Research-Led Inquiry Pedagogy when Re-Conceptualising Science Curricula: Promise and Pitfalls

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Abstract

Across the globe higher education is transforming due to rapid changes in technology, sector wide structural reform and advances in our understanding of how students learn. Questions are now being asked about which pedagogies will best engage students, add value to the on-campus experience, create global opportunities and meet the expectations of employers. In these challenging times, opportunities are emerging to systematically embed pedagogies in science curricula, which in previous times may have failed to get traction, and one such pedagogy currently emerging in science education world-wide is inquiry based learning. Inquiry based pedagogy is now seen by academics as the solution to adequately meet the needs of students studying science at all educational levels. Curiously, however, last century's curriculum reform in science education failed due to inquiry-based pedagogy. Hence, the question is: how do we stop history from repeating itself and systematically and successfully implement research-led and inquiry-based pedagogy into higher education science curricula? As an attempt to answer this, research-led inquiry was used as a unifying pedagogy to re-conceptualise Science and Biomedical Science degrees at a large metropolitan university. The "how to do this" is described using a top down and bottom up process at various levels, from the individual laboratory and transformation of "cook-book" laboratories, culminating in capstone units, and the pitfalls of implementation are also discussed, in order to answer the question of whether the promise of inquiry-based pedagogy in science education will ever match reality.

The promise of pedagogy

Higher education is being transformed across the globe. Questions are now being asked about which pedagogies will best engage students, add value to the on-campus experience, create global opportunities and meet the expectations of employers (Johnson et al. 2014, 2015). Academics are finally abandoning pedagogies and practices aimed at transmitting expert content, instead moving towards pedagogies which engage students through research-led inquiry and authentic problem solving.

While it may be good to think that the shift in pedagogy in higher education is occurring because principles have finally triumphed over poor practice, pedagogy is not the sole driver. Other perhaps more powerful drivers are technology (creating opportunities for free content and learning to occur "anytime" and "anywhere"), changes in student expectations (especially related to employment), student disengagement with poor quality lectures and increasing financial constraints upon universities. These factors have combined to create a disruptive space, and research-led inquiry pedagogy has emerged as a potential saviour in a range of disciplines, especially science.

It is not the first time that research-led inquiry pedagogy has emerged as a solution to the study of science. It first occurred over a century ago, when John Dewey stated that "*science should be taught as a way of thinking and a process of knowing*", rather than through memorising facts (Dewey 1916). Leading educators such as Bruner (1960) and Schwab (1962) championed Dewey's ideas, generating enough impetus for the subsequent science curriculum reform of the 1950's and 1960's. By the late 1970's and 1980's, however, science curriculum reform had stalled, the culprit being research-led inquiry pedagogy and the high cognitive load it placed upon students (Hart et al. 2000; Kirshner et al. 2006; Novak 1988; Solomon 1988). The re-emergence of research-led inquiry pedagogy in curricula worldwide and at all levels of education has not occurred solely to fill the disruptive space caused by technology. It has occurred because we can no longer ignore that research-led inquiry pedagogy more tightly links science research with science learning (Australian Industry Group 2015; Chubb 2014; Office of the Chief Scientist 2014).

Even government agencies are now repeating phrases similar to Dewey (1916). In their recent report, the Australian Industry Group (2015) emphasised the need to prioritise inquiry-based learning:

> '*Conventional education has struggled to deliver subjects in a way that links the learning process to the relevant application of that learning*'

When students use inquiry they create and test hypotheses, collect data, defend their explanations and engage more deeply. Research-led inquiry pedagogy stimulates students to ask questions about what they do and do not understand (Australian Industry Group 2015; Kirkup 2013; Ross and Gill 2010), and allows academics to position research processes earlier rather than later in the curriculum.

Although we need to keep in mind the potentially detrimental cognitive load that research-led inquiry pedagogy may create (Kirschner et al. 2006), there is now consensus that science curricula need to pair research and inquiry. It is, however, a complex task to successfully re-engineer an entire undergraduate science curriculum based on research-led inquiry pedagogy. To do so requires redesign of individual subjects simultaneously with the entire curriculum, through both a bottom up and a top down backward mapping exercise (Wiggins and McTighe 2005).

