CASE STUDY

Asking and Answering Questions: Partners, Peer Learning, and Participation

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ABSTRACT

Science is about asking questions but not all science courses provide students with opportunities to practice this essential skill. We give students ownership of the processes of asking and answering questions to help them take greater responsibility for their own learning and to better understand the process of science with its inherent uncertainty. Peer learning activities throughout the course embed multidirectional feedback within and between students and instructors. Students are our partners in the design and evaluation of exam questions and we learn from them as they rise to the challenge of identifying important information and applying it. The lab program is supported by peer assisted learning in which peer mentors partner with instructors to generate activities addressing the use of evidence and experimental design. While not all students engage as partners, those who do value these experiences and demonstrate they can use scientific content creatively and critically.

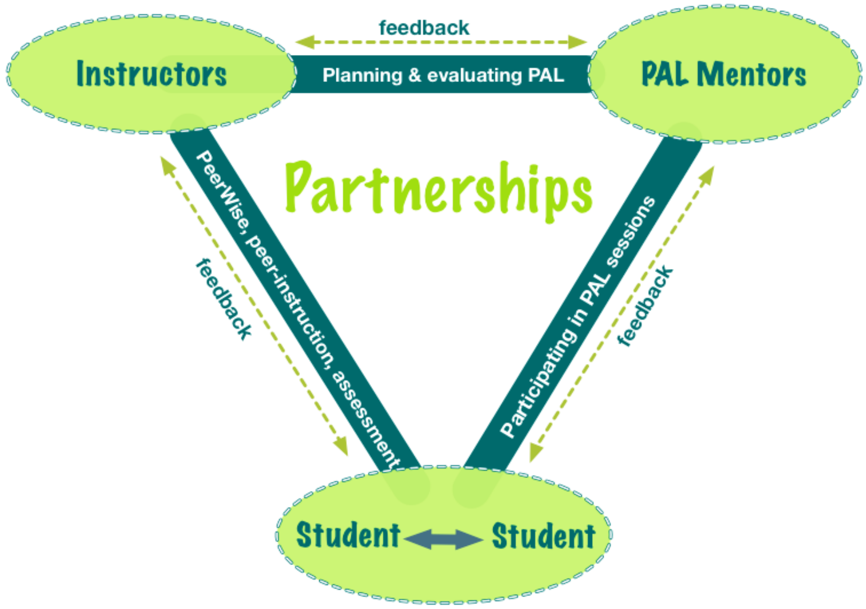
KEYWORDS

peer learning, feedback, asking questions, active learning, science

Learning to ask questions and to accept uncertainty are crucial aspects of the practice of science that are not always evident in large undergraduate classes. Students may find this difficult because of their prior experience of science as factual, leading to a reliance on rote learning and an expectation that questions have an unambiguous right answer (Hodson, 1999). To help students overcome this mindset in a second-year genetics course, we use a variety of peer-learning strategies that aim to provide students with greater ownership of the course content and its assessment. Our collaborative and process-oriented approach is consistent with the aims of the growing student-partnership movement (Matthews, 2016). Instead of the lecturers providing content, assessment and feedback, we engage students in multiple steps along the pathway to meeting the course learning outcomes. We see two aspects to this process of student engagement, which are united in their focus on questioning and process instead of transmission of knowledge. First, we aim to foster the view that science students are at university to learn to think like scientists and to understand the process of scientific discovery. We want students to understand the value of evidence and be able to critically assess data and conclusions. Second, by engaging students in the process of designing and appraising assessment questions, we hope to shift their focus from acquiring knowledge to evaluating and using it. Partnership implies responsibility, and it is therefore important to set up partnerships in ways that support students and value their input (Healey, Flint, & Harrington, 2014). Well-designed peer-learning activities can do just this, by promoting dialogue, agency and trust (Boud & Molloy, 2013), all of which are essential for a successful partnership (Healey, et al., 2014). A comprehensive review of peer-learning models (Topping, 1996) concluded they lead to gains in learning and/or confidence for participants, with gains equivalent to those obtained by academic tutoring in the best cases. The social component of peer-learning seems particularly important, leading to increased motivation and self-efficacy, as well as confidence (Keenan, 2014; Topping, 1996). Discussion and group activities provide opportunities for students to not only gain feedback on their own learning but also to observe different study skills and strategies, leading to more informed self-evaluation. Such activities contribute to their development as self-regulated learners, which is correlated with academic success (Nicol & Macfarlane-Dick, 2006; Zimmerman, 2013). Similarly, Boud and Molloy (2013) argue that feedback should be "repositioned as a fundamental part of curriculum design, not an episodic mechanism delivered by teachers to learners" (p. 699). This requires a shift in student thinking from being a passive receiver to an active adopter of course material. In the partnership model, feedback and engagement are the responsibility of students as much as lecturers.

