Problem-Based Learning in the Development of Laboratory Teaching Skills

A Case Study Submitted as a Finalist of the Royal Society of Biology Higher Education Bioscience Teacher of the Year Award 2016

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Background

The applicant is Director of the MSc in Clinical Embryology at the University of Oxford, a residential postgraduate course designed to motivate and inspire future clinical and scientific leaders in the diagnosis and treatment of human infertility, a medical condition affecting one in six couples. He designed and created the course in its entirety. Commencing in 2008, the course now has 89 graduates distributed all over the world, studying or working in clinical or research settings. Thus far, students have originated from 33 different countries with scientific or clinical backgrounds. The success of the course lies in its holistic approach in which a number of modern teaching methods are used to enhance the student learning experience. Routine lectures are supported by a variety of other teaching styles to promote deeper learning, including interactive tutorials, problem-based learning (PBL), and 'hands on' laboratory sessions. The aligned deployment of a suite of different teaching styles, and an emphasis upon reflective learning, encourages our students to develop a deeper state of learning and make tangible connections between different elements of the syllabus. Consequently, students develop scientific and clinical insight and link their learning experiences to the 'real world' (Albanese, 2006; Biggs, 2001; Biggs, 2005). The acquisition of practical laboratory skills is a critical aspect of the course, which was specifically designed to generate an appreciation of how laboratory skills represent the core of human infertility treatment, both in terms of diagnosis and treatment, but also in terms of the on-going scientific research which fuels the refinement or replacement of existing clinical technology.

The case study

This case study describes the implementation of a novel problem-based learning technique which provides our students with the opportunity to learn vital teaching skills in the wet laboratory. Originally supported by a Teaching Development Grant from the Higher Education Academy in 2011, this on-going project allows our students to design and present their own laboratory practical session to their peers, under the observation of senior staff. Specific learning objectives were created to encourage our students to learn within the context of their curriculum such that the exercise serves to inspire and motivate (Gibson, 2005). In addition, the model helps to link lecture content to the 'real world' and to highlight potential pitfalls, safety considerations, and the difficulty of facilitating teaching sessions in a laboratory scenario where experimental outcomes are largely unpredictable.

Prior to the laboratory session, course staff assist with a classroom PBL session to help student groups design a suitable experiment and to consider the best way of transmitting key learning outcomes to a peer group in a subsequent laboratory session. A typical example is using the polymerase chain reaction (PCR) to amplify a target gene from genomic DNA for sub-cloning into a protein expression plasmid. Designing such an experiment requires consolidation of lecture material involving recombinant DNA technology, primer design for PCR, bioinformatics, and specific knowledge of the target gene. This material forms an essential component of our core curriculum, and is delivered earlier in the course. During the PBL, the student body is divided into two groups – each tasked to design their own experiment and to develop a written hand-out to serve as an instructional tool for a subsequent laboratory session. Following the PBL, the two groups meet separately to discuss their experiment, and assign roles (e.g., briefing presenter, experimental demonstrator, debriefing presenter). Two weeks later, the students attend a second tutorial in which they discuss their experimental plans, hand-out, and feedback sheet with experienced tutors.

Later, each group are given half a day to prepare the laboratory (e.g., preparing solutions and installing relevant equipment), and to make final adjustments to their hand-outs. The two groups then take turns to deliver their respective practical sessions as 'teachers' for their peer group (a 'student body'). Interactive whiteboard technology is used to enhance their experimental briefing and debriefing sessions, and to help their peers engage with the teaching material. The whiteboard allows our students to present and adapt their briefing, add data arising throughout the practical session, and record discussion notes during the debriefing. This information can then be saved and transmitted to the class in electronic form for subsequent reference. For an overview of the key stages of this model, see **Figure 1**. Course staff monitor these teaching sessions but have no other involvement except for facilitating a final discussion session to encourage reflection, evaluate feedback, and to identify key learning outcomes. Staff use their own feedback sheets to collect quantitative and qualitative feedback over the entire exercise. This allows us to reflect upon how the model is developing, and instigate refinements on an annual basis. Collectively, this model encourages creativity, promotes deep learning (Biggs, 2001), provokes discussion, and demonstrates how lecture-based material can be enhanced by parallel laboratory sessions (Kirschner & Meester, 1988; Allison, 1995). In addition, this methodology aids in the development of metacognitive skills, facilitates a holistic understanding of the subject material, and highlights the need for delegation and teamwork.