This aim of this study is to tell the story of the re-design of undergraduate science curricula, specifically the Bachelor of Science and Bachelor of Medical Science, at a large metropolitan university, using "research-led inquiry" as a unifying pedagogy. It describes the process of throwing away the "cook-book" laboratories at first and second year levels and replacing these with "inquiry" laboratories, the design of third year capstone units and the implementation of undergraduate research experiences at all levels. It includes a description of the pitfalls of implementation and attempts to answer the question of whether research-led inquiry pedagogy in undergraduate science curriculum will fulfil its potential and promise.

We are in an age where universities are scrambling for presence in the market place; research funding is decreasing, student diversity is increasing, and community and student expectations of what higher education should bring are more demanding (Hare 2015). Disruption caused by these challenging times and new technologies is providing the best opportunity yet to embed educational pedagogies and to determine the factors which limit successful implementation.

Inquiry based pedagogy in subjects: a bottom up process

The practical laboratory

Our starting point, which spanned a five year period, re-structured the traditional recipe, cook-book practical laboratory (Dearn 1999), at first to third year levels, using research-led inquiry pedagogy. This was done because students across a wide range of science subjects identify the practical components of a degree as the best aspects of the undergraduate experience (Scott 2006). The practical has a long history in the sciences of being integral; a place where the "doing of science occurs". The practical is a time for students to work out 'why' things 'go wrong', and develop critical thinking skills (Hodson 1988, 1990, 1993, 1998; Dawson 1994), and while in past decades the practical has been considered supplementary to lectures (Hodson 1998), it is now seen as central and often mandatory. Indeed, students risk failure in subjects by missing practicals.

Although the value of research-led inquiry experiences in the laboratory is increasingly recognised, to date it has been restricted for only "some types" of laboratories. These "types" of laboratories include fieldwork and project based laboratories, often occurring only in the later years of the undergraduate curriculum. It is often argued that "inquiry" laboratories are only possible in the later years because only then do students have sufficient experience with a range of laboratory equipment, and so it is more difficult to re-design "cook-book" laboratories in the early years. As a result, a two stage process was used to redesign traditional "cookbook" laboratories into "inquiry" laboratories, with the first stage involving a series of introductory laboratories where students mastered a range of skills, and the second stage involving the utilization of these skills in a range of contexts.

Each "inquiry" laboratory had a three-part process: exploration, investigation and reporting (Table 1). In the exploratory stage, students worked in groups to identify an aim, hypothesis and designed an experiment to test the hypothesis. In order to overcome the potential lack of student background knowledge and manipulative skills, and to allow students to concentrate on designing experiments with controls and replicates, a series of 'technical notes' were provided to student, providing some certainty in methods (e.g. concentration of chemicals), and technical staff could prepare the laboratories with the necessary equipment (Table 1). In the second stage, students undertook the experiment, gathered data, made mistakes, repeated the experiment (as required) and finally collected and analysed the data. In the final reporting stage, students presented their results verbally to their peers and in writing to the demonstrators. It was essential to have enough time for group discussion about approaches, mistakes, re-design of experiments as well as the results obtained. These "inquiry" laboratories de-emphasised the correct outcome and immediately provided an engaged, authentic, professional scientific context. When assessment occurred it was based on the process of the students working in groups and not the final "correct" product. The time frame of these "inquiry" laboratories often spanned a two or three week time period, rather than being traditionally constrained into one three hour period. This extended time period ensured that there was ample time for students to complete the activity, and repeat experiments. Many traditional and tired "cookbook" laboratories were re-designed using this two stage and three part process (Table 1).

Table 1. A traditional laboratory on the enzyme action of saliva on starch and hydrolysis re-structured using a three part process.

