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Research Article

Collaborative Experiments Online in a Module Presented Globally

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Abstract

A new module for Level 1 students called 'Science Investigations' provides an introduction to practical work, in an on-line environment. Most of the activities in the module require observational or experimental work done at home, with only the field work being 'virtual'. The aim is to encourage practical and group work in an era when the amount of laboratory teaching is declining. Students are required to work in groups to design experiments and collect data sets. The assessment is computer-based, tailored to the type of final experiment that the student has been involved with. Tutorial help is provided both synchronously via video/audio conferencing and asynchronously via on-line forums. Students must meet minimum requirements in order to pass, including entering data into on-line databases, achieving satisfactory participation in tutorials and forums, and passing the end of module assessment. The key lesson learnt from the first presentation and survey data was that some students came with expectations that were at variance with the design philosophy of the module and that it is essential to make the module structure and the expectations for group work explicit at the start, to guide students in participating in experimental science in an online, distance learning environment.

Keywords: Practical, on-line, investigations, collaborative, global

Introduction

Practical science has long been a central part of science teaching and learning and is codified in regulatory frameworks. In the UK, the Quality Assurance Agency's (QAA) subject benchmark statements for both (i) physics, astronomy and astrophysics, and (ii) biosciences include the following in the lists of required subject skills:

- How to plan, execute and report the results of an experiment or investigation (QAA, 2008)
- The ability to employ a variety of methods of study in investigating, recording and analysing material (QAA, 2007)

These statements reflect the view that hands-on experience is at the heart of science learning (Nersessian, 1991) and that it stimulates student interest (Holstermann *et al*., 2010). However, there are other reasons why science degrees include practical work. Laboratory or field practical activities offer contextually rich opportunities for the acquisition and practice of a wide range of transferable skills. The QAA's subject benchmark statement for biosciences (QAA 2007), for example, lists communication, presentation and information technology skills, interpersonal and teamwork skills, and self-management and professional development skills. Some of these skills can undoubtedly be acquired in other ways, but there is a general conviction that inquiry in the context of practical work in science education is central to the achievement of scientific literacy (Hofstein, 2007). Activities that are built around inquiry develop the skills of posing questions, erecting hypotheses, designing appropriate experiments, interpreting data and communicating results. As science becomes more reliant on team work, the value of this approach is to develop a community of practice in which students hone their collaborative and social skills while learning, a process that sustains them in their studies (Lave, 1991). Developing a community of practice also mirrors aspects of the modern research environment.

Clough comments that laboratory experiences 'make science come alive' (Clough, 2011). The challenge facing science educators in the distance learning field is to make science come alive through experiments, but without the physical laboratory. This paper describes a new online science investigation module at Level 1 that allows individual students working remotely to participate, as part of a small group, in collaborative investigations. The investigations are relatively simple but robust scientifically and allow them to acquire transferable skills in experimentation. The module was developed to test three propositions. Firstly, that it is possible for students to engage in interesting and stimulating science investigations at home without specialised equipment. Secondly, that supportive collaboration between students was possible using computer-based communications. Finally, that a module could be produced that would deliver the learning outcomes needed from an introductory module on science experiments, enabling students to progress to further experiment-based modules at Level 2 and Level 3.

Design criteria

The module was designed to last 12 weeks with 100 hours of study in total. Key design criteria were formulated at the start, criteria that would be applicable generally to online practical modules.

- The module as a whole and the individual activities must facilitate effective learning
- The module must involve the student in scientific activities that are scientifically accessible and stimulating
- The activities must be culturally appropriate across a wide range of possible students
- The technologies that are required to deliver the module must be accessible and robust

There are considerable challenges in matching effective learning to the technology that is delivering or mediating it. The technology must be exploited effectively within the appropriate pedagogy, as Bennett, *et al*. (2004) pointed out in their analysis of some of the myths of online education. The design criteria above are clearly interdependent too in that if you cannot meet the criterion of a robust technology (4) you will not meet the criterion of effective learning (1).