This model was developed due to the noticeable lack of appropriate training opportunities for members of our student cohort who may move into careers in which there is a high expectation to teach in the laboratory. It is vital to bridge this gap as laboratory teaching requires a distinct suite of teaching skills that are very different from those routinely deployed in classroom teaching. The model has now been running for four consecutive years and student feedback has been very positive amongst the 69 students who have taken part.

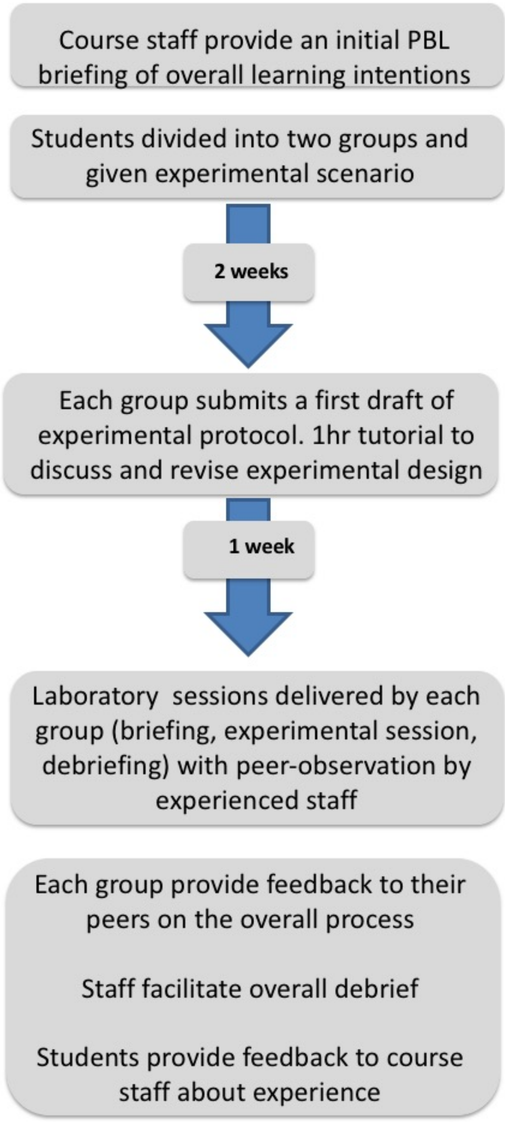

Figure 1. Schematic overview of the practical teaching model

Reasons for introducing this teaching model

The course runs from state-of the-art teaching and laboratory facilities alongside 'Oxford Fertility'. Our teaching facilities were purposefully designed to provide a nurturing, motivational and inspirational learning environment. In the first two terms, the taught syllabus covers the fundamentals of reproductive science, laboratory skills, reproductive medicine and assisted reproductive technology (ART). Emphasis is continually placed upon the acquisition of laboratory skills, especially those applicable to ART and research in the reproductive sciences.

