Online Pre-laboratory Exercises Enhance Student Preparedness for First Year Biology Practical Classes

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Abstract:

Effective preparation prior to a practical class is essential if meaningful learning is to occur. If effective preparation does not occur, then students are at risk of "information overload" as they attempt simultaneously to come to terms with novel technical or manipulative tasks as well as learning new concepts. We designed on-line multi-media pre-laboratory exercises (Pre-labs) to support dissection-based practicals in a first year biology unit. The aim of this study was to gauge the effectiveness of the Pre-labs in improving students' perceptions of their preparedness for practical classes. We surveyed the students before and after introduction of the Pre-labs, and monitored use of the Pre-labs on the class on-line learning site. The surveys showed that 68% of students reported they like to "see or be shown what to do". In the initial survey, only 15% of students reported doing a substantial amount of preparation for practical classes. However, the majority of students used the "visual" Pre-labs regularly, and reported finding them "very useful" in preparing them for the practical class, and 47 % (compared with an initial 22.4%) reported being well-prepared for class. Better preparation should lead to enhanced learning outcomes for students as well as better meeting ethical guidelines for instructors designing practicals based on animal specimens.

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Introduction

Why encourage students to prepare for laboratory classes in biology?

Laboratory classes are where science students acquire and practise key manipulative and process skills, while learning to move concepts from an abstract into a concrete setting (O'Brien & Cameron, 2008). However students may be at risk of "information overload" during a laboratory class as they try to cope with novel technical and manipulative tasks as well as master new concepts (Meester & Maskill, 1995; Pogacnik & Cigic, 2006). Cognitive load theory suggests that a student's learning will be inhibited if "the instructional materials overwhelm a learner's cognitive resources" (Cook, 2006, p.1076). Hodson (1993, p.100) describes this effect as "too much noise": there is information overload due to the large number of tasks that need to be completed, as students find it difficult to see connections between what they are doing and what they are meant to be learning.

One effective way to reduce cognitive load and to increase meaningful learning during laboratory classes (O'Brien & Cameron, 2008) is through effective pre-laboratory preparation. Pre-laboratory exercises are widely employed in the sciences, and various

models have been developed, with the underlying technology becoming more sophisticated over time. Preparatory exercises take many forms, including short face-to-face tutorials with associated tests (Pogacnik & Cigic, 2006), or on-line work modules in which the practical task is carried out in a virtual environment (Schmid & Yeung, 2005). For example, Case (1980) described using auto-tutorials, or minicourses, which included a printed study guide and an audio-visual module, to help students prepare for biology laboratories. Later, online modules that set out a real life problem to be solved in a virtual environment have been used to prepare students for Chemistry laboratories (Yeung, Schmid, Tasker & Miller, 2005), while molecular visualisations provide powerful tools to help students understand chemical theory, particularly three-dimensional molecular structures and how they change over time during chemical reactions (Jones, Jordan & Stilings, 2005). None-the-less, many life sciences students enter the laboratory with little or no preparation, with detrimental impacts on their learning outcomes (Gorst & Lee, 2005).

Effective design of pre-laboratory learning exercises

To be effective, pre-laboratory preparation needs to be more than just an encouragement for students to read their manual before coming to class: pre-laboratory exercises must be designed as carefully as the practical manual itself (Johnstone & Al-Shuaili, 2006). Pre-laboratory exercises are essentially a form of guided instruction. There is strong evidence that students learn more deeply through guided instruction, rather than through discovery-based learning (Kirschner, Sweller & Clark, 2006). Examples of guided instruction are activities such as worked examples or worksheets which have been shown to have positive effects on student performance (Nadolski, Kirschener & van Merrienboer, 2005). Guided instruction leads to longer term transfer of knowledge and problem-solving skills, and guards against students acquiring misconceptions or disorganised knowledge (Kirschner et al., 2006).

Lujan and Dicarlo (2006) point out that motivation and performance improve when learning activities accommodate students' varying learning preferences and styles. In our first year biology practical classes, we have observed that many students seem to have difficulty visualising what they are expected to do in class from reading a set of written instructions in the practical manual, even after a verbal introduction to the practical by the lecturer in charge. French (1998, p.1) similarly considered that students "have difficulty accurately identifying features of specimens from written instruction". This is particularly true of students with visual learning styles: even if they have already read the relevant section of the manual, such students may not be well prepared for class, and therefore be less able to take full advantage of the learning experiences offered by the practical exercises.