Part 1. Exploratory stage; thinking about the action of saliva and enzymes on starch. When you eat or when you anticipating eating saliva forms in your mouth. What does saliva do? What is saliva for? Here are some previous suggestions from students - tick the one(s) which you agree with. Saliva is involved in taste, a hormone in saliva is swallowed and affects the stomach, saliva helps filter air when you breathe through your mouth, saliva breaks down some foods but not others. Saliva moistens the mouth, saliva moistens the food which we eat so it is easier to swallow, saliva starts pouring in to the mouth when we think about food. Part 2 Investigation: Technical notes for an investigation into the effect of temperature on amylase activity. The quantities of 20 mL starch (%) to 1 mL (%) of amylase will work. You can change the quantities to find out what effect it will have. These original quantities are, however, known to give a result. It takes time for the reaction to work which can be indicated by adding a dropper of the solution on a white tile with two drops of iodine. A blue black colour will indicate that starch is present and a yellow colour will indicate that there is no starch present. Part 3 Background Information on experimental design provided as reading before the commencement of the experiment. You need to have a **control** in your experiment. The control is part of your experiment, which does not receive treatment. It can be used as a comparison for the *treated* aspects of your experiment. You may need to repeat your experiment to find out whether your results are valid and reliable. A CONTROL can be placed in any of your experiments. One type of control could be in the form of starch with amylase known not to work (if an enzyme such as amylase is boiled – it will no longer work and is said to be denatured). Another type of control could be starch with no enzyme, but 1 mL of water added. You need to think about what your control will be. Another good aspect of an experiment is a clearly articulated hypothesis. So decide what you are doing and write it here.

Inquiry in independent learning

Research-led inquiry pedagogy was also used as the basis of independent learning investigations in small and large classes. For example, in large classes of up to 500 students the effect of bushfires (simulated through smoking and heating) on seed germination was investigated. To do this, students were provided with equipment which included *Acacia* seeds and petri dishes with cotton wool. Students were directed to explore the research literature on the topic, formulate a hypothesis, design an experiment, collect and analyse the data and write a report which explained the results of their experiment within the broader research literature on the effects of heat and smoke on seed germination. The assessment included students submitting a report which required them to act on feedback, before resubmitting the revised report for a final grade. Additionally, students submitted the draft report only following a workshop where they read and assessed a range of student reports from previous years. This modelled the process of peer-review of a journal submission, allowing students to gain direction and confidence.

The learning outcomes from many of these activities were for students to:

- create a story and a rationale for a scientific experiment,
- formulate a scientific hypothesis for investigation,
- design and conduct a scientific investigation or experiment to test the hypothesis,
- analyse and integrate ideas from the scientific literature, use scientific conventions to produce a report that communicates data, trends and results and
- use scientific language to deliver an oral and written presentations on the meaning of the data arising from a scientific investigation or experiment.

Inquiry in lectures and final exams

To ensure that inquiry was infused throughout all the aspects of the subjects, research-led inquiry pedagogy was used to re-design lectures and exams. Lectures were delivered actively, using current global research issues (including research from academic staff and postgraduate students). Content and classical concepts which form the basis of the subject and discipline were re-structured to include historical competing hypotheses of the time, and this minimalised the emphasis on facts and better contextualised how facts/theories were created. Research scenarios (from published research articles) were used as questions in final exams and marks were awarded for how well students could identify hypotheses, critique experimental design, interpret data and justify the conclusions.

Inquiry in capstones subjects

Third and fourth year units were re-designed to form capstone experiences for students. These capstone experiences were seen as culminating learning experiences for students in the final year, where knowledge and skills were purposely integrated. Many subjects developed students' skills in inquiry and critical thinking, using undergraduate research experiences to make an original, intellectual or creative contribution to the discipline (Brew 2006). For example, in conservation biology and ecology, students proposed hypotheses and designed experiments concerning biodiversity in the surrounding region. Some of these capstone experiences stretched across an entire year of work, and were linked to both industry and an external provider so that students had Work Integrated Learning (WIL) in a professional working environment. These capstone units provided undergraduate research experiences and can be seen as a rite of passage due to the real world experience gained and a Work Integrated Learning experience (Kift et al. 2013).

Inquiry based pedagogy in curriculum re-design; a top down backward mapping process

Although our starting point was to re-design subjects, simultaneously "research-led inquiry" as was used as a unifying pedagogy to re-design the Bachelor of Science and Bachelor of Medical Science. To achieve this, a top down and backward mapping process was used (Wiggins and McTier 2005; Figure 1).