Laboratory sessions are specifically designed to complement lecture material and allow students to apply theoretical concepts, enhance cognitive and technical skills, and to develop an aptitude for problem solving and data analysis (Kirschner & Meester, 1988; Allison, 1995). This style of teaching has been practiced routinely in higher education for many years (Allison, 1995), although the use of virtual training software is becoming more prevalent as class size increases and financial resources become more limited (Coward & Gray, 2014). In our case, laboratory sessions serve to encourage a deeper understanding of how laboratory skills under-pin the success of ART. In doing this, our teaching adopts the cognitive apprenticeship model (CAM) in which tutors make teaching processes more explicit by providing a learning experience which is enhanced by observation, imitation (enactment) and modelling (practice) with the support of experienced tutors (Collins *et al*., 1987; Brown *et al*., 1989; Collins *et al.,* 1991). While the CAM features six different phases (modelling, coaching, scaffolding, articulation, reflection, and exploration), the true effectiveness of the CAM derives from two main features: (1) students learning in context and (2) situated cognition. Indeed, contextual learning is regarded as being crucial to this model as cognitive apprenticeships are far less effective when skills and concepts are decontextualized (Collins *et al.,* 1989). Consequently, practical skills are taught much more efficiently if tutors deliver their teaching in a 'real world' context. In order for our graduates to perpetuate such critical understanding to their own future 'apprentices', it is vital that they learn an appropriate set of key teaching skills. This however, presented us with a critical problem, as opportunities to learn such skills are incredibly rare, and it is often presumed that an experienced classroom teacher can also deliver in a laboratory scenario. Our new model was designed to bridge this gap and provide students with a 'safe' learning environment in which to develop their own laboratory teaching skills.

Performance indicators: the student's perspective

Quantitative and qualitative feedback was collected from all 69 students undergoing this laboratory teaching model between 2012 and 2015 using bespoke feedback sheets. Quantitative data was given on a scale of 0 (not useful/very poor) to 10 (incredibly useful/excellent). Mean feedback scores for key aspects of the teaching model are given in **Figure 2.**

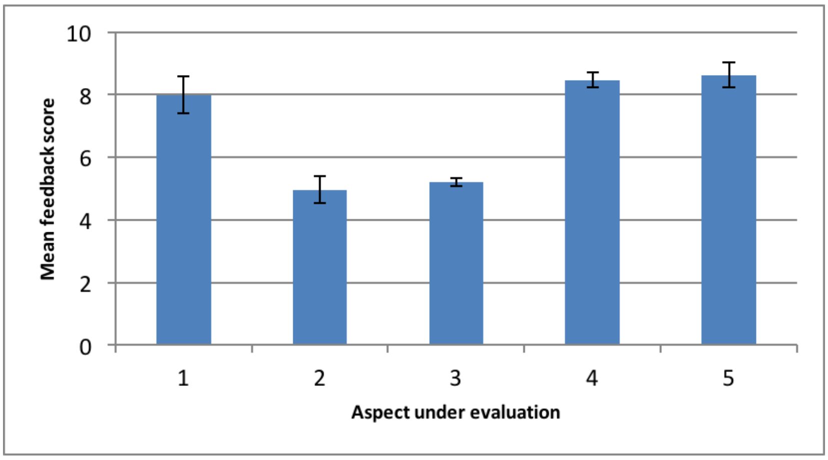

Figure 2. Mean feedback score (±SEM) from four cohorts of students (2012 – 2015, n = 69) experiencing the new methodology in terms of: (1) overall enjoyment; (2) difficulty of setting up the experiment/laboratory; (3) difficulty of explaining the practical session to peer group; (4) usefulness of the overall exercise; and (5) use of interactive technology. Feedback scale ranged from 0 (not useful/very poor) to 10 (incredibly useful/excellent).

Particularly high feedback scores (≥8) were obtained in terms of overall enjoyment, usefulness of the exercise and the use of interactive technology. Lower scores in the remaining two criteria showed that the students found it difficult to set up and explain their practical session. A snapshot of qualitative feedback, in the form of direct quotations, is provided in **Appendix 1**. Students clearly embraced the overall objectives of the exercise and enjoyed the opportunity to use interactive technology to engage their peers in a 'safe' learning environment. Students also realised the complexities of setting up and running a laboratory practical session, and how unpredictable such sessions can be from a tutor's point of view. The most dominant realisation was the importance of working as a team and delegation in such scenarios.