Cognitive load theory provides a number of instructional design rules for pre-laboratory exercises. These include the use of multiple representations, and the use of dual mode presentations (e.g. verbal plus visual). Mayer, Bove, Bryman, Mars and Tapangco (1996) specifically investigated the role of illustrations in promoting students' understanding of scientific principles. They demonstrated that students learn most effectively from what they termed a *multimedia summary*: a "sequence of annotated illustrations depicting the steps in a process". In addition, they concluded that a multimedia summary is most effective when it contains only a small amount of text. Slaughter (undated) commented that static images are preferable to moving images because they allow greater attention to detail; facilitate identification of sequence in procedures; and can be used to illustrate technical terms.

An ethical perspective on the use of pre-laboratory learning exercises in biology

From a different perspective, teachers of biology must also appreciate that when a learning exercise involves animal specimens, there are some important ethical considerations to be

made. The *Australian Code of Practice for the Care and Use of Animals for Scientific Purposes* (National Health and Medical Research Council, 2004) specifically requires that, when using animals in teaching, students should take responsibility for maximising their learning (which would include preparing well for classes), and that teachers should provide effective mechanisms to support their learning. Well-designed pre-laboratory exercises are examples of such mechanisms.

The initiative

Based on our reading of the literature, we designed and produced a series of pre-laboratory exercises (henceforth, Pre-labs) to support each of five dissection-based practical classes in a first year biology unit. The Pre-labs take the form of PowerPoint shows in which the procedures or outcomes of each stage of the dissection, as described in the practical manual, are illustrated with still colour photographs. Procedures such as attaching a scalpel blade to the scalpel handle are also illustrated. We added short written instructions that summarise text in the practical manual, questions designed to highlight key learning concepts, and a list of key vocabulary terms. The tight integration of these pre-laboratory exercises with the practical manual mirrors the approach of O'Brien and Cameron (2008). Each Pre-lab is loaded into our on-line learning site the week before the relevant practical classes, and students are alerted to this by bulk email. Use of the Pre-labs is voluntary, and there is no associated assessment.

Aims of this study

This study aimed to gauge the effectiveness of pre-laboratory exercises as a learning support tool for dissection-based practicals in a first year biology unit that focuses on the biology of animals. This unit runs in Semester One, so most students are inexperienced with tertiary learning at the start of the unit. Although none of the dissection exercises require approval from an Animal Ethics Committee, the concept of an ethical approach to animal-based science is introduced in the first practical class, and students are asked to consider their ethical responsibility to maximise their learning opportunities when using animal specimens. This strategy conforms to the Australian and New Zealand Council for the Care of Animals in Research and Teaching (undated) *Ethical guidelines for students using animals or animal tissues for educational purposes*.

The specific aim of this study was to investigate how our biology students usually prepare for practical classes, and whether they felt "well-prepared" for practical classes before and after introduction of the Pre-labs. An additional aim was to gather quantitative data on usage of the Pre-labs. As the study was carried out in an authentic educational setting (*sensu* Richardson, Sharma & Khachan, 2008), we did not attempt to directly measure the impact on learning outcomes. Instead, we focussed on how the availability of the Pre-labs affected students' perceptions of their preparedness for practical classes.

Methods

This study was carried out in 2008, the year that we first introduced Pre-labs into our unit. The first Pre-lab was associated with the practical class for Week 5 of a 13-week semester. We surveyed the students twice: in Week 4, before the first Pre-lab was released (and before the students were aware that Pre-labs would become available), and again in the penultimate

week of semester, after the class had had the opportunity to access all five Pre-labs and undertake the associated practical activities. The anonymous, voluntary, surveys were designed to elicit information on how well-prepared they felt for their practical classes, and what type of preparation they usually do for these classes. We used a combination of Likert Scale questions and questions requiring the student to circle the most appropriate answer; free form comments were also solicited. Note that Questions 3 and 4 were common to both Surveys.

Survey One, administered before the introduction of Pre-Labs, probed:
How much, and how, do you prepare for class?
How do you prefer to learn?
How prepared do you feel for class?
What worries you most (about working in the practical class)?

Survey Two, administered after introduction of the Pre-Labs, asked:
Were the Pre-Labs useful?
What other strategies do you use?
How prepared do you feel for class?
What worries you most?

We also included a specific question on the perceived usefulness of the Pre-labs in the formal unit evaluation (Student Evaluation of Teaching and Learning: SETL). This is an anonymous class survey carried out at the end of semester, and centrally administered by the University of Tasmania. In addition to ten common core questions, lecturers are able to add questions specific to their unit to the SETL survey.