We (the course convenors Susan Howitt and Alex Maier) designed our molecular genetics course with these ideas in mind, focusing specifically on partnership in learning, teaching and assessment (Healey, et al., 2014). The class has a typical enrolment of 200, limiting one-on-one student/lecturer interaction. Instead, we engage students in questioning throughout the course via multiple mechanisms including assessment question design and evaluation, peer instruction in lectures and peer-assisted learning (PAL) to support the lab program (Figure 1). All activities are optional but linked to the summative assessment by providing practice in the types of activities that are assessed through quizzes and lab reports. Thus, students can choose to become partners by taking responsibility for engaging in these activities as formative assessment. We briefly discuss each strategy and then provide some evidence of impact; our focus here is on the course convenors' perspective as we illustrate how partnership is integrated into the course design.

Figure 1. Dimensions of partnership



We have adopted PeerWise as an online tool for question design and evaluation (Denny, Luxton-Reilly, & Hamer, 2008). This allows students to design multiple-choice questions and to answer, evaluate and comment on other questions anonymously. The exercise exemplifies the challenges in formulating meaningful questions by giving students responsibility for co-creation of assessment (Deeley & Bovill, 2015). Good question design is discussed and the lecturers model good questions in class—often using a scenario-based approach that encourages students to apply their knowledge to solve problems. We choose some of the best PeerWise questions for the final exam, accepting students as our partners in assessment.

Peer instruction is used much as it has been in physics (Crouch & Mazur, 2001) with a phone-based audience response system (mQlicker). Students in class answer a multiple-choice question individually, then discuss answers with their peers before responding again. This provides an opportunity for students to test their learning immediately after presentation of material and gives feedback to the lecturer on whether the class has understood. Students can also gauge their level of understanding relative to the rest of the class, leading to more effective self-evaluation. Studies consistently show that the discussion increases the proportion of correct responses (Crouch & Mazur, 2001). Interestingly, this is also the case even when no student in a discussion group knows the correct answer (Smith et al., 2009). This suggests that the discussion promotes learning in ways other than simply sharing information and is consistent with a constructivist view of learning. Where possible, we use questions from PeerWise but usually from previous years. Such questions are identified as student-generated to reinforce the partnership and its value.

The lab program is structured as a full-semester project in which students isolate and analyze bacterial mutants (Healy & Livingstone, 2010). The emphasis is on using and evaluating evidence; since we don't know in advance which mutants will be isolated, it is up to the students to use their data to justify their identification. The project contains an element of uncertainty, not just in the mutant outcomes, but also because the experiments are not always sufficient for a full identification. Thus, students need to be open to the idea of several possible interpretations of their data and include in their argument an analysis of what extra information is required and how it would help. Because students found the uncertainty, the incremental nature and the length of the project initially difficult, we introduced peer-assisted learning (PAL). At our university, PAL runs for first-year science courses and is used to support lecture content. We adapted it to the lab program, with four sessions throughout the semester focusing on the ways in which scientists ask questions and use experimental evidence to answer them, providing another dimension to our partnership strategy (Figure 1). The PAL mentor development program was deliberately designed (by Ruth Mills and Denise Higgins) to focus on supporting mentors to make the most of their experiences as recent students in the course, to constantly gather useful feedback from students, and to foster closer collaboration with course convenors. The planning process for PAL sessions involves the mentors (John Rivers and Aaron Smith) reflecting on past learning experiences, breaking down the thinking processes involved in these experiences and planning activities that allow students to move through the same thinking processes to solve problems or develop understanding of complex concepts. During the PAL sessions, mentors also seek to identify cues from students that may assist in understanding whether they are successfully progressing through the thinking process or if stalling is occurring along the way. This permits constant feedback during the PAL session which mentors are then able to incorporate into their reflections when planning future sessions, improving the quality of the thinking processes and activities. PAL mentors also collect feedback directly from students throughout the semester and write reports on the PAL program, both for their own benefit and for that of the course convenor and future PAL mentors.

EVIDENCE OF IMPACT

A theme throughout the course is that we are encouraging students to think and actively engage with course content, rather than passively accept knowledge. We want them to be partners in the learning journey through learning to ask questions and evaluate conclusions and answers, both in the lab program and in the peer questioning strategies adopted. We can evaluate how effective this is through the level of engagement with each activity and feedback on what is valued, as well as by observing changes in students' attitudes towards learning science.

