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Undergraduate students as co-producers in the creation of first-year practical class resources

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ABSTRACT

Undergraduate students are increasingly working with academic staff to evaluate and design teaching materials in Higher Education, thereby moving from being passive consumers of knowledge to genuine partners in their education. Here we describe a student partnership project run at the University of Cambridge, which aimed to improve undergraduate biology practical class teaching. Student interns were recruited to act as researchers, pedagogical consultants and producers of teaching resources. Research by the interns revealed that students with limited practical experience at high-school level tended to have lower confidence and more negative responses to first-year university practical classes than peers with more experience. Interns and academics therefore redesigned the workflow for practicals to include online pre- and post-practical tutorials to support understanding and consolidation of laboratory-based material, which included student-produced quizzes and videos. We reflect on the process of building the partnership, and explore the value of partnership approaches in Higher Education.

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Student partnership; students as producers; students as researchers; practical classes; online resources

Introduction

Student engagement has become a key theme in Higher Education, with institutions increasingly focusing on the need for students to be actively involved in their own learning. The 'students as partners' model has been proposed as a mechanism to move students from being passive consumers of information to making an authentic contribution to their own education (Healey, Flint, & Harrington, 2014; Wenstone, 2012). Partnership goes beyond traditional models of engagement with students, becoming a genuine collaboration between an institution and the student, which involves both joint ownership and joint decision-making (Bergmark & Westman, 2015; Healey et al., 2014). Student partnership can take many different forms, with students potentially being involved in aspects of learning, teaching and assessment, subject-based research and inquiry, scholarship of teaching and learning, or curriculum design and pedagogic consultancy (Healey et al., 2014). There can be significant

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gains in developing partnerships for both students and staff in terms of engagement, awareness of alternative viewpoints and an increased willingness to adopt collaborative approaches to education (Cook-Sather, 2014a, 2014b; Cook-Sather & Luz, 2014). One model of partnership is that of 'student as producer', where students go from consuming teaching resources to creating them, working alongside staff to design and deliver aspects of the course (Neary & Winn, 2009). This approach recognises that undergraduates are experts in their own student experience, and can therefore provide a valuable perspective on both the content and presentation of teaching materials (Cook-Sather, 2010; Healey et al., 2014; Neary & Winn, 2009). Cook-Sather (2014b) has described student partnership as a '*threshold concept in academic development*' due to the '*troublesome, transformative, irreversible, and integrative*' nature of this approach. Genuine partnership requires the asymmetric relationship between students and teachers to be challenged and changed (Bergmark & Westman, 2015), with the contributions of both parties being respected and valued.

Here we present the 'Bridging the Gap' project, a student partnership initiative that aimed to improve first-year biology practical class teaching at the University of Cambridge. Laboratory practicals are a key component of a science degree, providing students with an alternative perspective on their theoretical knowledge as well as developing technical skill. It has long been recognised that the university practical class environment places high cognitive load on the student, as they must simultaneously assimilate information from a number of sources, use unfamiliar equipment and develop a conceptual understanding of the experiment (Adams, 2009; Johnstone & Wham, 1982). There are concerns about decreasing exposure to practical work in school, resulting in a lack of confidence and skill in first-year undergraduates (Adams, 2009; Whittle, Pell, & Murdoch-Eaton, 2010). Lack of confidence or familiarity with the laboratory environment also contributes to a difficult transition into university practical classes (Collis, Gibson, Hughes, Sayers, & Todd, 2015).

Pre-practical resources have been successful in increasing student preparedness and confidence regarding practical work in a number of different institutions (Cann, 2014; Jones & Edwards, 2010; Whittle & Bickerdike, 2014). These resources are usually produced by academic staff for use by students, and typically consist of short videos, quizzes or short exercises to be completed before the practical, hosted on the course Virtual Learning Environment (VLE). However, academics may make incorrect assumptions about the needs of students, and producing resources may also incur significant time costs for staff. The 'students as producer' model is therefore a potentially attractive way of developing resources and has been successfully used in geography, education and physical sciences courses (Bovill, 2013; Woolmer et al., 2015).

Here, we describe the implementation and our experiences of an academic-student partnership project to develop pre- and post-practical resources for first-year practical classes taught by the Department of Plant Sciences and Department of Physiology, Development and Neuroscience. This partnership involved two academics (KEH and MJM) and four students (SD, MPG, RB, MP), all of whom are authors of this manuscript. To reflect the nature of the partnership, throughout this manuscript 'we' refers to all student and staff members of the project team unless otherwise stated. Where necessary, during the description of the project implementation we refer to 'the interns' or 'the academics', or use initials to identify individuals. This is not intended to undermine the collaborative or inclusive nature of the project, but may help others to clearly understand the allocation of roles and tasks between

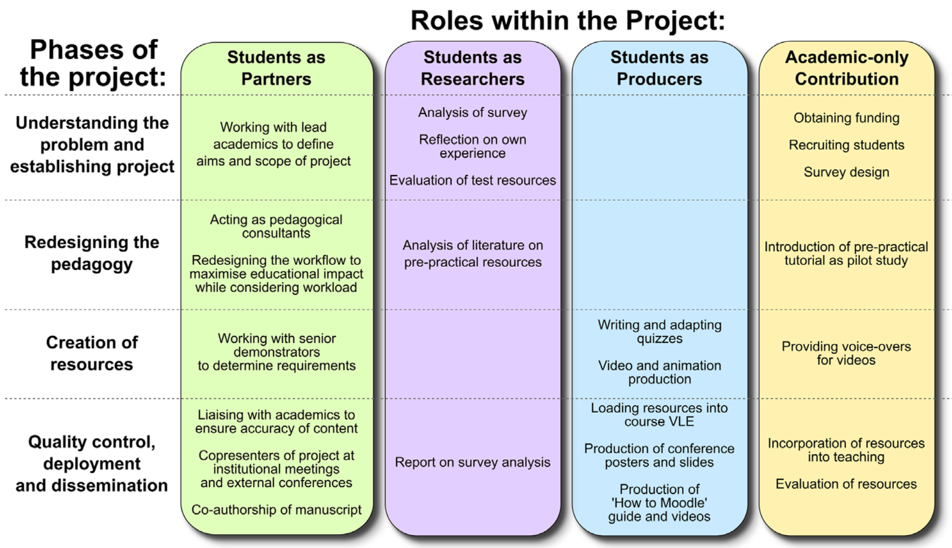

Figure 1. Student partnership approaches that were embedded throughout the project. The project was divided into four main phases (although the boundaries between these were relatively diffuse), as indicated on the left hand side and described in the text. Activities of students within the project fell into three general categories: acting as partners or pedagogical consultants, acting as researchers and acting as producers. Specific roles of the student and academic partners described in the text are aligned here with the four phases of the project.

student and academic partners within our work. We identify our reflections on the project as being either from students or academics, but present the direct quotations anonymously.