Table 1 *A generic set of learning outcomes for a Level 1 practical science module*

Knowledge and Understanding		
(1) Understand that detailed planning is necessary for successful and safe experimentation.	(2) Identify the general characteristics of experiments that will yield valid scientific conclusions.	(3) Understand the role of hypotheses in experiments.
Cognitive skills		
(4) Convert scientific questions into hypotheses that can be tested experimentally.	(5) Select and design appropriate experiments to test hypotheses.	(6) Evaluate the strengths and weaknesses of experiments and their design.
Key skills		
(7) Prepare and present recorded results accurately and in an understandable form.	(8) Cooperate effectively with others in a shared project.	(9) Organise your course activities effectively.
Project and Planning Skills		
(10) Make and record measurements and observations accurately.	(11) Reach conclusions that are supported by the experimental results.	

The learning outcomes devised for the Level 1 module are given in Table 1. These have been formulated on the basis that their attainment will be assumed in future online practical modules at higher levels. There are no entry requirements for Level 1, so a significant minority of students may have few skills at the module start and may have had limited science education in schools. However, these learning outcomes are considered to be achievable for such students in the time available and form a set that can be used generally for practical modules at Level 1, whether those modules are online or laboratory-based.

Pilot presentation

A pilot of some online experiments was carried out with a small group of overseas students. The key lessons learnt from this pilot were that there was a tension between the number of data points required for experimental results to be meaningful and the manageable size of a group in a synchronous conference. Experiments that require each student to collect a set of data themselves rather than just one observation or measurement are obviously preferable. As a consequence, the experiment(s) chosen for online group work must be sufficiently stimulating to motivate independent collection of data sets (Robinson and Swithenby, 2009).

The structure of the module

Unlike most distance-learning modules that use a core text, the core of this module is the sequence of activities that the students undertake (Figure 1). The activity sequence forms the spine of the course, into which are linked the Experimental Handbook sections and the online tutorials. The activities determine the pace of the module too and, again unlike many other distance-learning modules, students must study at the pace of their group and not their own pace. Thus this module is more like the sequence of laboratory classes that face-to-face students engage in than the typical distance-learning module.

