Experiences in Inquiry: Exploring the experiences of coordinators, tutors and students involved inquiry-oriented laboratories in science (UQ)

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

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

Student experiences of the transition to inquiry-oriented curricula described in the interviews, and thus the narratives developed from them, clearly indicated that different students experience the curricula and its impact on learning in different ways. Specifically, it appears that regardless of how open the curricula design was,

the degree of autonomy experienced by the students was more dependent on the degree of leeway provided by a tutor to a student during the implementation of the inquiry-oriented class, and the prior experiences of the student with inquiry-oriented projects. These experiences subsequently determine the degree to which students feel responsible for the planning of experiments and interpretation of experimental findings, which ultimately influences the degree to which students believe they are gaining experience in developing skills such as critical thinking.

Tutors generally perceived a shift in their roles with the transformation from recipe-based curricula to inquiry-oriented curricula. Firstly, tutors found that inquiry classes were more fun to teach. In inquiry-oriented classes, tutors saw their major role as facilitating learning by encouraging students to think about the scientific process and about the findings, expressing this as guiding the students to learn rather than demonstrating. Tutors also highlighted that inquiry classes gave students the opportunity to understand the perspective of the scientist.

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

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

Table 1. Mapping of quotations from each stakeholder group against each of the components of TLO3 - Critically analyse and solve scientific problems by:
3.1 gathering, synthesising and critically evaluating information from a range of sources

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

3.2 designing and planning an investigation

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

3.3 selecting and applying practical and/or theoretical techniques or tools in order to conduct an investigation

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

3.4 collecting, accurately recording, interpreting and drawing conclusions from scientific data

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

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

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