Implementation of the project

The academic partners obtained funding from the University of Cambridge Teaching and Learning Innovation Fund to support four undergraduate internships for 10 weeks over the long summer vacation. An advertisement for summer studentships was sent to the first- and second-year class email lists, with applicants asked to provide a CV, a short covering letter and a letter of recommendation from their tutor. Six students applied, five of whom attended a short interview to discuss the project and four from this group were appointed. Three of the students had just completed the first year, and one had just completed the second year. All of the students had completed at least one of the two relevant courses (Natural Sciences Tripos part 1A Biology of Cells and Physiology of Organisms). Interns were selected on the basis of enthusiasm for the project, existing skills (e.g. video editing) and/or an interest in teaching or education. The interns were allocated office space and computers in the Department of Plant Sciences, and were provided with all course materials and Senior Examiner reports, as well as relevant library and online resources and the departmental video camera. One intern chose to bring in their own computer so that they could use software which they were familiar with (Adobe Premiere Pro CS5 [2010], Apple Logic Pro 9 [2009], Adobe AfterEffects CS5 [2010]). We coordinated the project through a dedicated site on the course Virtual Learning Environment (VLE; Moodle Version 2.8, released 2014), with interns reporting their progress through regular blog posts and the creation of a documentation wiki. We held a project meeting once a week, where interns presented their work and ideas for improvement and further resources were discussed. Interns also met informally with one or both of the academic partners on most days, to ensure smooth running of the project.

Conceptually, the project was divided into four broad phases: (1) Understanding the problem, (2) Redesigning the pedagogy, (3) Creation of resources and (4) Quality Control, Deployment and Dissemination. These phases overlapped to some extent and were not formally defined, so that the project could evolve naturally. We acted as partners in all four phases, and student interns played a variety of different roles at different stages of the project (Figure 1).

Phase 1 – understanding the problem

Before the interns started working on the project, KEH designed a survey to investigate how first-year students experience practical classes. The online survey was sent to students who had just finished their first academic year, and who had taken the Biology of Cells and/or Physiology of Organisms courses; 102 students replied to the survey, representing a 32% response rate. At the start of the project, the interns were asked to analyse the survey data so that we could better understand the needs of the wider student body, and also to provide a perspective on the data other than that of academic staff. The survey asked students about their school backgrounds and how often they performed seven different aspects of practical work while studying for their A levels or equivalent qualifications (Table 1). We used these data to determine a 'practical experience score' for each student. The frequency of performing each aspect was given a score from 1 to 4 (1 = Never, 2 = Once or twice in the whole course, 3 = Once or twice a term, 4 = Every week), then these were added together to give an experience score of between 7 and 28. We then grouped students into 'low' (scores of 11–17, $n = 32$), 'medium' (18–22, $n = 40$) and 'high' (23–27, $n = 30$) levels of experience for further analysis. There was a significant relationship between school type attended and practical experience score (Kruskal-Wallis H = 13.26, d.f. = 2, $p = 0.001$**). 46% of the UK state (publicly funded) school students fell into the 'low' practical experience group, compared with only 16% of the UK independent (fee-paying/private) school students and 13% of the international school students (Figure 2(A)). We observed this trend for all seven aspects of practical work, with students from independent schools being consistently more likely to report regular engagement in practical activities (Table 1). With the exception of light microscopes, most pieces of laboratory equipment used in first-year practicals were unfamiliar to the majority of the class (Table 2).

Given the diverse levels of practical experience within the cohort, we wanted to see if there was a relationship between level of prior experience and confidence in first-year university practicals. The survey asked students to reflect back and rate their confidence regarding practical work at the start of their university course. Students with limited levels of practical experience were more likely to report low confidence levels, with 50% of those in the 'low' experience group describing themselves as 'Not at all confident' (Figure 1B; Kruskal-Wallis H = 6.647, d.f. = 2, $p = 0.036$*). Despite the relationship between school type and practical experience, there was no relationship between reported confidence level and

Table 1. Levels of practical experience gained by first-year students before university.

During your A levels or equivalent, how frequently did you do the following?		Never	Once or twice in the whole course	Once or twice a term	Every week	Total	Kruskal-Wallis H	Degrees of Freedom	*P*-value
Performing lab experiments	State	2	3	26	23	54	9.38	2	0.009**
	Independent			11	21	32			
	International		3	7	5	15			
Designing own experiments	State	27	22	5		54	16.90	2	<0.001**
	Independent	9	16	7		32			
	International	4	5	6		15			
Analysing experimental data	State	3	12	21	18	54	14.04	2	0.001**
	Independent		4	8	20	32			
	International		2	8	5	15			
Drawing conclusions from data	State	1	16	20	17	54	11.41	2	0.003**
	Independent		3	9	20	32			
	International		1	9	5	15			
Calculations based on data	State		14	23	17	54	17.33	2	<0.001**
	Independent		5	7	20	32			
	International		2	7	6	15			
Performing statistics on experimental data	State	14	26	13	1	54	15.56	2	<0.001**
	Independent	3	12	12	5	32			
	International	2	4	7	2	15			
Writing up experiments	State	11	25	14	4	54	16.66	2	<0.001**
	Independent	3	11	12	6	32			
	International	1	4	9	1	15			

Notes: First-year biology students were asked to report how often they had performed various aspects of practical work during their A-levels or equivalent qualifications. 'State' includes all *publicly funded* school types in the *UK* (Sixth form college, Grammar, Comprehensive, Academy and Further Education college). *Independent schools include all private or fee-paying schools.* 'International' schools were those outside the UK, which may or may not have demanded fees from students. Kruskal–Wallis tests were performed to test for differences in frequency of experience between students from different school types.

**Indicates significance at $p < 0.01$.

school type (Figure 1(B)), indicating that frequency of exposure was the primary determinant of confidence with practical work.