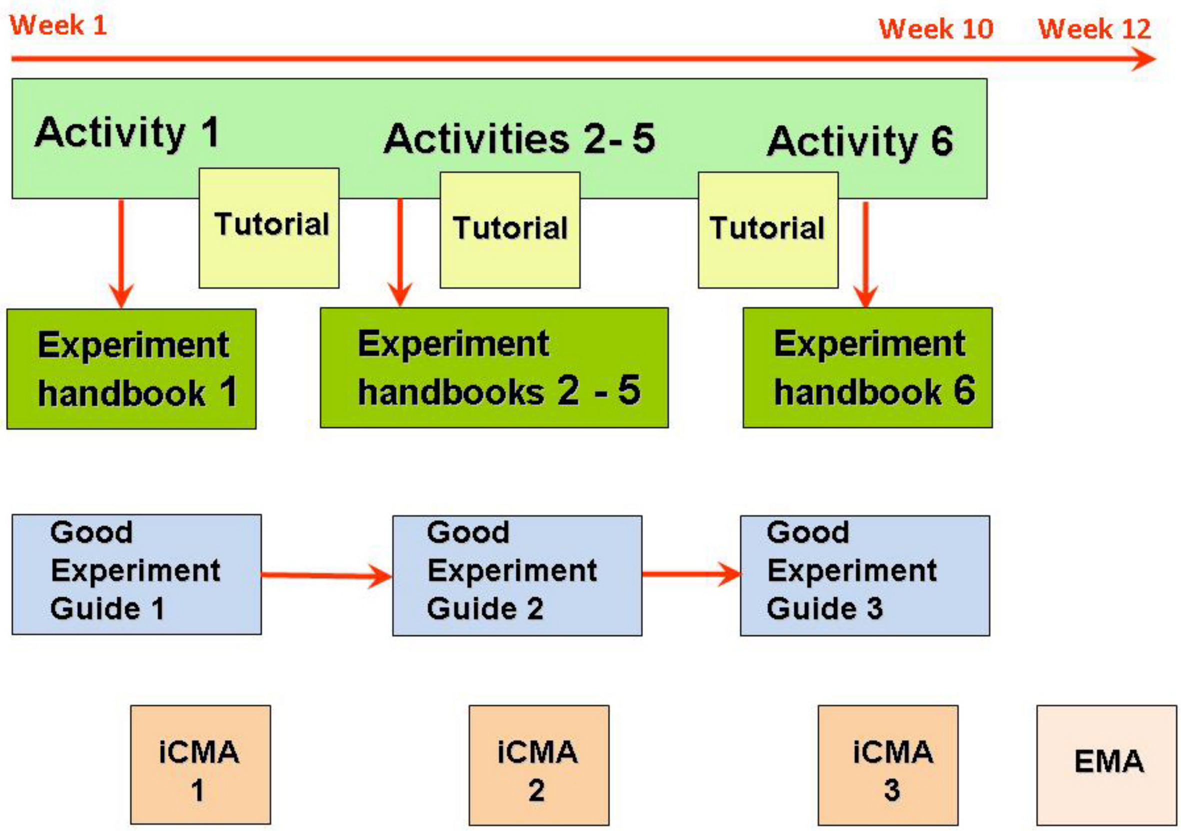

Figure 1 *Outline of the components of the 12 week module. iCMA – interactive Computer Marked Assignment; EMA – End of Module Assessment*

The module text is studied in parallel with the activities, but is not directly cross-linked. Tutorial sessions concentrate on discussion related to the activities and are not used as remedial sessions to go over sections of the module text. The three iCMAs (interactive computer marked assignments) are formative in nature and can be attempted as many times as the student wishes. The EMA (end of module assessment) has questions similar in style to those of the iCMAs.

Tuition

Students taking the module are allocated to tutors in batches of 40. Each tutor then divides their batch up to make four groups of ten (Figure 2). The tutor will try and ensure that students from the same geographical region are grouped together.

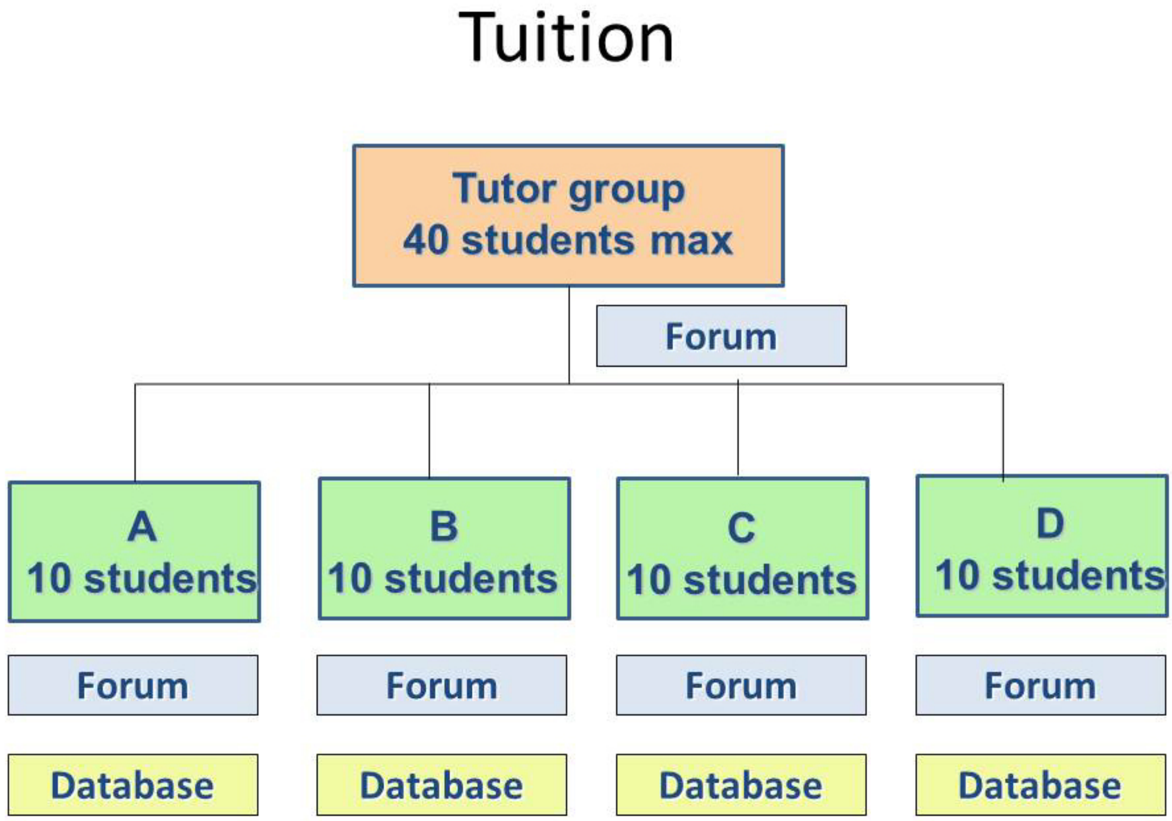

Figure 2 *The tuition model for the module. Tutorials are provided using Elluminate Live and forums are within the Moodle Virtual Learning Environment*