Reflections

Overall, this exercise has proved to be incredibly insightful, both for the students and the course staff. Exit data from the first five cohorts showed that 83% of graduates went on to work in a discipline where they will be required to teach practical skills to their juniors, in one form or another. Prior to the development of our new model, it was clear that opportunities for students to acquire such teaching skills were incredibly sparse. We are now able to provide our students with at least some experience in the design and delivery of a laboratory practical session. It is clearly evident that students embrace this rare opportunity to gain a key set of skills. One clear message was that individuals always carry out practical work at a pace they feel comfortable. Some are fast and efficient, others are slower and more methodical. Those lacking self confidence often require additional encouragement and modelling from tutors. Within a group scenario, a heterogeneous mixture of ability, efficiency and confidence, can soon lead to disarray and confusion for tutors. Developing the confidence and ability to 'jump' from one part of an experimental protocol to another, often with little warning, is a critical part of a laboratory tutors training, and is mostly acquired 'on the job'. Aside from teaching skills, this exercise also promoted confidence in the laboratory environment, particularly in students from a clinical background. We also realised that some students were not adequately coherent in some aspects of the core syllabus, and this allowed us to modify problem areas with additional facilitation. Interestingly, differences were noted in relation to educational background. Scientists tend to take the lead in terms of 'front-line' delivery, while clinicians tend to be happier 'behind the scenes'. This perhaps reflects the importance of familiarity and confidence and is something we should explore.

In future, this method will be re-mapped to provide bespoke sessions for sub-sets of our students aiming for specific vocations. The present model best fits students moving into PhD programmes and heading for an academic career where they will eventually be required to assist or lead laboratory sessions for their own students. Those moving into embryology are more likely to be responsible for one-on-one laboratory teaching, while clinicians are most likely to undertake bed-side teaching. It is evident that these latter groups of students will require a very different set of teaching skills than those remaining in academia. Nevertheless, the present model was incredibly well received and clearly highlights that teaching outside of the normal classroom can generate a range of problems and questions, that are often unpredictable. Teaching in such scenarios thus requires an ability to improvise, adapt, and overcome. Our model has begun to address this unmet need in higher education, and could readily be modified for other bioscience subjects. One aspect, of which I was particularly proud, was that this exercise clearly identified a number of individuals who possessed the inherent abilities of a good teacher, someone who could deliver academic material in a calm and motivational style. Without fail, these individuals were unaware of having this ability, and were delighted to realise that they possessed such 'hidden talents'.

Acknowledgements

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Appendix 1. Snapshot of student feedback.

Did you enjoy this practical? *"Yes, it showed us how the laboratory needs to be maintained, materials ordered, safety taken into consideration, materials made handy to students, make a reader-friendly hand-out, and interact with a wider audience with differing capabilities"* *"Lots of fun. Felt more comfortable in the laboratory"* *"Yes, it gave me increased familiarity in the laboratory, which made me much more confident"* *"Very useful. I really like how we had the opportunity to teach and conduct the experiment. These features promoted thoughtful/reflective learning. It was also a lot of fun"*
How difficult was it to set up your practical? *"Physically setting up the laboratory was fine but primer design was difficult. Working in large groups made it difficult for work to be distributed evenly'* *"Working in such a large group made planning the practical challenging, as it was difficult to please all team members"* *"It was hard with such a big group to organise and allocate tasks. Some people did a lot more work than others.*
How difficult was it to present your practical to your peer group? *"The main difficulty was deciding how much detail to include on the theory behind the science"* *"The use of a topic that was somewhat familiar, but not entirely, was very constructive. In future, there will surely be aspects of the practical that we, as teachers, are somewhat unfamiliar with. This session prepared us to 'deal' with the minor unknown"*
How useful do you think this model was in terms of your future career? *"The practical was extremely useful. The opportunity to create a method, explain the practical to students, and set-up the laboratory has give me much more confidence"* *"I learned some useful insights on how to teach and noticed some issues that may arise during the practical. Therefore, being aware of that is boosting my confidence while teaching"*
How useful did you find the interactive features of this practical? *"I think it is useful in terms of confidence, i.e. standing in front of the other students and explaining procedures"* *"Helped student understanding and help facilitator convey their message"* *"Loved the whiteboard – gave us the ability to pre-prepare slides and access the internet"*