Large scale transformational change in universities is difficult. Part of this difficulty is because structural processes need to be established to manage change. To create structures that enable the re-design of science and biomedical science degrees, a Science Curriculum Review Management Committee (SCRMC) was created, co-ordinating the development of a set of "Guiding Principles for Pedagogical Structure of the Curriculum" (Table 2a). This committee was comprised of discipline leaders who were asked to respond to these guiding principles by creating an eight point report (Table 2b) which would form the basis of a new curriculum structure. To develop the curriculum structure the SCRMC also created a set of standard statements concerning what a graduate should know and be able to do, based on the Science Threshold Learning Outcomes (STLOs, Jones et al. 2011) developed by the Learning and Teaching Academic Standards project (LTAS). A comprehensive curriculum tool modified from Curtin University was used to capture essential subject information (Table 3), with the planning for the review initiating in 2007, before commencement in 2009 and operation over a period of almost three years. In this time the curriculum was re-designed using research-led inquiry as the unifying pedagogy. The entire process ended abruptly at the end of 2011 with a university re-structure. By then the reconceptualised curriculum had been through the approval processes, and the final year of the successful implementation of the new curriculum was 2014.

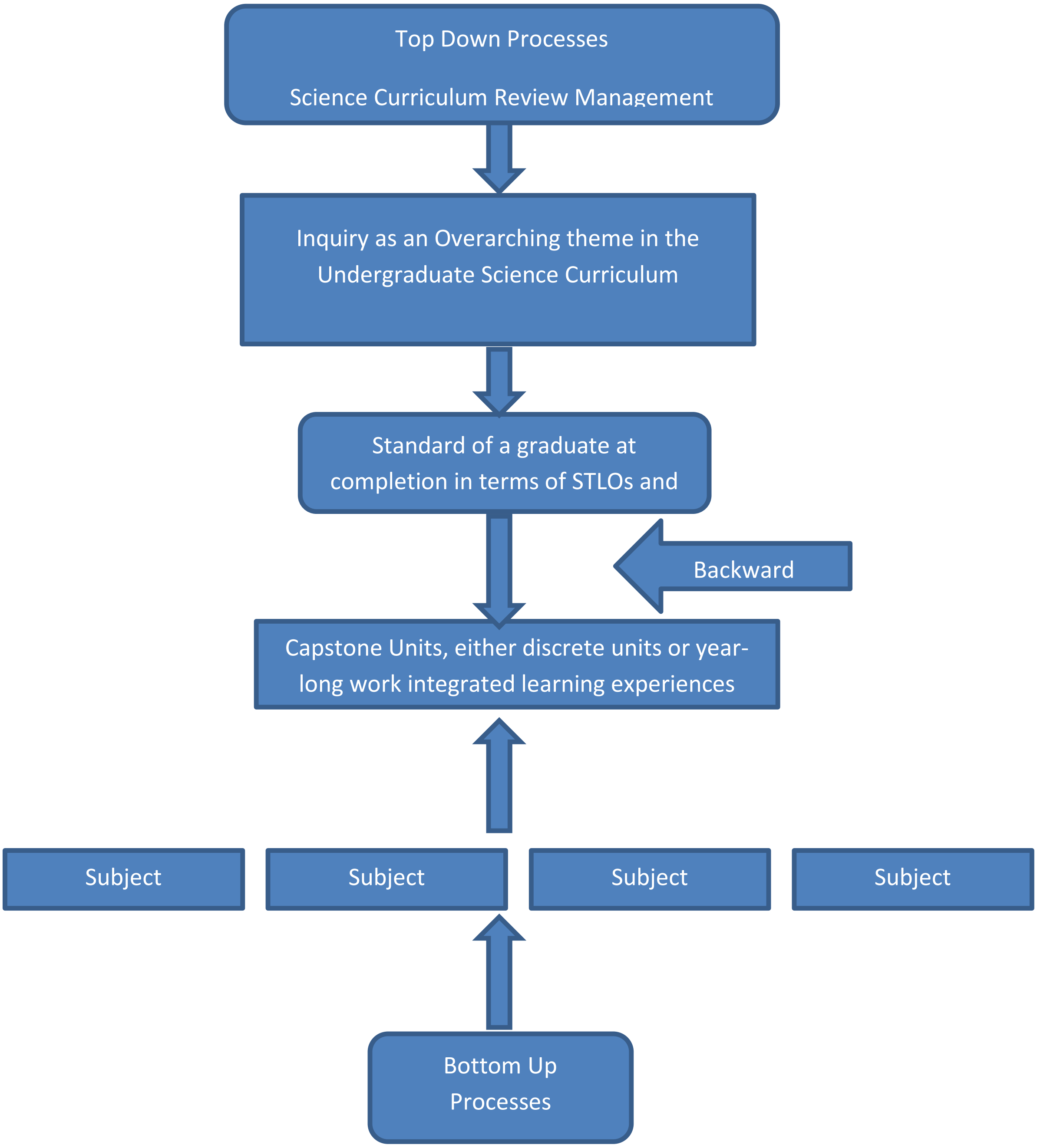

Figure 1. Top down and bottom up processes used to embed an inquiry pedagogy into an undergraduate science curriculum.

Table 2a. Guiding Principles for Pedagogical Structure of the Curriculum within specialisations and core working parties.

The key curriculum drivers of the courses and standard of a third year student[1] are: Thinking and Knowing: students require a sound knowledge across the base of scientific discipline and their specialist area, which is created using sound methods of experimentation, so that they are able to propose models, make and test predictions, draw conclusions and demonstrate capacity to pose and evaluate arguments based on evidence. Inquiry and Doing: students require experiences with the methods of experimentation in their discipline and demonstrate use of laboratory equipment especially at a standard of proficiency where they can transfer these skills to another context. There is a need for "coherency of conceptual development" (so that there is an integrated structure among units and a whole of course approach) and "congruence" which centres on a theme of inquiry, so that content and the scientific processes used to create knowledge are bought together. In this way thinking, knowing and doing (inquiry) become interrelated and the uncertain probabilistic, contestable and complex nature of knowing in the scientific context is realised. Communication: Literacy underpins good communication and our students need to read and write effectively across a range of genres (scientific report writing, popular articles, and