Each student group has its own forum on the Moodle VLE (Virtual Learning Environment), which the members run for themselves with oversight – but minimal intervention – from the tutor. The tutor has a forum for providing help and advice, which all students from the four groups can access. Each group has an online database into which students can enter their experimental results. They are unable to view the data sets from the rest of the group until they have entered their own set, a measure designed to reduce the likelihood of plagiarism. Tutorials are offered using Elluminate Live, a synchronous web-based conferencing system. Each tutor offers three tutorials during the ten weeks of study, and repeats each tutorial at a different time of the day, to accommodate students with different work patterns or those based in different time zones.

Assessment

The assessment package has three elements, two of them acting as thresholds and the third one as a summative EMA. The first threshold is linked to the final experiment. A student must enter a valid set of data into their group's online database and have it checked by the tutor, before the EMA is released to them. The second threshold is satisfactory participation in the activities, forums and tutorials. The tutor keeps a record of participation. The third element, the EMA, is a computer-marked multiple choice assignment. The EMA is designed to generate a large number of variants, so that the chance of two students on a presentation getting identical EMAs is small. There are three sections of seven questions. Section A is changed for each presentation while Section C remains unchanged but has at least five variants for each question. The questions in Section B are linked to the final activity in the module, of which there is a choice of one from five experiments. The student gets a set of questions that relate to the experiment that they carried out.

The activities

There are six activities in the module, one of which is virtual.

***Table 2** Summary of the activities in the module*

Activity	Outline of activity	Group work	Data collection	Tutorial support
Mug mats (Figure 3)	Measurement, populations and sampling	Discussion of measurements, results and hypotheses	pre-prepared database	Forum and tutorial
Sound perception	Design of experiment with human subject	Discussion of methods	Discussion of presentation of results and nomination of member of the group to collate	Forum and tutorial
Reaction time measurement	Design of experiment in which reaction time is measured while doing another task	Discussion of task selection and design, including consideration of types of variable	Pre-prepared database	Forum
Soils	A suite of activities involving individual work and group work	Discussion of results and problems of combining data	Group devises way to present results	Forum and tutorial
Field study (virtual)	Survey methods and sampling on a seashore to record lichens	General discussion	No group data collected	Forum
Seed germination	Group choice of 1 from 5, 2 on root growth and 3 on shoot growth	Discussion within group to produce agreed hypothesis and design	Generalised database for all 5 experiments which the group must agree the column headings	Forum and tutorial

Each activity has an online Experimental Handbook that provides instructions and background. There is also a podcast and the audio track is available as an MP3 download, for students who wish to listen to the instructions while working on an experiment.

Figure 3 *'Mug mat'. Each student receives one mat which they are required to describe to other students in their group. The mats are allocated randomly within the total student population. Although the 6-sided red plastic mats are superficially similar, there are actually three different ones, with differing side lengths and each morph has a different frequency within the population. Additionally, there is one very rare blue type*

The online text

The text for the module is the Good Experiment Guide, which is studied in parallel with the activities. It contains embedded audio and video, hot links to external sources and plenty of illustrations. There are five chapters that are ordered according to the major steps in the process of experimentation from original idea to publication. Threaded through the text is a case study on the discovery of insulin. This study is illustrated with images from the archives of the University of Toronto, where the work leading to the discovery was carried out. The Good Experiment Guide will soon be available to students in e-book reader versions.

Learning the lessons

The first presentation of this module had only 62 students and two tutors, giving the opportunity to run with low numbers first, before scaling up to the planning figure of 300 students. The pilot module had shown that technological problems were less significant than had been feared and so the evaluation of the first presentation could concentrate on teaching and learning. A detailed questionnaire was sent to 48 students of whom 23 responded. An extract from the answers is shown in Table 3.