To explore emotional responses to practical work the survey asked students to identify three words to describe how they felt about practical classes, from a list of 12 adjectives (Table 3). The most popular words were 'Interesting' (68%) and 'Challenging' (48%). However, 28% of students described the practicals as 'Stressful', and 29% as 'Confusing'. In subsequent analysis, we allocated words a score of 1, 0 or −1 to reflect positive or negative emotional responses, and the total 'emotional score' for the three words chosen was calculated (Table 2). There was a significant relationship between the level of practical experience and the emotional score (Figure 1(C); Kruskal Wallis H = 13.31, d.f. = 2, $p = 0.002$**), with students in the 'low' experience group being more likely to use the words 'Overwhelming' and 'Stressful', thereby obtaining a negative score. Students from state schools also tended to use more negative words to describe the practical class environment (Figure 1(C)), however this result was not statistically significant (Figure 1(C); Kruskal Wallis H = 5.80, d.f. = 2, $p = 0.055$). The survey therefore indicates that low confidence in university laboratory classes is primarily a function of limited frequency of exposure to practical work, and is not directly a result of the school type attended. The survey also asked students 'Briefly describe which aspects of practical classes you have found most challenging this year' as an open-ended question. The three most common responses were associated with time management

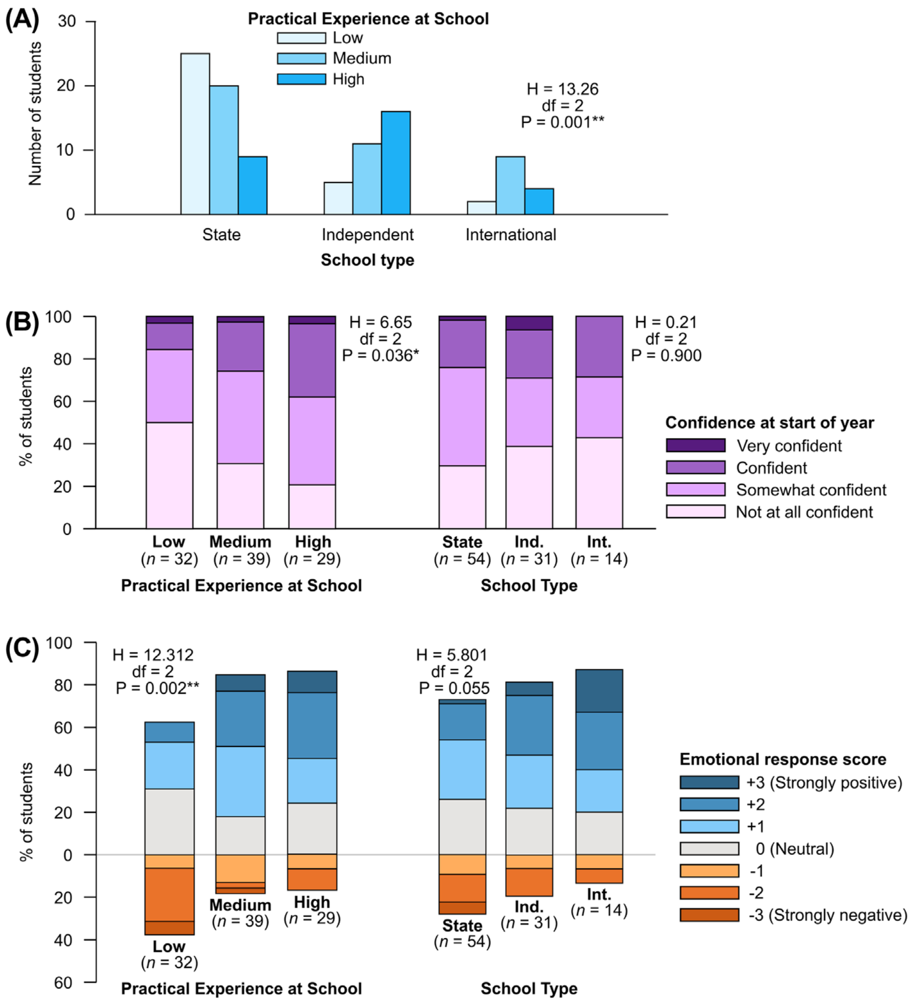

Figure 2. The experience and attitudes of students from different educational backgrounds, with reference to first-year university practical classes. Surveys were sent to first-year biology students at the end of the year; 102 students responded representing a 32% response rate. (A) The level of practical experience students have at school is a function of school type (see also Table 1 for details of practical experience). (B) Student confidence with practical work at the start of the academic year is a function of prior practical experience but not of school type. (C) Emotional responses to practicals are a function of prior practical experience but not of school type.

(n = 19), calculations (n = 15) and lab reports/write-ups/questions (n = 15), however no individual concern was mentioned by more than 20% of the respondents (n = 102).

Phase 2 – redesigning the pedagogy

After analysing the survey, the interns were asked to reflect on their own experiences of practical classes, and to identify where they felt resources would be best targeted. The survey had suggested that there was no specific skill gap that needed to be addressed, but rather a more general unease with the laboratory environment and new equipment experienced

Table 2. Laboratory techniques encountered in first-year biology practical classes, and the percentages of students already familiar with them.

Technique or piece of equipment	% of students who had not seen the technique before (n = 94)
Light microscopes	12
Dissections	49
Spectrophotometers	50
Gilson pipettes	52
Sterile culture techniques	58
DNA electrophoresis tanks	61
Centrifuges	64
PCR machines	80
Restriction enzymes	84
Protein electrophoresis tanks	89
Oxygen electrodes	92
Fluorescence microscopes	93
Protein structure webtools	95
ECG equipment	96
PowerLab (data acquisition hardware)	97
Electrophysiology equipment	98

Table 3. The variety of different emotional words used by students to describe their experience of first-year practicals.

Word	% of students selecting word (n = 101)	Associated score
Interesting	68	+1
Challenging	48	0
Stimulating	35	+1
Demanding	32	0
Confusing	29	−1
Stressful	28	−1
Boring	19	−1
Exciting	13	+1
Relaxing	13	+1
Difficult	10	0
Overwhelming	7	−1
Easy	6	0

Notes: Each student was asked to select three words from a list, which appeared in a random order for each student. Words were scored independently by KEH and the interns: words with a score of 0 were either neutral or were words that could be interpreted as either a positive or negative experience, while scores of −1 and +1 indicated negative and positive emotions respectively. This was used to calculate an overall 'emotional response' score for the three words chosen by each student, which could vary between −3 and +3.

in particular by those with limited prior exposure. We therefore considered optional pre-practical tutorials to be an appropriate intervention. This would give all students who felt the need for more background an introduction to the techniques involved in the class, and a better sense of the goals. This might increase confidence, reduce stress levels and also reduce the amount of time spent waiting for help with simple operational tasks within the class itself, thus helping students to use the time in the laboratory more effectively (Cann, 2014; Jones & Edwards, 2010; Whittle & Bickerdike, 2014). Pre-practical resources have also been shown to increase student confidence with practical work (Whittle & Bickerdike, 2014). However, pre-practical resources alone would not tackle the problems some students experience with calculations and post-laboratory work, suggesting that additional consolidatory resources may be required.