In Week 10 of semester, we sought feedback from the demonstrators about the types of questions being asked by the students in order to gauge the effectiveness of the Pre-labs in helping the students conceptualise what they will be required to do in class. Questions were coded as *"method questions*" (asking how to do something), "*factual questions"*(asking what something is) or *"checking questions"* (seeking affirmation of the student's thinking). The practical that week, for which a Pre-lab was available, focussed on dissection of a seastar.

Quantitative data on the usage of each Pre-lab exercise, and, as a comparison, of other study aids provided on our on-line learning site, were collected via the course item usage reports in Web-CT Vista.

Results

Survey One:
Over the three replicate practical classes, 128 students responded to this survey, representing 67% of the total enrolment of 192 students at the end of semester. Only 15% of students reported that they did a substantial amount of preparation for practical classes (i.e. rated as 4 or 5 on a Likert scale of 0-5); 40.3% of the class considered they did some preparation for class (i.e. rating 3 on the Likert scale), but 45.2% reported doing little or no preparation (rating 1 or 0).

In response to Question 2, a clear majority of students (68%) reported that they "*like to see or be shown what I have to do*" rather than "*read about*" or "*be told what I need to do*" (Figure 1).

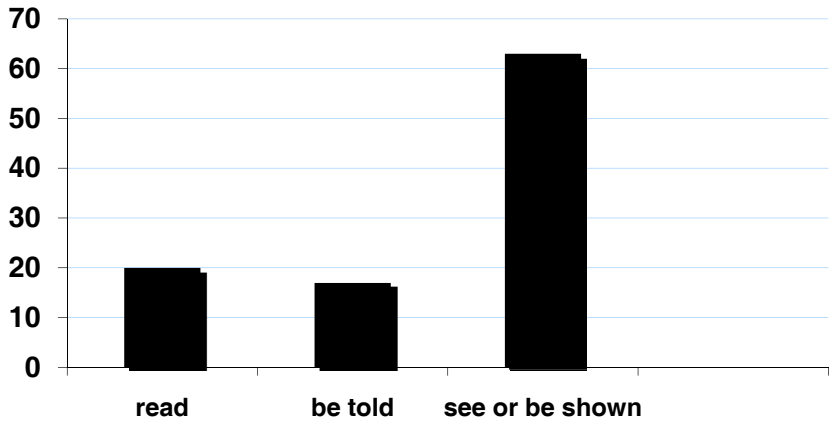

Figure 1: Responses to Question 2, Survey One, demonstrate that the majority of students preferred *to see or be shown what to do* in their practical class.

Question 3 asked students to self-report on how well prepared they felt for that Week 4 practical class. Only 22.4% felt *well prepared* (rated as 4 or 5 on a Likert scale of 0-5) for class; 40% rated their preparedness at 3 on the scale, with the remaining 12% scoring as 2 on the scale (i.e. relatively *unprepared*).

Analysis of responses to Question 4, which asked about "*the kinds of things that worry me most*" showed that students' greatest concerns were: "*using my time efficiently"* (25.7% of total responses) and "*knowing what the main or important parts of the practical class are" (20.5%), followed by "drawing"* (14.7%), *"knowing what to do next"* (14.7%) and *"understanding the information in the practical manual" (12.0%).* Some free-form comments highlighted particular concerns. For example:
"Even though I read prac manual before class, sometime I can't understand what shoud (sic) I do in a class".

Survey Two
Of the class of 192 students, 107 (56%) responded to this survey. Question 1 asked students to rate the usefulness of the Pre-labs in helping them prepare for practical classes on a scale of 1 to 5, where 1 = not at all, and 5 = extremely useful. An overwhelming majority (81%) of students rated the usefulness of the Pre-labs highly: at 4 (38.1%) or 5 (42.9%). Only 7 students (6.7%) felt the Pre-labs were of little or no assistance. Responses to Question 2 showed that other strategies used for preparation were: "*reading the practical manual"* (50% of 104 responses); "*textbook"* (28%); "*lecture notes"* (14%); "*asking friends"* (7.6%) or "*internet"* (2 %). Note that many students reported use of more than one strategy in addition to the Pre-labs. Of the students who did not find the Pre-labs very useful, 74% preferred to *read* to prepare for class.