Table 3 *Extract from student survey results*

95%	happy with tutor support
87%	passed the module
82%	felt that participation from other students in assessed collaborative activities was good
80%	felt confident in using the technologies required for assessment
80%	felt that online interactions with other students help them to feel part of a community
77%	felt that assessment was a fair reflection of what they had learnt
69%	would recommend the module to others
64%	were satisfied with the course-related online tutorials and forums
18%	did not enjoy their study

Both the questionnaire and the experience of the teaching team highlighted a particular problem with the module structure. As described earlier, the module is based around a core of activities which drive the study of the other components of the module, notably the Good Experiment Guide. This is the opposite of what students would expect from most other distance-learning modules, where the main text drives their study, tutorials generally offer remedial help with understanding the principles taught in the text and the students can study, within broad limits, at their own pace. It was clear, on reflection, that we had assumed that the structure of the module was obvious and clearly it was not. An indication of student failure to perceive the structure was that some planned to start early, get ahead and then turn to something else whilst others had planned to work first on another module and then switch into this one late and catch up. Neither strategy is appropriate in a module driven by an integrated set of group activities.

Modules that are fully online are still relatively uncommon in the university curriculum and for most students this was their first online module. The lack of a printed text and the online assessment were two criticised elements of the module, yet both are features that are an intrinsic part of such a module. It seems unrealistic to sign-up for an online module and then be disconcerted by the online features.

Technology was expected to present problems in the presentation of the module, but in fact the systems were surprisingly robust and, for example, 80% of students felt confident in using the technologies for assessment (Table 3). However, there is a mismatch between the fact that 95% were happy with the tutor support, which is provided by tutorials, forums and email, yet only 64% were satisfied with the course-related online tutorial and forums. This does not appear to represent a problem with the technology, but may reflect a view of student contributions rather than tuition. The number of posts to the asynchronous forums was large, with over 119 posts by a group of 15 students for the seed germination experiment (Table 4).

Table 4 *Number of forum posts by two groups of students, relating to 4 activities*

Activity	Group A (9 students)	Group B (15 students)
Mug mats	79	71
Reaction time measurement	35	61
Soils	16	49
Seed germination	89	119

As a result of the online design being unfamiliar to many students, a clear explanation of what they should expect from the module should be built into the pre-module information and should be reinforced at the start of teaching. For the present, we cannot assume that students will be at ease with online learning at a distance.

Discussion

Collaborative learning is an important tool for enabling learning and there is an extensive literature that supports this view, as for example, in the review by Robert Slavin (Slavin, 1996). A meta-analysis of a large number of studies, concluded that on average, students placed in small groups achieved more, held more positive attitudes and reported higher general self-concept than students in non-grouped classes (Lou *et al*., 1996). This may be because shared tasks are more effective in community building than overtly social activities (Whitton, 2005).

Having reviewed a number of earlier studies, Rozenszayn and Assaraf (2011) identified five major components that need to be present if collaborative learning in small groups is to be efficient. The design of the group activities in this module has incorporated 4 key components that map onto those identified by Rozenszayn and Assaraf (2011). The four that are key to group experiments are listed in Table 5.

Table 5 *Four major components required for efficient collaborative learning in small groups (derived from Rozenszayn and Assaraf, 2011)*

Component	Description
Interdependence	Each of the group members has to understand that success in reaching their mutual goal depends upon each of them and their mutual support
Collective responsibility	Group members accept collective responsibility for dealing with difficulties
Reciprocity	Individual contributions are made on a reciprocal basis with each member's personal knowledge and understanding being merged into the group outcome
Sociality	Social processes and skills must be shared in order to reach the mutual goal

By requiring students to collect data sets as a group and discuss the results online, the module makes them interdependent in achieving their mutual goal. Decisions on experimental design need to be made collectively and problems in design need to be overcome by consensus. The social cohesion of the group is essential to success and is easier to achieve in a face-to-face environment with a tutor present to intervene, than in an online environment where much of the communication is asynchronous. The high levels of postings to the forums revealed by the figures in Table 4 strongly suggest that the module has achieved success in the promotion of group discussion. The linking of the seed germination experiments to the release of the end of module assessment offers a motivation for engaging in the group discussion of design and database entries and provides that mutual goal that is essential to efficient group work.

Experience with designing and presenting this module has shown that it is possible to present a series of sufficiently interesting experimental activities to stimulate students to engage in group collaborative work collecting data and discussing methodology. However, the design criteria for successful experiments that can be done by small groups in a global context, substantially constrain the choice of suitable experiments. There is a fine line between experiments that are practical but trivial and those that are practical and interesting. Those offered in this module have been successful within an online distance learning environment. Extending the range of experiments will require careful choice but delivering hands-on experiments to distance learners is a fundamental feature of the science curriculum.

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