The interns identified a number of different theoretical concepts and practical techniques that they felt would be good targets for pre-practical support, including polyacrylamide gel

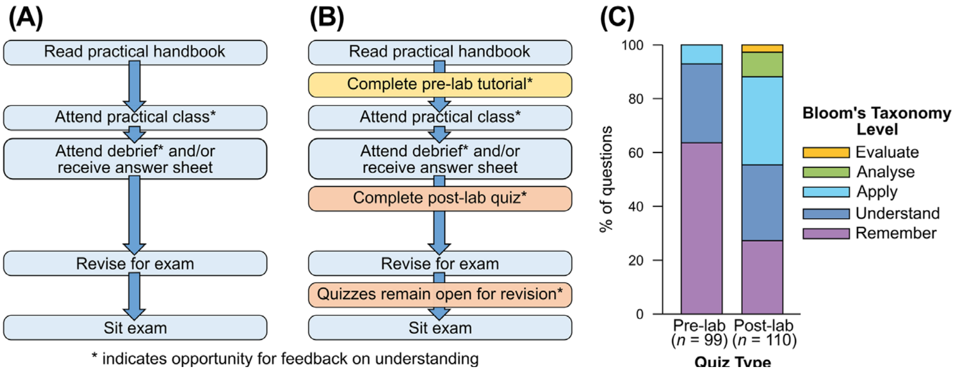

Figure 3. A revised workflow model for first-year practical classes incorporating pre- and post-practical resources. (A) The original workflow model, which contained little opportunity to prepare or consolidate material for the practical class. (B) The revised workflow model, including pre- and post-practical resources. Boxes in yellow were proposed by academic staff, boxes in orange were suggested by the student interns. * indicates opportunities for feedback on understanding. Note that in both models students also receive weekly small-group tutorials in which they are encouraged to discuss practical material if they or the tutor so wish, but no central departmental resources are provided for these tutorials. (C) The two quiz types test understanding at different levels. Questions were classified according to Bloom's Taxonomy by the student interns and academic staff.

electrophoresis, serial dilutions and the polymerase chain reaction. They also identified that there were currently few opportunities for post-practical consolidation, and that there was relatively little opportunity for feedback on some practicals after the laboratory class had finished. As one intern put it '*There is a need to bridge the gap between school and university, but there is almost another gap to be bridged between the practical and the exam*'. This need had not been anticipated by the academics involved, demonstrating the benefits of working in partnership with students in considering pedagogical strategies. We therefore designed a new workflow model for laboratory classes which included both pre- and post-practical resources (Figure 3(A,B)). This was designed by the interns in partnership with KEH and MJM, and then the interns liaised with individual senior practical demonstrators to determine a way in which the model could be used effectively for each practical. It should be noted that it was outside of the scope of the project to change the practicals themselves, or to change the terminal examination assessment structure.

The interns felt that immediate feedback on understanding would help considerably in both the preparation and consolidation processes, so automated feedback on quizzes was incorporated into resource design. The potential for high-quality automated feedback makes online quizzes particularly attractive when working with large class sizes (Ferrara & Butcher, 2012; Voelkel, 2013), and the interns could immediately see the advantages that this would bring. We considered it important that additional resources should not significantly increase student workload, so pre-practical tutorials were designed to take 15–30 min each, including watching the relevant videos. We decided that each quiz should contain no more than eight questions, which should include a mixture of questions to test fundamental understanding and application of the knowledge gained. We designed pre-practical quizzes to be completed by all students to give a good understanding of the material which they would encounter in the laboratory, whereas the post-practical quizzes contained more complex questions to challenge the students and increase their depth of understanding. Participation in the quizzes would be optional and would occur in the students' own time, and marks would not be collected in by the academics.

Phase 3 – creation of resources

We decided that the resources created should be as consistent as possible across practicals, therefore all 14 first-year practicals delivered by the two participating departments were selected for student-produced resource development. This represented 11 out of 12 practicals on the 'Physiology of Organisms' course, and 3 out of 12 on the 'Biology of Cells' course (the remaining laboratory classes were run by departments which were not involved in the funded project). KEH, MJM and the relevant practical class organisers checked the resources for errors and quality on a regular basis. Three of the interns primarily focused on writing quiz questions, while one mainly focused on video editing and animation, although there was flexibility in task allocation depending on the skills required and stage of the project.

The interns created supporting videos where we felt they were appropriate; for some practicals there were multiple videos while for others no video was deemed necessary. 14 videos were created in total, each focusing on a different aspect of the practicals. Some videos (e.g. use of Gilson pipettes) were appropriate for more than one practical, and so were designed to be stand-alone. Others were more closely aligned to a particular practical, explicitly linking the theory to the specific activity. For example, in the video on polyacrylamide gel electrophoresis the properties of the protein of interest were discussed so that students could clearly understand the link between the technique and the results expected in the laboratory class. Scripts for the voice-overs were written and recorded by KEH and MJM as the interns felt that they did not have sufficient knowledge to convey the relevant information, and it was felt that the resources may command more respect from students if they appeared to be produced by the academic team. The interns then edited the voice recording to give a high audio quality in Logic Pro 9, and animated the content or edited live-action footage using a combination of VideoScribe, After Effects CS5, Premiere Pro CS5, and iMovie 10. We decided on the presentation style in collaboration, where a balance was struck between an informality of tone which was valued by the students, and high production quality which was important to the academics. For some videos, live footage was used to link an animated theoretical presentation to the laboratory activity. We met regularly to review the content of the videos, from the perspective of academic content and production quality. Finished video files were uploaded to the University of Cambridge Streaming Media Service (www.sms.cam.ac.uk), from where they could be inserted into the VLE.

