is also going to inform a Peer Review program that the Faculty of Science here at Sydney University is thinking of implementing more permanently.

I’d like to start off with the objectives that you had set in your first workshop with Manju and Helen. Here it is:

1. Do you have any other comments on these objectives? Would you like to expand on them?
2. Do you remember how you prepared FOR your lectures with the aim of achieving these objectives?
   Did the exercise of writing and thinking of objectives affect your ‘actions’ and ‘mindset’?
   How did you research X? Did you research it on google, talk to someone else?
3. Were you challenged in this preparation or was it easy to do?
   In what way..?
4. How did you feel about X when you first about it/them in the first workshop for peer mentoring?
   Were you confident about using it? Had you seen somebody else use it?
   Why did you choose X?
   Can you remember how confident or not confident you felt about using X on your own?
5. How did you feel about X when you first used it/them in a lecture?
   They may have chosen a new X
   Were you confident in using X for teaching students for the first time?
   Why did you feel this way?
   If you were not confident, then what challenges stopped you from feeling confident?
6. How would you compare your use of X between the 2 lectures?

I will now show you my analysis of your two lectures. These are standard codes from Helen’s PhD thesis. The transmission style code is for proportion of time spent telling content to students. The interactivity code is for proportion of time spent engaging students and successful interaction. The demonstration code is for proportion of time spent on activities that demonstrate the concept. The dead time code is for proportion of time spent in silence or students leaving the theatre and so on. I found that, in a lot of cases, individuals did not do as they perceived or intended. I understand from the literature that there are a challenges involved in realising an intention to use alternate teaching methods.

Shows lecture graphs

7. I was wondering how you have interpreted my analysis of your lectures?
8. Did you expect this result?
   Why or why not?
9. Sometimes we don’t think the challenges in implementing alternate teaching methods are as big as they are. However, these challenges can implicitly restrain our preparation and teaching. We may think we have changed, but we have not in a measurable way.
   Could you please review your preparation and experience of lectures and reflect on any challenges you faced?
   Do you remember any of these challenges restraining you?
   Unpacking these challenges is important for future iterations of the program and it would be greatly appreciated if you helped us in supporting future lecturers. I am going to dig deeper here, as these challenges are universal.
10. Did you expect more support? What other support have you had for lectures?
    Do you have any tips for future early career lecturers?
    Do you have any tips for us, the program?
    What would you like to do in future years?
    Has this program made you more eager to explore alternative teaching methods?
DVC-Education certification

Certification by Deputy Vice-Chancellor (or equivalent)

I certify that all parts of the final report for this OLT Fellowship provide an accurate representation of the implementation, impact and findings of the project, and that the report is of publishable quality.

Name:  Professor Philippa Pattison  Date:  11 April 2016