fact sheets) for a range of audiences (specialist and lay audience) using different modes (oral, written, virtual). Numeracy and ICT: Students need to develop information management skills (ability to retrieve and analyse information from different sources) and use spreadsheets, enter and collate data and use appropriate statistical analytical methods to draw correct conclusions which incorporate probability and uncertainty into analysis and conclusions. Self-Direction and Responsibility: Students need to work safely, ethically and collaboratively and understand the social/political context of science and the relevance for the national and global community. These outcome statements, set a draft set of standards for discussion that are in line with the Learning and Teaching Academic Standards (LTAS) project of the ALTC (http://www.altc.edu.au/standards/disciplines/science) and the Tuning Project (http://tuning.unideusto.org/tuningeu/) and the Quality Assurance process from the UK (http://www.qaa.ac.uk/) and underpin the following guidelines for course and core working parties:

Table 2b. Each course will provide an 8 point report in which the following must be included to guide curriculum development.

1. A statement of the standard of an undergraduate at completion of their course based on their curriculum drivers above and the ALTC, LTAS threshold learning outcomes.
2. Conceptual structure of the content which will be scaffolded throughout the course which is linked to relevant, meaningful and contextual experiences for students.
3. A philosophy or process of knowing (inquiry) on which the course curriculum is based (e.g. active learning strategies, laboratory/experimental/field work) and how this is scaffolded and developed throughout the 3 year course (with specific statements on where students are at first and third year)
4. An identification where undergraduate research experiences are located in the course structure (using the Jenkins et al. 2007[2] model as a guide)
5. A scaffolded and coherent process of assessment for and of learning (which is focussed on assessing whether the third year standard has been achieved as well as incorporating the principles of the first year transition project so that students have an early diagnostic assessment)
6. A suggestion for an integrated assessment at first and third year among units to encourage integration of big ideas and key concepts or skills.
7. Identification of IT skills within the unit.
8. Identification of numeracy and statistical analysis and skills developed in the unit.

[1] The text following is an amalgamation of describing and prioritising curriculum threads and standards as workshopped by groups on the second day of the re-conceptualisation retreat 11-12 November 2010.
[2] http://www.heacademy.ac.uk/assets/York/documents/LinkingTeachingAndResearch_April07.pdf page 29

The pitfalls of pedagogy

This is a story of the top down and bottom up processes used to embed research-led inquiry pedagogy into subjects, and as an overarching pedagogy in the re-conceptualisation of undergraduate science curricula, encompassing almost a decade.