As in Survey One, Question 3 asked the students how well-prepared they felt for classes. There was a significant shift in the pattern of responses to this question (Paired t test: t= 2.781, df=4, p=0.05). Compared with the results of Survey One, the class were less likely to report low levels of preparedness for practicals, with a shift towards ratings of 4 or 5 for 47%

of the class (Figure 2). Free-form comments most often highlighted the perceived usefulness of the format of the Pre-labs. For example:
"The visual aids and simple step-by-step instructions helped breakdown the activities into easy-to-remember steps and carrying them out in these steps really helped"

"It was good having pictures of the disection (sic) step by step, because it made it easier to interperate (sic) the prac manual".

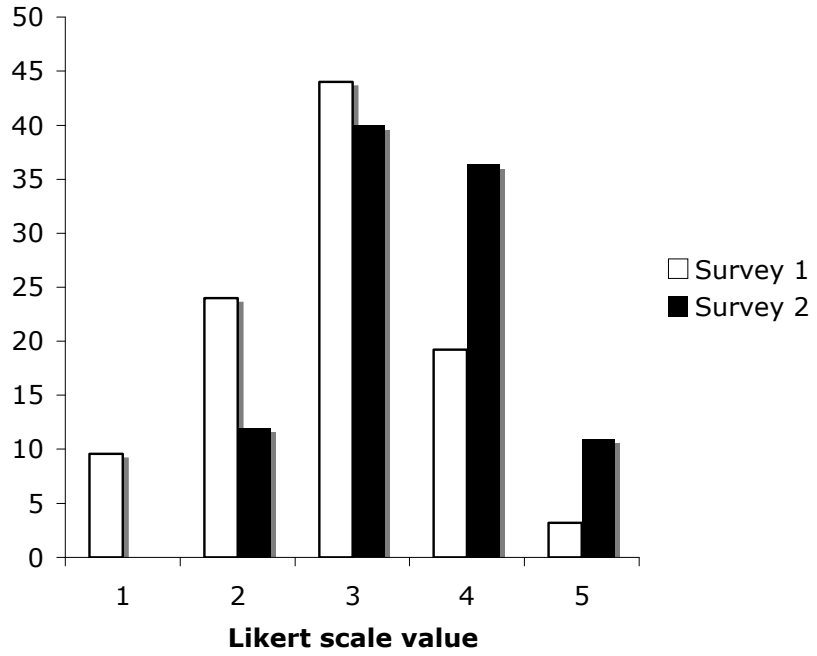

Figure 2: Responses to Question 3 on Surveys One and Two: % of students rating themselves on a scale of 1 = unprepared to 5 = well-prepared for that practical class. Note the increase in % of students self-reporting as *well-prepared* (rating 4 or 5) in Survey Two, after introduction of the Pre-labs.

In Survey Two, analysis of responses to Question 4, which asked about "*the kinds of things that worry me most*" showed that students' greatest concern was still *using my time efficiently* (25.6% of total responses), and only 8.5% reported feeling confident to undertake all aspects of the practical class. Compared with responses to the same question in Survey One, there were somewhat lower levels of concern about "*knowing what the main or important parts of the practical class are" (14.5%), "knowing what to do next"* (11.4%) and *"understanding the information in the practical manual" (8.5%).* There was a greater level of concern about *"drawing"* (18.2%), which may reflect the students' recent experience with assessment of their scientific drawings.
"It made me feel more confident in what I was expected to do and how to do it".

Demonstrators' comments
The demonstrators' notes from the practical classes in Week 10, after the students had had the opportunity to use four of the five Pre-labs, showed that some students were printing out the Pre-labs and bringing the print-outs to class as a supplement to their manual, or even accessing the Pre-labs on lap-top computers during class. One experienced demonstrator commented that students seemed to complete the dissections in less time compared with the previous year. Classification of the types of questions asked by the students indicated that,

despite using the Pre-labs, they asked "*method questions*" (32%) and "*factual questions*" (42%), with "*checking questions*" representing 26% of records.

Usage of Pre-labs

All five Pre-labs were accessed intensively in the week prior to the relevant practical class. With 7140 visits to the home page of the online learning repository for the unit, there were 1715 hits on the folder containing the Pre-labs compared with 596 for Lectopia (i.e. recorded lectures) and 2212 for the folder containing all the lecture notes for the thirteen-week semester. Although individual usage was not tracked, the average number of hits for a Pre-lab was 296, suggesting that most members of the class used them regularly. Every Pre-lab scored more hits than any other individual item in the learning repository.

Student evaluation of teaching and learning

In the formal SETL unit survey, 87% of students agreed or strongly agreed with the statement "*The pre-lab exercises on MyLO were useful in helping me prepare for the dissection practicals*" (mean score 4.38 ± Std Dev 0.7, with Strongly Agree = 5).