Table 1. Student engagement with different activities (averaged over three years)

Activity	**Percentage of class participating**
Writing PeerWise questions	27
Commenting on PeerWise questions	31
Answering PeerWise questions	73
Peer instruction (as indicated by lecture attendance)	30-40
PAL sessions for lab program	42

Table 2. Thematic analysis of course surveys to identify what students value and why (over three years)

Most valued aspects of the course	Student comments
Lab program	• [The labs] really gave a good idea of how science actually works • I feel like I could apply the skills and ways of thinking learnt in these pracs in other genetics research questions
Course structure and assessment	• The course had many opportunities to help students succeed with PAL sessions, the pre-exam tutorial and Peerwise • I love how we got to test our understanding the whole way through with in-class questions, mqlicker, peerwise , as well as in the tutorials • Assessment nicely structured with small tests • PAL sessions and constant feedback
Opportunities for problem-solving and developing thinking skills	• An obvious focus on understanding and applying concepts rather than just memorization • I even liked the exam! The contextual, problem-solving nature of the questions asked was very interesting.
Lecturing	• Engaging with good examples and clear indications of what was important information • Fantastic lecturers who not only displayed obvious passion for the subject, but a genuine interest in students' learning and progress

Table 1 shows the percentages of students participating in the different formative activities. PeerWise is mainly used as a bank of revision questions, with activity peaking before each quiz and the final exam (results not shown). Most students do not write questions unless some incentive is given, so we have set a minimum requirement of four questions and four meaningful comments for eligibility for a more advanced form of the course required for some degree programs, which results in students generating around 200 new questions each semester. In common with many universities, lectures are recorded and attendance declines over the semester, limiting exposure of students to peer instruction (although the questions are made available online). In the second half of the semester, we retain a core group of students who attend and appreciate the peer instruction opportunity (Table 2). PAL associated with the lab program is well attended, with almost double the proportion of the class attending compared to the first-year biology PAL program. This suggests that it is meeting a student need, most likely associated with the greater complexity of the lab program. What Table 1 also shows, however, is that we are not reaching all students with any activity. Although we do not have good data on who does not participate, it is likely that there is a minority of students who do not engage with any of the opportunities provided.

We have substantial qualitative feedback on these activities from students, through the institutional student surveys, our own PAL surveys and the extensive bank of comments on PeerWise, which are surprisingly informative about student attitudes to learning. Course surveys include an open-ended question: “What is the best thing about this course?” We have conducted a thematic analysis of answers to this question from the last three years to find out what students value and the reasons they give for doing so. The resulting themes, illustrated by exemplar comments (Table 2), indicate that many students recognize and value our efforts to integrate opportunities for formative assessment and feedback throughout the course, including the peer-led activities. The comments for the first three themes demonstrate that students are accepting responsibility for developing scientific thinking skills, consistent with the relational approach of partnership in which lecturers and students work together to achieve learning outcomes (Matthews, 2016). In addition, they demonstrate enhanced metacognitive awareness of the nature of learning tasks and the need to practice them, another recognized benefit of partnership strategies (Bovill, Cook-Sather, Felten, Millard, & Moore-Cherry, 2016).

One of our goals with PeerWise was to engage students as partners in the design of assessment. Such democratization of assessment can be challenging but has benefits in improving students’ assessment literacy (Deeley & Bovill, 2015; Healey, et al., 2014). While students valued answering questions, we saw less evidence that they recognized that writing questions was a good learning experience. They did, however, evaluate questions in ways that showed that they (a) recognized the value of applying and analyzing knowledge and (b) truly became our partners in their more critical evaluation of question design. Both outcomes are illustrated by the following PeerWise comments:

> Awesome question! I love the fact that it's a hypothetical question, which means you have to really think about the answer rather than be able to look it up.
>
> I really liked how this question involved a bit of puzzling together.
>
> This question is more about memorising the facts presented in the lectures, rather than getting us to think about the content and apply problem-solving skills.

A successful partnership should result in students taking ownership of course content (Healey, et al., 2014). We see this illustrated in the degree to which creativity and humour are used in PeerWise questions (something the lecturers also model). One year, several student-generated questions featured Dr. Dimwhitt, who was “somewhat clever but not very clever” and therefore needed help in designing experiments or analyzing data. We picked up on this for the exam and used Dr. Dimwhitt questions from PeerWise as well as adding some of our own. Another PeerWise question used for the exam began, “An intron and an exon walked into a bar,” leading to a scenario that addressed the potential functions of introns. Not only do students use the course material creatively and playfully, but they also extend it, for example, by writing questions based on alternative experiments or outcomes for the lab project or, more rarely, an interesting scenario from the primary literature.