At the practical level, laboratories based on research-led inquiry pedagogy have been sustained in subjects which are co-ordinated by energetic individuals are committed to the student experience. Although not all the aspects of the practicals have been evaluated, there were certainly some challenges for students and staff. Students were challenged by having to "think" in "inquiry" laboratories, as they preferred to know "the correct answer" or the "solution", while being concerned that they would lose marks and be penalised in the assessment. Once students experienced both the open ended nature of the laboratory and assessment, however, they were more supportive of the benefits of thinking, rather than following a cookbook recipe. Students have also stated that the independent learning exercises were powerful experiences, especially the process of acting on feedback from the review.

> *'The most useful task I undertook was the seed germination report. The process of drafting a report, handing it in for feedback and then having the opportunity to implement that feedback I found very useful and was then able to apply my learning from that tasks across to other subjects.'*

Academics were not always comfortable with the open-ended nature of the laboratory and field work, but fortunately there was often a quick adjustment to the new way of thinking concerning a laboratory and the benefits. They stated:

> '*Students require experiences with the methods of experimentation in their discipline and demonstrate use of laboratory equipment especially at a standard of proficiency where they can transfer these skills to another context. There is a need for "coherency of conceptual development" (so that there is an integrated structure among subjects and a whole of course approach) and "congruence" which centres on a theme of inquiry, so that content and the scientific processes used to create knowledge are brought together. In this way thinking, knowing and doing (inquiry) become interrelated and the uncertain probabilistic, contestable and complex nature of knowing in the scientific context is realised*'

In the reconceptualised curriculum several pitfalls were encountered which require comment. The first pitfall was the time difference between the finalising subject and curriculum approval processes, and the restructuring of faculties within the university. The time period involved in the re-conceptualisation described in this paper was almost five years. The explicit planning process commenced in 2009, however ideas concerning how inquiry could shape the curriculum were canvassed prior to this time. From the outset it then took almost three years to move the documentation through the university planning and approval processes, and another three years to be implemented. Up to six years is a long time for curriculum re-conceptualisation, and government regulations, funding initiatives and the composition of university executive changed during the curriculum review? Academic staff changed their priorities from implementing inquiry in the curriculum to disciplinary research, and overall clearly the time involved in approval processes remains a challenge for reform in many universities. Further, bureaucratic processes within universities can, instead of acting as a quality control, have the opposite effect and constrict flexibility. The SCRM committee could have equally if not better acted as a quality control mechanism for documentation of new and modified units, yet by following university guidelines the new outlines for each of almost 150 subjects had to be read and approved by at least another four committees. Although these committees provide sometimes useful feedback, the cost of the time involved in teaching the decision and providing feedback outweighed the benefits. Large scale curriculum reform requires streamlined committee processes.

Other pitfalls include seeing curriculum reviews as "communities of practice" (Lave and Wenger 1991, Wenger 2006), where academics "*share a concern or a passion for something they do and learn how to do it better as they interact regularly*". Although academics share concern and passion for curriculum reform, a community of practice model does not describe the relationships between academics in a curriculum reform. Communities of practice require the development of "trusting communities", with universities, in contrast, becoming more like "fast communities" that quickly establish and dissolve for a purpose (Roberts 2006). Universities are now more like business organisations and re-structuring is an increasing solution to position the university in the marketplace (Roberts 2006).

The biggest pitfall for successful implementation of research-led inquiry pedagogy as outlined here was not the shift in pedagogy or resistance of coal face academics, but the shifting priorities of universities. Even before the first year of the new curriculum was implemented, the university restructured faculties and merged schools. The process of re-conceptualising the curriculum allowed the merging of schools which had been acting independently with substantial overlap of subjects. Most striking in this process was that the pitfalls were not pedagogical. While academics had good reasons to be fearful about ownership of subjects and the security of their jobs, academics were often not the problem. Much of the conflict between academics was resolved through discussion. The more difficult conflict was perhaps, yet unsurprisingly, political. There was, unfortunately, also little concern for how the political process affected student outcomes. Perhaps the political processes could have been in part ameliorated by leveraging more from the external advisory committee, although it is unclear how. The role of the external advisory committee was to guide the pedagogical structure of the curriculum. The members of the expert advisory committee were clear voices providing direction and advice on best practice.