For each of the 14 practicals we wrote a pre- and post-practical quiz using the Moodle quiz construction tools. A total of 202 quiz questions were written by the interns in collaboration with the academics. The quizzes for each practical contained 5–8 questions each, and used a variety of formats including multiple choice, numerical and matching answers. We designed quiz questions to include instantaneous feedback on both correct and incorrect answers, with hints being given if a student gave an incorrect or partially incorrect answer. The type of automated feedback provided can have a significant impact on the depth of student understanding, with deeper learning occurring when feedback identifies conceptual misunderstandings and provides suggestions for how to improve understanding (Ferrara & Butcher, 2012). We therefore wrote feedback prompts in the form of hints rather than simply giving the correct answer. At least half of the quiz questions were written from scratch by the interns, working in collaboration with academics where required. Other quiz questions were based on pre-existing problems in worksheets or practical guides. The interns used their own experience to identify common student mistakes in answering these questions, and then wrote hints and feedback comments which could be revealed to students depending on the answers that had been provided. The interns thereby anticipated likely mistakes and provided instant feedback via the VLE, increasing the pedagogical value of existing resources.

The interns were introduced to Bloom's Revised Taxonomy (Anderson, Krathwol, & Bloom, 2001) so that they could consider the underlying pedagogy in resource design, particularly through designing questions that addressed higher levels of the Taxonomy, to increase educational impact. This taxonomy was selected as it is relatively easy for undergraduates with minimal pedagogical expertise to understand and implement, and has been used by biology undergraduates at other institutions to increase student metacognitive development (Crowe, Dirks, & Wenderoth, 2008). The interns scored each quiz question for which level of Bloom's Revised Taxonomy was being used, mainly on the basis of the verb used in the question. We then worked in partnership to increase the educational benefit of the questions, turning questions that had focused on remembering or understanding into questions in which students were asked to make predictions or interpret experimental data. Some of the interns found this challenging, and required significant academic input at this point as their own knowledge was somewhat limited (see Discussion). After revising the questions, 12% of pre- and 44% of post-practical questions were classed as either 'Apply', 'Analyse' or 'Evaluate' (Figure 3(C)). Pre-practical questions were therefore more focused on retaining information that would be required in the cognate laboratory class, whereas post-practical questions were more focused on applying the knowledge gained in the class to unfamiliar situations, thereby allowing consolidation and promoting depth of understanding.

Phase 4 – quality control, deployment and dissemination

Towards the end of the summer vacation we recruited 13 student volunteers to test the resources; these came both from the friendship groups of the interns and from a call for volunteers sent to the first-year class list. Volunteers were given a pizza voucher if they completed at least three quizzes and filled in a short feedback survey to give their opinions on the resources. 11 out of the 13 students said that the resources would be 'Quite useful' or 'Very useful' for helping first-year students prepare for practical classes. Comments from student volunteers indicated that the resources had been well pitched:

> The feedback given once every question was answered is particularly useful in my opinion, whether it corrects a wrong answer or consolidates a correct one.

> Will help students to check whether or not they understand the theory behind the practicals, and how to use the equipment. This will then save time during the actual practicals, making them less stressful.

The interns corrected technical or factual errors identified in consultation with the academics. One suggestion that came from the testing period was to make the number of attempts for each question unlimited, rather than the single attempt that had been allowed in the tests:

> Most questions only let you have one attempt, which was just a little bit frustrating as I don't want to be given the answer after only one try!

The interns then imported the resources into the relevant course sites for the forthcoming academic year, having learned how to do this directly from Moodle support staff. The interns thereby became technical experts as well as producers, reducing the burden on academic and administrative staff for the duration of the project. The interns wrote a 'How to' guide containing technical documentation on setting up quizzes, and produced four videos on Moodle quiz-making; these are now hosted on the University internal website for other departments to access. MJM has since used the guide to create pre- and post- practical quizzes to cover an additional first-year subject on the Medical & Veterinary Sciences course, demonstrating the impact of the technical expertise gained by the students and the usefulness of the training material that they provided.

Our interns have been, and continue to be, involved in the dissemination of the project, either acting as co-presenters or as presenters of the work in their own right. Dissemination has been in a variety of forms including poster presentations, oral presentations at institutional meetings and conference presentations. The interns were responsible for creating the project Moodle site which has been used to demonstrate quizzes and videos to other members of the university. As co-authors of this paper, they gained a number of authentic dissemination experiences, from which undergraduates are often excluded (Spronken-Smith et al., 2013; Walkington, 2015).

Evaluation of the project

Evaluation of students as producers of projects requires both the *product* and the *process* of the partnership to be considered (Woolmer et al., 2015). The impact of pre-practical and online resources on student understanding and confidence has been considered extensively by many others (Cann, 2014; Jones & Edwards, 2010; Voelkel, 2013; Whittle & Bickerdike, 2014), so we will not attempt systemically to evaluate the pedagogical benefits of the video and quiz resources here. To analyse the products of the partnership we present usage data collected from the VLE, while we evaluate the process of partnership through a structured reflection from both student and staff perspectives.

Use of the resources themselves (i.e. the products of the partnership)

The student-created resources were deployed into the relevant first-year courses (Biology of Cells and Physiology of Organisms) for the 2015–6 academic year. 26 videos were made available, including some created by academics prior to the student partnership project. Of these, twelve videos were relevant only to Biology of Cells, ten to Physiology of Organisms and four were relevant to both courses. There were 6884 video hits over the course of the year, 1584 of which were for academic-produced videos and 5300 for student-produced videos, the latter representing 77% of the total video usage (Figure 4(A)). A total of 308 students were enrolled across the two courses (294 on Biology of Cells, 197 on Physiology of Organisms, with 183 enrolled on both), meaning that each student watched an average of 22 videos out of the 26 available. It is likely that engagement with videos varies considerably between individuals, but we were unable to obtain this level of detail from the server records. Video resources were used throughout the academic year. In weeks where the resources were directly relevant to teaching there was high engagement, but there was also use of videos during the vacation periods and during the revision period at the end of the academic year; 12% of total video use was in the two-week examination period (Figure 4(A)).

The quizzes, hosted on the VLE as optional resources, were completed at some point during the year by 50.1% of students on average (quizzes remained open all year, and we were unable to track how many times a given student attempted each quiz). Engagement with the quizzes varied considerably across a non-normal distribution, with between 34% and 93% of students attempting each quiz (Figure 4(B)). There were higher mean quiz attempt and completion rates for the pre-practical quizzes (attempted = 69%, completed = 58%) than for the post-practical quizzes (attempted = 67%, completed = 49%) although this difference was not significant (Figure 4(B,C); Quizzes attempted: Wilcoxon signed-rank test $Z = -0.909$, $p = 0.363$; Quizzes completed: $Z = -1.647$, $p = 0.100$). Comments from students made part-way through the academic year suggest that any relative lack of engagement with post-practical quizzes may be due to workload, although other factors may also contribute:

> I find the practical quizzes helpful, in particular the pre-practical quizzes to ensure that I know what is going on in the practical. I've found that [In Lent Term] I have not had as much time to do the quizzes just before and after the practicals like I did last term. I find the calculations helpful because I find them quite challenging, especially because I didn't do A level physics which is why I find the explanations useful when I get the calculations wrong.