When we first introduced the lab project, there was some negative feedback from students whose prior experience was mostly labs that could be completed in three hours with a clear (and expected) result. Surveys indicated that this had led to a view of labs where the most important thing was to follow instructions in order to achieve the correct result. Many students were not seeing labs as answering questions or as modeling the scientific approach. We introduced PAL to support students in coming to terms with these issues and to help them understand the importance of critically evaluating both the data obtained and the experimental design. We aimed to engage students as partners in the scientific enterprise, firstly by emphasizing that we also did not know which mutants would be isolated and secondly by working with peer mentors to design and present study sessions. Student mentors form another component of our partnership strategy as we aimed to create a learning community (Healey, et al., 2014) with mentors reflecting on and sharing their responses as peers to the lab project. Our surveys of students attending PAL show many develop a more sophisticated and appreciative understanding of the way that science is done, as indicated by the following comments:

> Showed us how research is flexible and has different explanations.
>
> You need to think out of the box in order to draw a good conclusion because the results lead to multiple possibilities.
>
> Interpreting data and drawing conclusions is useful for determining what isn't yet known and finding opportunities for further investigation.

SUMMARY AND IMPLICATIONS

Our course has been designed to engage students as partners in multiple ways: through co-creation of assessment questions, taking ownership of the content, and using it productively to apply and analyze course material. Feedback from students indicates this approach supports them to take greater responsibility for their own learning as they develop better assessment literacy and become more able to think scientifically.

One concern is that not all students participate (Table 1) despite our use of multiple modalities: in-class, online, and targeted sessions. We suspect that many of the non-participants are the students who most need support. Although student survey results are mostly positive, the negative comments suggest that some students are overwhelmed by the content, prefer to learn by rote rather than apply knowledge, and do not understand the potential benefits of peer learning. These responses are indicative of students who do not yet operate as self-regulated learners (Zimmerman, 2013) but are reliant on authority to provide correct answers on an individual basis. Reaching and assisting these students remains a challenge. The nature of a partnership is that it is entered into voluntarily and that both parties have responsibilities. We can provide well-designed and relevant opportunities for formative feedback and a learning environment that values student input, but we cannot force students to take advantage of these opportunities. Institutional and other challenges associated with the introduction of partnerships are well-recognized (Bovill, et al., 2016; Healey, et al., 2014) and a culture shift in the higher education landscape may be required to change student expectations.

One way in which all students benefit, however, is through improved teaching resulting from our partnership with those students who do engage and the PAL mentors. We value the idea of multilateral feedback advocated by Boud and Molloy (2013) in which instructors are positioned as receivers of feedback from students (Figure 1). We find that PeerWise and peer instruction provide valuable insights into student thinking, through comments and responses, for example, where most students get an in-class question incorrect or where a misleading question on PeerWise is highly rated. These examples illustrate another aspect of partnership—the exposure of lecturers' implicit assumptions (Healey, et al., 2014)—and provide opportunities for lecturers to share their own learning journeys with the class. The cycles of PAL session design and implementation with new mentors each year provide another opportunity to learn from students and improve the course. Thus, the partnership appears to be positive for students, who are taking greater control of their learning; PAL mentors, who gain leadership experience; and lecturers, who remain engaged with teaching as an intellectual exercise.

This research has been approved by the Australian National University Human Ethics Research Committee.

NOTES ON CONTRIBUTORS

John Rivers *first enjoyed the molecular genetics course as an undergraduate, subsequently helping to establish and run the course's PAL sessions. He has remained engaged with the course, helping evaluate student feedback, whilst completing his PhD in Plant Sciences at the Research School of Biology, ANU.*

Aaron Smith *graduated from the Australian National University in 2016 with a Bachelor of Genetics specialising in Plant Sciences and will begin a PhD in 2017. He has been a PAL mentor in first and second year biology courses since 2014.*

Denise Higgins *is an educational developer with extensive experience in course and program development, curriculum review and design and approaches to student-centred learning and research-led education. She has managed and participated in several education research projects on high order thinking skills and reflective practice in STEM undergraduate contexts.*

Ruth Mills *was coordinator of the ANU Science Peer Assisted Learning Program from 2011 to 2014, while also studying for a PhD in physics education research.*

Alex Maier *is a molecular parasitologist and applies functional genetics approaches to dissect the malaria parasite. His educational interests lie in conveying the excitement, challenges and*

benefits of the scientific method and how best to communicate the intrinsic aspects of it. He co-convenes the molecular genetics course with Susan.

Susan Howitt *is a biochemist with an interest in educational research. She is especially interested in research-led education and how students understand research and the nature of science. She co-convenes the molecular genetics course with Alex.*

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