While many of the top down processes disintegrated because of shifting priorities and re-structure, many of the bottom up process persisted. The core curriculum remains, including first year subjects devoted to explicitly developing scientific literacy and quantitative thinking skills. Capstone units enabling students to consolidate learning and achievement over the course, providing a research and Work Integrated Learning experience for students also appear sustainable, albeit with some inevitable drift in structure. Fewer subjects make up the curriculum, mainly through removal of subjects with duplicated content, and the pedagogy of research-led inquiry has overwhelming support from academic staff as the right direction for science curricula, as does the broadening of the curriculum and alignment of graduate outcomes with the STLOs. The fatality in the entire process was assessment. It is now more common to assess learning outcomes using assessment which does not require feedback such as multiple choice, hence avoiding assessment types such as scientific reports and writing, which provide a broader picture of student understanding despite requiring more feedback.

Conclusion

Opportunities are emerging to systematically embed research-led inquiry pedagogy in science curricula at all levels of education. We need research-led inquiry pedagogy if we are ever to align science learning with science research and contribute to the economic growth of our nation. If we are ever to embed research led inquiry pedagogy in the curriculum successfully and create future science researchers and a public well disposed towards science, science educators will need to be resilient and cognisant of the politics. When we set out to attempt large scale science curriculum reform we need to be mindful of the promise and the pitfalls.

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Table 3. Comprehensive Course Review: Curriculum mapping.

Revised unit information or new unit If this is a new unit please provide a brief rationale justifying the need for this unit.			
Course Code(s): Title of Course:	Unit Set Code:	Name of Unit Set:	
Unit Code:	Name of Existing Unit(s):	Credit points:	Year / Session:
Unit Code:	Name of New Unit:	Credit points:	Year / Session:
Pre-reqs:	Co-reqs:	Equivalent/s:	
Handbook Entry: Write <u>description</u> here. MAX 100 WORDS. The Handbook entry is a clear, brief statement reflecting the rationale and unit objectives. It must be consistent in style across the whole course.			

Unit Learning Outcomes: clear, observable and measurable outcomes which begin with a concrete active verb.	Level of thinking skill (1 - 6) Key to right	Identify up to three of the Graduate Attributes that this significantly relates to 1st GA	2nd GA	3rd GA	Meets Professional Accreditation Requirements Y/N	Level of Thinking using Krathwohl's revised Teaching Taxonomy
1.						**KEY** 1. Remembering ★ 2. Understanding ★★ 3. Applying ★★★ 4. Analysing ★★★★ 5. Evaluating ★★★★★ 6. Creating ★★★★★★
2.						
3.						
4.						
5.						
6.						

Assessments: How do students demonstrate their achievement of these outcomes? *(* Fill in week number or 'W' if assessment occurs over whole of course)*			
Type: essay, test—give brief detail *e.g. Case Study examining the differences between x and y, a lab report or essay (sub-elements should be clearly identified)*	Weighting %	Submission Week *	Unit Learning Outcomes assessed

1.					
2.					
3.					

Assessments: More detail about Assessments shown in the categories below:

	Type	Medium	Format if Written	Role	Authenticity	Engaged Learning	Supervision	Principal Assessors	Purpose
1.									
2.									
3.									
Choose from:	*Test; Final Exam; Presentation; Essay; Critical review; Case study; Creative/ Design task; Exercise; Practical class task; Research task; Report; Professional document; Project; Journal; Portfolio; Engaged learning/Practicum; Class participation; Other.*	*Written; Oral; Practical; Performance; Visual; Combination; Other.*	*Long answer; Short answer; Multiple choice; Combination with multiple choice; Combination without multiple choice; Other.*	*Individual; Pair; Group; Individual/Group; Other.*	*Nil; Low – Knowledge test or theoretical only; Medium – Assess task situated in the real world, e.g. Case study; High – Assess task simulating the real world, e.g. Project on real world task; Very high – Assess of performance in actual work/professional setting*	*Clinical; Practicum; Community engaged learning; Work placement; Internship; Other.*	*Closed book; Open book; Unsupervised; Supervised; Other.*	*Teaching staff only; Industry only; Peer only; Self only; Teaching staff/ industry; Teaching staff/ peers; Teaching staff/self; Other.*	*Assessment for learning (formative); Assessment of learning (summative); Both; Other.;*