Discussion

This study shows that multimedia, online, pre-laboratory exercises were enthusiastically embraced by the students in our first year biology class. This was despite there being no assessment associated with the Pre-labs. In contrast, Meester and Maskill (1995) contended that (chemistry) students will only take pre-laboratory work seriously if there are external motivational factors such as associated assessed exercises or activities. Indeed, Case (1980) suggested attendance at pre-lab exercises should be mandatory, and that a written assessed exercise should be incorporated in order to encourage the students to take advantage of these learning opportunities. In our initial survey, only 15% of the class reported that they did a substantial amount of preparation for practical classes. However, the majority of our class used the Pre-labs regularly, and reported finding them "very useful" in preparing them for the practical class. Thus, for our biology students, one effect of the Pre-labs was to increase their motivation to prepare for practical classes. They reported increased levels of preparedness for practical classes after the Pre-labs were made available to them. As one student commented:
"It was very good to see what we would be looking at before we came to class, so we could prepare and know what the real specimens look like."

As our previous informal observations suggested, a high proportion of our students identified as visual learners, and therefore the Pre-labs, which provided a visual representation of key steps in the laboratory procedures, were better adapted to their preferred learning style than the largely text-based practical manual. Conversely, students who did not find the Pre-labs very useful identified as preferring to read to prepare for class. Gorst and Lee (2005) reported that only 54% of a large sample of life sciences students claim to *read* the practical manual before most of their laboratory classes, and nearly 20% of a class of 223 chemistry students did no preparation at all (Pogacnik & Cigic, 2006). Through this project, then, we were better able to address the diversity of learning styles within the class, thus promoting motivation and enthusiasm (Lujan & DiCarlo, 2006).

Although we were not able to measure any influences of the pre-labs on learning outcomes, the literature suggests that reduced anxiety and increased student confidence should result in a more positive learning experience (O'Brien & Cameron, 2008; Schmid & Yeung, 2005).

Learners need to understand, and be familiar with, the learning task if they are to be sufficiently motivated to engage effectively (Hodson, 1990). Students can easily be overwhelmed by the amount of new information they have to process in a laboratory class so that much of the information, including written and oral instruction, is filtered out of working memory (Johnstone & Al-Shuaili, 2001). Pre-laboratory exercises such as ours, which focus on clarifying the procedures to be carried out, give students a better understanding of what is expected of them; thus time is not wasted in class, and students can better concentrate on improving their conceptual understanding (Schmid & Yeung, 2005). Students who have "a prepared mind" will be able to make more effective observations in the laboratory because they will be more able to focus on the primary task (Johnstone & Al-Shuaili, 2006). In one student's words:
"The prelabs made me able to know what I was looking for even before I came to the lab. This meant that looking at the prelab for 30 mins saved me an hour in the lab."

The shifts in our students' views of "what worried" them about practicals do suggest that they were less anxious about being able to follow and interpret the instructions in the practical manual after using the Pre-labs. We acknowledge that we cannot discount the effect of greater experience with this type of practical class on student confidence in their ability to work independently in the laboratory. However, in week 10, the demonstrators reported at least one third of the questions they were being asked at this stage of semester reflected students merely 'checking' their information or ideas were correct, suggesting their preparation for the practical had been effective. The Pre-labs:
"Gave me better understanding of how to start and finish the prac appropriately".

We did not, however, gather matching data before the introduction of the Pre-labs. A further study could focus on exploring demonstrators' accounts of changes in the types of student questions before and after the introduction of such learning tools. Such an approach mirrors that of Tronson and Ross (2004, p. 13), who asked: "What do our tutors and demonstrators do?"

Conclusions

This study has highlighted the effectiveness of multimedia Pre-labs in improving the preparedness of first year students for biology practical classes. Our Pre-labs meet Johnstone and Al-Shuaili (2006)'s criterion for effective pre-laboratory work in that they prepare the students to be active participants in the laboratory through enabling them to visualise themselves carrying out the key stages in each dissection, and highlighting key concepts illustrated by the practical work. The focus on photographic images in our Pre-labs complements the primarily text-based practical manual and the oral instructions delivered at the start of class by the senior demonstrator. This blend of instructional modalities caters for the diversity of learning styles among our students. In addition, the literature suggests that better preparation should lead to enhanced learning outcomes, thus meeting ethical guidelines for instructors designing practicals based on animal specimens.

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