> I do not use the post practical quizzes. I find there just isn't time particularly with reading the debrief sheets and checking answers to any of the numerical questions set. I feel like they might be more useful when we are going through the material again during Easter.

Similar to video usage, 29% of quiz completions occurred between the last lecture of the year and the examination, indicating that students were using the quizzes as a revision aid. This may be an underestimate, as students who started their revision early are excluded from this figure. During the revision period there was significantly higher engagement with the post-practical quizzes than with the pre-practical materials (Figure 4(C); Wilcoxon signed-rank test $Z = -3.408$, $p = 0.001^{**}$), indicating that some students delayed consolidation of practical material until later in the year. Feedback from student representatives in end-of-year course management meetings supported the idea that students had found the online resources particularly valuable for revision, which validates the suggestion of the interns to have resources made available all year (Figure 3(B)). The usage patterns we observed suggest that students access pre- and post-practical resources for different purposes, and that there is variation in the way that individual students engage with online resources. For example, despite the fact that pre-practical resources were intended as tools for use immediately before practical classes, there was some use of these resources during the revision period (see Figure 4(C)), indicating that students are independently repurposing materials to suit their own needs. The factors driving this differential use would be valuable for academic staff to be aware of when considering the design and implementation of similar materials.

Variable use of online resources has been reported by others (Voelkel, 2013; Whittle & Bickerdike, 2014): some students appear to use all available resources while others barely use them unless they are required for summative assessment. It may also be that the more confident students find the resources less useful than students with limited practical experience. Alternatively, they may be mainly used by conscientious, high-achieving students, as has been reported with similar web-based formative assessment tools (Henly, 2003; Voelkel, 2013). Due to technological limitations, local examination regulations and a lack of

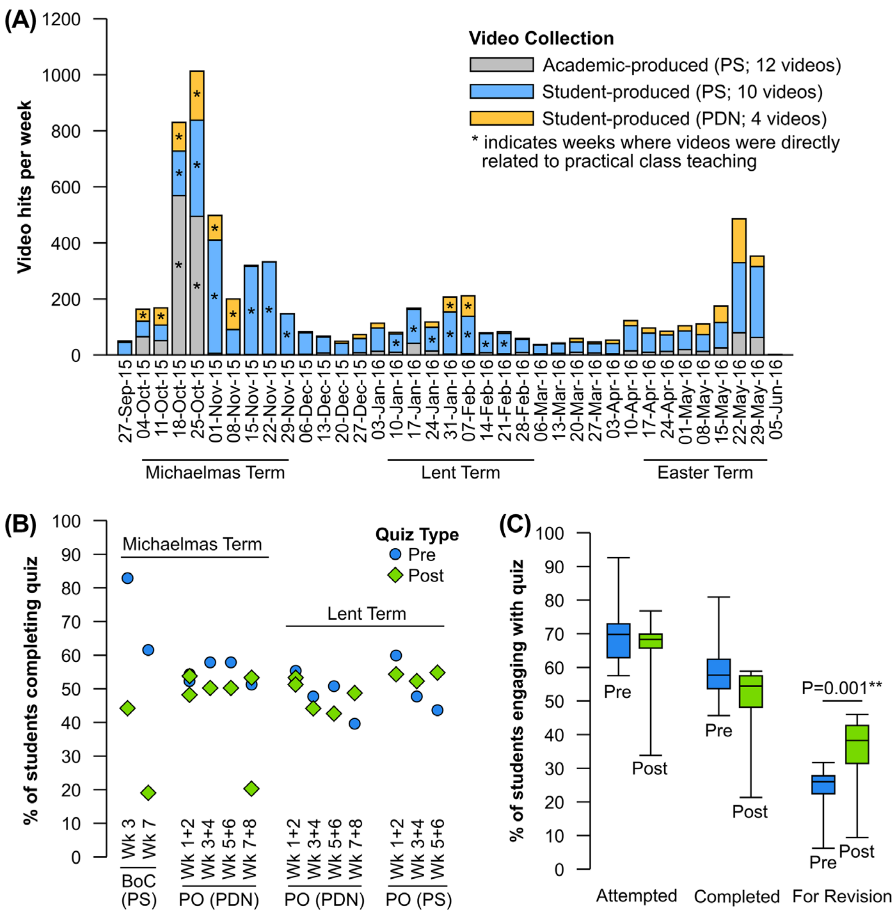

Figure 4. The use of student-produced resources throughout the academic year. (A) Use of video resources for each week of the academic year. Videos were hosted at www.sms.cam.ac.uk and were embedded in the respective course VLE sites for streaming. Academic-produced videos were made for one practical class in week 3 prior to the student partnership project, but were made available in addition to the student-produced videos. Weeks where videos were directly related to practical class teaching are indicated by *. Examinations for the two relevant courses were held on May 24th and June 2nd. Video hits are displayed separately for the departments of Plant Sciences (PS) and Physiology, Development & Neuroscience (PDN). A total of 308 students were enrolled on the two relevant courses, with 294 on Biology of Cells (BoC; taught by PS only) and 197 on Physiology of Organisms (PO; co-taught by PS and PDN). Data were collected from the statistics viewer at www.sms.cam.ac.uk. (B) Student engagement with quiz resources across the practical classes. Quiz engagement is separated for the two courses, and also for the two departments. Note that some weeks had two pre- and/or post-practical quizzes. (C) Summary of student engagement with pre- and post- practical quizzes for all practicals across the two departments in terms of attempts, completion and use for revision (defined as usage between the last day of teaching and the examination). P values indicate the results of Wilcoxon signed-rank tests (non-parametric tests were used, as there was a non-normal distribution of quiz usage). For all box and whisker plots, coloured boxes indicate the interquartile range, the solid horizontal line indicates the median, vertical lines indicate the range.

ethical process for doing this analysis, we are unable to link the VLE usage data to academic performance, so are unable to determine which groups of students are gaining the most benefit from the resources in this case. Since the introduction of the resources there have been requests for additional resources for a number of different topics, including a demand for pre- and post-lecture quizzes. Staff in other departments have also received requests for supporting online materials, so the project may have inadvertently increased pressure on academics. It is unclear whether this reflects the success of the resources, or the development of a perceived need for electronic media resources which did not previously exist.