Learning experiences: What sorts of learning experiences are appropriate for students to achieve these learning outcomes?			
Tuition Pattern:	Duration:	Frequency:	Main Student Activity:

1.				
2.				
3.				
4.				
Key to Tuition pattern, Duration, Frequency and Main student activity: Tuition pattern; *Clinical practice, fieldwork, laboratory, lecture, practical, seminar, studio, tutorial, workshop, individual study, online, other* Duration: *1hour, 1 ½ hours, 2 hours, 3 hours, 4 hours, half-day, full day, other.* Frequency: *Daily,4 times a week, 3 times a week, twice a week, weekly, fortnightly, monthly, twice a session, once a session, other.* Main student activity: *Listening/viewing/reading, writing, speaking, reflecting, hands-on-practice, listening/writing, listening/writing/speaking, problem-solving, other*				
Unit Coordinator:		**Telephone contact:**		
Course coordinator:				

Table 4. Levels of thinking (or cognitive demand) adapted from Bloom's Revised Taxonomy[i] with matched verbs and sample learning outcomes

Level of thinking	Definition and sample assessment verbs[ii iii iv v]	Example unit learning outcomes
1. Remembering ★	Retrieving relevant knowledge from memory Recognise, recall, memorise, list, name, recite, identify, label, select, state, organise	Identify the major organs, tissues, cellular and non-cellular components of the immune system Recognise architectural technical drafting standards and symbols
2. Understanding ★★	Determining the meaning of instructional messages, including oral, written and graphic information Interpret, classify, summarise, infer, compare, explain, perceive, discern, deduce, relate, conclude, describe, define, outline, discuss, illustrate, exemplify	Explain what strategic cost management is and how it can be used in the creation of competitive advantage Describe the structure of gene regulatory sequences, the roles of transcription factors and the various ways in which gene expression is regulated in both prokaryotes and eukaryotes
3. Applying ★★★	Carrying out or using a procedure in a given situation Apply, implement, conduct, verify, carry out, use, execute, employ, utilise, operate, exercise, practise, solve	Apply legal principles and ethical frameworks associated with the provision of holistic nursing care for a person Carry out the basic experimental procedures of restriction site mapping, PCR, plasmid purification and DNA cloning
4. Analysing ★★★★	Breaking material into its constituent parts and detecting how the parts relate to one another and to an overall structure or purpose Analyse, differentiate, organise, attribute, separate, dissect, examine, investigate, study, critique, estimate, test, diagnose, explore, consider, distinguish, compare, contrast	Analyse risk management strategies for investment and insurance decisions Examine regional and local identity within the Sydney basin from 1788 to the present
5. Evaluating ★★★★★	Making judgements based on criteria and standards / reasoned argument Evaluate, critique, value, appraise assess, check, judge, rank, rate, gauge, estimate, approximate, calculate, compute, quantify, determine, ascertain, weigh, measure, review, justify, predict	Assess the resources needed and technical requirements for an interactive digital media project Evaluate the different theoretical approaches in the study of personality, motivation and emotion
6. Creating ★★★★★★	Putting elements together to form a novel, coherent whole, or making an original product Create, generate, plan, produce, invent, imagine, frame, fabricate, develop, design, devise, initiate, craft, build, construct, set up, compose, write, argue, teach	Argue for the reform of selected areas of criminal procedure and evidence Design new products according to the conditions of minimal environmental cost, maximum product longevity and maintenance

[i] Source: Krathwohl, D.R. (2002) A revision of Bloom's taxonomy: An overview. *Theory into Practice*, 41(4), 212-218
[ii] Ibid
[iii] Urdang, L. (1991). *The Oxford thesaurus*. Oxford: Clarendon Press
[iv] (n.d.) Roget's II: The new thesaurus. Third Edition. Retrieved 30 March 2011, from Thesaurus.com website: http://thesaurus.reference.com/browse/apply
[v] Microsoft Office Word 2003 thesaurus