The process of developing a student partnership

To evaluate the use of the partnership approach, we reflected on the project through an online survey consisting of a series of open-ended questions designed by KEH (responses have been anonymised here). When describing what the best thing about the project was, the academics highlighted working closely with the students, while two of the interns highlighted the level of autonomy they had been given:

> [The best thing has been] contact with an enthusiastic team of undergraduates who were implementing the project. [Academic A]

> The creativity and quality of work of the intern team [has been the best thing] …..As the interns developed more independence the project became more and more rewarding. [Academic B]

> The high degree of autonomy that we've had [has been the best thing] - we have been able to make our own decisions and shape the project quite a lot, which has been quite rewarding ……. I came back after the summer glad that I had achieved a defined goal rather than doing the admin tasks prevalent in other internships [Intern A]

> 'I really enjoyed the high level of independence. We were free to make the resources as we saw fit, after initial guidance and a few glance-overs.' [Intern B].

These two interns were able to work independently throughout the project, and needed relatively little academic input. The other two interns displayed lower levels of autonomy during the project, and one commented that they were not sure that their level of expertise was sufficient to develop new content:

> As part of this project, I felt that my perspective as a student was not sufficient to incorporate new quizzes for students - it was great to have [the academics] much wider perspective to light up the way. [Intern C]

Interestingly, Intern D displayed relatively low levels of confidence when it came to subject knowledge, but was able to work highly independently on video production due to their pre-existing skills. Intern C also became more independent over the course of the project due to their increasing skill with video production, and used the last three weeks of the project to create a promotional video for the department which has since been used at science festivals and other events.

> I got to edit [videos] and do science stuff which was so much fun. [Intern D]

> I really liked that the project extended its boundaries and I could make the short film promoting plant sciences; this was a wonderful opportunity to meet great people in the department and begin to appreciate plants more! [Intern C]

Concerns over the relative lack of subject and/or pedagogic knowledge held by students has been identified as a potential source of resistance to co-creation (Bovill, Cook-Sather, Felten, Millard, & Moore-Cherry, 2015; Croft, Duah, & Loch, 2013); this concern may be held by academics or by the students themselves. For partnership to be successful the student should not be pushed too far from their own areas of expertise (Bovill, Cook-Sather, Felten, Millard, & Moore-Cherry, 2015). In our experience, while interns were able to create resources rapidly, their lack of subject knowledge resulted in significant amounts of academic time being required to proof-read and correct student-generated questions. This was particularly true for more complex topics, for which the undergraduates did not have sufficient subject knowledge or confidence to develop resources effectively, consistent with similar partnership projects (Croft et al., 2013)

> I had to put more time into editing the quizzes and videos that were produced than I had anticipated (for one thing, editing [the VLE] was somewhat clunky). [Academic A]

> Managing the team of interns took quite a lot of time - work needed to be proof-read more than I had anticipated, and some students needed more direction than others. [Academic B]

> There are some topics which required particular nuance, such as some of the electrophysiology, where we needed a lot of support to make sure we weren't propagating any misconceptions we had. [Intern A]

This project was fairly ambitious in terms of what the interns were asked to do (particularly for those who had just finished their first year), which may have contributed to feelings of unease from some of the students and academics. In our experience it is essential to give student partners an element of choice in their work so that they feel they are making a valuable contribution even when their skills or knowledge are limited. Having a team of interns working on related projects meant that this flexibility was relatively easy to combine with producing all the required resources: this may be more difficult to achieve in projects with very small numbers of students or with overly prescriptive tasks for students to complete.

The interns also described what they thought the value of student partnership projects were. They clearly identified that while academic input was important in terms of content, having a student perspective in the design of educational materials was of great benefit. They valued having a consistent set of resources across a course taught by multiple individuals, and thought that students had a clear role in steering the presentation of material. Working on the project also made them appreciate the time pressures that academics are under, so they could see the practical advantages to having students creating resources. An increased understanding of alternative perspectives on learning and teaching is a common result of student–academic partnerships (Cook-Sather, 2010, 2014a), with both students and academics gaining greater understanding of the goals and needs of the other party.

> It gives the student the opportunity to work with academics and to better understand teaching from their perspective. The partnership also provides very good experience for working in a team towards a common goal. [Intern D]

> I think it is very important to consider the opinion of the student in developing teaching resources; however, I think the teacher should have the last word. [Intern C]

> I think that students can add their own perspectives about what might be easy or difficult to understand because they have had to use the materials that the department currently provides, and understand it purely from a user perspective which, even with the best will in the world,

> can be hard for the academic who made the materials. Furthermore, the internship model can be a good way of getting the project done; students don't have other commitments and responsibilities that they need to attend to over the summer, so they can focus on creating a single product with a streamlined and constant design both aesthetically and educationally which a more time-pressed academic might find it more difficult to do purely because of how their employment works. [Intern A]

> They are quite valuable for a project like this one, as the students will have experienced the practicals as students much more recently than the supervisor, and so for example might interpret the survey findings more accurately. Students also know what their peers are more likely to want/use as resources (e.g. a 4-min video rather than 12 pages of notes), and this is likely to change faster than the average academic is willing to adapt under normal circumstances. Therefore partnership projects are useful as the academic provides the educational content but the student can present it in a more appropriate way. [Intern B]

In contrast, the two academics had very different responses when asked what the value of student partnership projects might be:

> Largely, ticking boxes for the educationalists. It is useful getting a student perspective, but I feel that I get a lot of that through feedback and [tutorials], as well as in the practicals themselves. [Academic A]

> Education is fundamentally a collaboration, so students should be part of the design and consultation process as much as academics. Academics have a clear role in providing the structure and fundamental content, but students can play a much larger role in shaping how that is delivered, and can help to make that delivery feel more relevant to their own experiences. Students also provide a unique voice - they may not be subject experts but they are experts in being students! In this project there were things that the interns pointed out to me about our teaching strategies that I hadn't even considered. [Academic B]

Academic A did not think that the project had changed the way they thought about their own teaching, whereas Academic B reported that it had done so, and that they now wanted to embed partnership approaches in their teaching much more widely, including to get students acting as producers routinely within modules. Student partnership has been described as a threshold concept in academic development, which requires the fundamental roles of teacher and student to be reconsidered as well as an emotional shift within the academic (Cook-Sather, 2014b). In our case, one academic had crossed that threshold and wanted the partnership approach to be fully integrated in their practice, whereas the other saw limited value of the approach for their own teaching. It should be noted that first-year teaching in Natural Sciences at Cambridge involves a larger proportion of contact hours than equivalent programmes elsewhere (42% compared with 28–39% of course time; Unistats.direct.gov.uk, 2016), and involves weekly small-group tutorials (2 or 3 students with one academic member of staff). It may be that in the context of this level of staff–student contact a formal partnership approach has less value to academic staff than in institutions with more limited staff-student interaction.

We reflected on whether the use of student partnership projects in Higher Education should be extended. The interns could clearly see the value of the type of project that they had done, and thought that it should be extended across other first-year practical classes. Interestingly, we were all more cautious about extending the approach across Higher Education in general, and thought it was important that balance was maintained:

> I think all of the practicals could benefit from approaches such as the one of this project, particularly as students are very rarely supervised on practical work, and often only at their

> request. Similarly, it would be great to extend short quizzes or animations to cover all lecture content; whilst this would require a much greater effort to develop and adapt each year, I think it would be an effective tool for students in consolidating understanding of and being able to recall lecture content, perhaps in some cases more so than writing an essay. [Intern B]

> The student partnership tool is useful for particular kinds of one-off project - I don't think that it's intrinsically beneficial for HE generally, but with some careful management and recruitment it could be a good way of getting these slightly more labour-intensive projects completed so long as the task is well-defined without being monotonous or trivial. So it's something which I can imagine will become more used in future years, but it has to be a carefully selected tool rather than being used because it's the next fad in HE or it will lose its usefulness. [Intern A]

> Yes [the use of partnerships should be extended], but it should be a genuine partnership - being entirely student-driven has as many potential problems as being entirely academic-driven. Both sides have valuable perspectives and expertise to bring, but a balance needs to be struck between them in order to create academically rigorous educational experiences that students feel that they are able to make a genuine contribution to. [Academic B]

> It is always useful getting in a team of students to help with a time-consuming project, especially where much of the work is fairly routine computer-based programming. However, I think that there is a danger in letting students have too much impact into a course. They lack the perspective that comes with experience, they may lack perspective on the ability level of the year-group as a whole, and there is a risk that they will create resources to make things easier, rather than to improve the academic quality of a course (which may actually require increasing the independence of students by reducing the amount of course-related material). [Academic A]

There are concerns about the inclusivity and scale of student partnerships (Bovill, 2013; Healey et al., 2014) which are applicable to this project, as it only involved a small number of students who were paid for their contributions. The interns involved described a significant impact on their own learning, which was not available to the wider student body:

> It has made me realise that I need to be more inquisitive in regards to my learning and think more about what I learn. [Intern D]

> Producing quizzes and animations for the project has also shown me clearly that to test if you really understand a topic, you must be able to explain it to others. As we have said throughout, I don't think any of us understood the practicals at the time as well as we do now. [Intern B]

> I have prepared more effectively for [tutorials] after this project because I was made more aware of the difference it would make, and the structure that the preparation needed to take. [The project gave me] a greater understanding of what the academics are trying to do with the resources that they create …. There is always some disconnect between students and teachers, and reducing it helped me approach practical classes etc. more positively [Intern A]

This suggests that 'students-as-producer' approaches can have multiple positive impacts for those involved. Our interns saw considerable benefits of exploring a topic through creation of new resources rather than passive consumption of material; seeing teaching from the perspective of academics helped the interns to structure and target their future study. Cook-Sather and Luz (2014) also describe students changing their relationship towards their own learning as a result of partnership, suggesting that this may be an effective strategy to redefine the way that students engage with education (Cook-Sather, 2014a). To do this in an inclusive manner, there may be benefits to embedding the creation of educational resources or pedagogical consultancy roles into taught modules. Embedding resource creation into curricula would also represent a more authentic assessment strategy than terminal examination, and could provide a sustainable mechanism for academic staff to develop new resources, if supervised and managed carefully.

Summary and implications for practice

This was a relatively small-scale student partnership project which took place over one summer vacation. However, we consider that there were considerable benefits gained by both academics and students. The academics gained an up-to-date insight into student needs and received new resources for use in teaching in future years. Students enrolled in the courses gained new materials which were used to structure preparation for practical classes and to consolidate understanding, including during the revision period. As has often been found in similar projects, the main beneficiaries were arguably the interns themselves (Croft et al., 2013; Keegan & Bell, 2011; Lee, Chan, & McLoughlin, 2006). In addition to the impact on their approach to learning described above, the interns gained insight into the perspectives of academics, felt that their work was valued and had made a difference to future teaching.

This project was ambitious in what it asked undergraduate interns to do and different tasks were completed with varying levels of success. In our experiences of working in partnership, students can:

- Offer different and valuable perspectives on the effectiveness and design of teaching strategies.
- Identify incorrect assumptions that academics may have about student needs and prior knowledge.
- Bring skills to projects that academics may not have, particularly in relation to content creation and digital technologies.
- Present existing materials in more accessible or 'student friendly' formats.
- Create new content relating to fundamental concepts under academic supervision, dependent on the complexity of the subject area.
- Identify common misconceptions held by undergraduates, and write feedback hints and/or suggestions to aid student understanding.
- Present partnership projects to local, national and international audiences.
- Contribute to the writing of manuscripts for publication, including responding to reviewers comments from a student perspective.
- Perform routine tasks that academics may not have time for.

However, in our experience students are less able to create some content from scratch, particularly for complex topics where they lack sufficient knowledge or authority (Croft et al., 2013). For such topics, using undergraduates to generate original questions may not be a time-efficient strategy; academics must have realistic expectations about what students can achieve, particularly when working with students who have only just completed the course that requires resource development. Under such circumstances, students can still provide valuable perspectives on academic-produced resources, help academics identify where their peers may struggle, and write 'helpful hints' or other resources for other students to use when completing problems. It may be that increasing the gap between the academic stage of the student partners and the course under development (e.g. inviting final-year students to produce resources for first-years) would have the benefits of partnership without the problems associated with a lack of subject knowledge (Woolmer et al., 2015).

While student partnership and 'students-as-producer' models offer clear benefits to the participating students, it can be difficult to scale them up such that all students and teaching staff have an opportunity to benefit (Bovill et al., 2015; Healey et al., 2014). These concerns notwithstanding, our experience suggests that our small-scale model of partnership can be a valuable mechanism for creating high-quality resources to address student needs in a way that students find engaging. As such we believe that it is a model that has potential benefits throughout the sector, but it requires careful management if both student and academic partners are to benefit.

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