Engaging students and improving learning outcomes with inquiry based biology practical classes

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Abstract: *By providing tertiary students with practical laboratory experiences that are academically stimulating, students are more likely to engage meaningfully with the task and subsequently achieve a higher assessment grade. The importance of basing practical experiences on realistic inquiry is recognised throughout the literature and is more consistent with constructivist approaches to learning than traditional content driven practical activities (Cunningham, McNear, Pearlman and Kearn 2006; Myers and Burgess 2003; Zion and Sadeh 2007); tertiary educators were initially slow to change their methodologies (Sundberg, Armstrong, Dini and Wischusen 2000) but an increasing number are incorporating inquiry based approaches (Sundberg, Armstrong and Wischusen 2005) with good results and support from national science and education organizations (FitsPatrick 2004; Myers and Burgess 2003).*

We incorporated an engaging inquiry driven laboratory exercise for first year biology students and compared the average grades achieved from the resulting report with the grades achieved by the same students in less engaging 'recipe book' exercises. Student grades for combined practical assignments in which outcomes were predetermined, and the visualisation component focussed on static subjects, had a combined mean final grade of 74.01% (±15.48SD). In contrast, the average grade for the inquiry based exercise was 82.0% (±12.9SD). Surveys indicated that students not only enjoyed the new exercise format more than other practical exercises offered, but could see the value of it to their learning. We believe these results were achieved because students could not complete the new exercise if they did not engage with the task both academically and visually. These kinds of practical opportunities encourage a constructivist learning environment, which enable students to learn and gain insight into difficult concepts, in ways not possible from traditional lectures experienced in a tertiary setting. Many students expressed their interest and enthusiasm in this practical exercise, with 20% of students surveyed volunteering that it was 'the best practical of the whole semester'.

Introduction

It is well known that students who enjoy science do well in science (Kremer and Walberg 1981; Oliver and Simpson 1988; Raven and Adrian 1978; Steinkamp and Maehr 1983). Improving students' attitudes toward science can therefore not only ensure greater student interest but also potentially contribute to greater success and retention in science-based courses. As a 20% decline in student enrolments in tertiary science courses in Australian universities has been shown between 1994 and 2004 (Krause, Hartley, James and McInnis 2005) it is now particularly important to address these issues. Student attitudes may be affected by many variables; however most researchers agree that the laboratory/practical experience ranks highly as a contributing factor toward students' attitudes to their science courses (Fraser 1980; Osborne, Simon and Collins 2003). Consequently, if the laboratory and practical experience is done well, it should play a major role in influencing student attitudes and performance. In fact, it can define a student's experience in the sciences, and if done poorly, can be the major contributing factor in causing students to disengage from the subject area.

In this paper we demonstrate that, providing a constructivist learning opportunity increased student engagement in laboratory experience, resulting in higher mean grades and enhanced interest, enjoyment and learning awareness.

Materials and methods

The data consisted of open-ended response survey results and laboratory report marks of students enrolled in the first year semester topic Evolution of Biological Diversity (BIOL1101) at Flinders University, South Australia. The topic BIOL1101 incorporates six practical laboratory exercises of three hours each. In 2007, a constructivist laboratory exercise (fighting fish practical FF) was introduced that required students to complete an inquiry based task during which they partially designed and completed an animal behaviour experiment involving observation of live Siamese fighting fish (*Betta splendens*) responses to stimuli specified by students. This assignment was different from others as students were expected to perform like scientists, pose a hypothesis, collect data, and interpret the results (for example see Lynn, Egar, Walker, Sperry and Ramenofsky 2007). In contrast, the other five laboratory exercises typically were more content driven and required students to follow prescribed steps, make observations that were presented to them and had predetermined outcomes. We refer to these assignments as a 'recipe-book' style approach where students follow explicit instructions and focus only on the tasks required with little or no independent inquiry involved (for an example of this style of exercise see: Photosynthesis Laboratory Exercise, http://apps.caes.uga.edu/sbof/main/lessonPlan/LabEx.pdf).

We used the marks of the student laboratory reports as an indicator of student engagement, with the reasoning that a satisfying and engaging practical experience will be reflected in the quality of the work submitted and result in higher average grades. Demonstrators, who were also responsible for the marking, were not made aware that the student assessments would be used in this study so could not show any bias in this regard.

In addition, anonymous student survey results were used to gauge student perception of engagement relative to the new laboratory exercise. Open responses from the Student Evaluations of Teaching (SETS) for the practical component of the course included a question that asked students to comment on the Fighting Fish practical and students were invited through the Flinder University's online learning system to complete two surveys via the online platform, *Survey Monkey*. These online surveys were designed to assess student opinion and satisfaction of specific aspects of the fighting fish exercise (FF) and one other more traditional laboratory exercise concerning *Animal Diversity* (AD). Previous cohorts had indicated the *Animal Diversity* practical was not stimulating or engaging even though poor academic performance did not result from the expressed lack of enthusiasm for the laboratory exercise. The survey comments were qualitatively categorised using similar methodology to Quinnell and Wong (2007).

Results

Students' practical laboratory report marks were compared between the fighting fish exercise and each of the other practical exercises using paired t-tests (Table 1). Results indicate that on average each student performed significantly better academically in the fighting fish practical laboratory report than they did on any other laboratory report during the semester.

Figure 1 illustrates that there is no trend for increasing mean grade for the cohort, with increasing number of practical exercises, although there is an obvious increase in mean grade for the fighting fish exercise (Practical 6).

Table 1: Paired samples t-test results comparing the means of the fighting fish practical report (practical 6) with the mean marks achieved of all other practical exercise undertaken during the 2007 semester (**p<0.01).

Paired practical results	*Mean difference*	*Standard deviation*	*t statistic*	*Df*	*Sig. (two-tailed)*
1 and 6	-6.8	13.0	-10.18	396	<0.01**
2 and 6	-5.1	14.6	-6.89	397	<0.01**
3 and 6	-8.2	14.7	-11.09	384	<0.01**
4 and 6	-9.3	13.3	-13.89	387	<0.01**
5 and 6	-5.4	11.3	-9.27	382	<0.01**

The results of the paired t-tests demonstrate the significantly higher mean grade for Practical 6 (fighting fish exercise) relative to all other semester practicals (Table 1). The lack of a clear improvement in marks during the semester also indicates that the higher achievement in Practical 6 may be attributed to factors other than improvement due to skill accumulation.

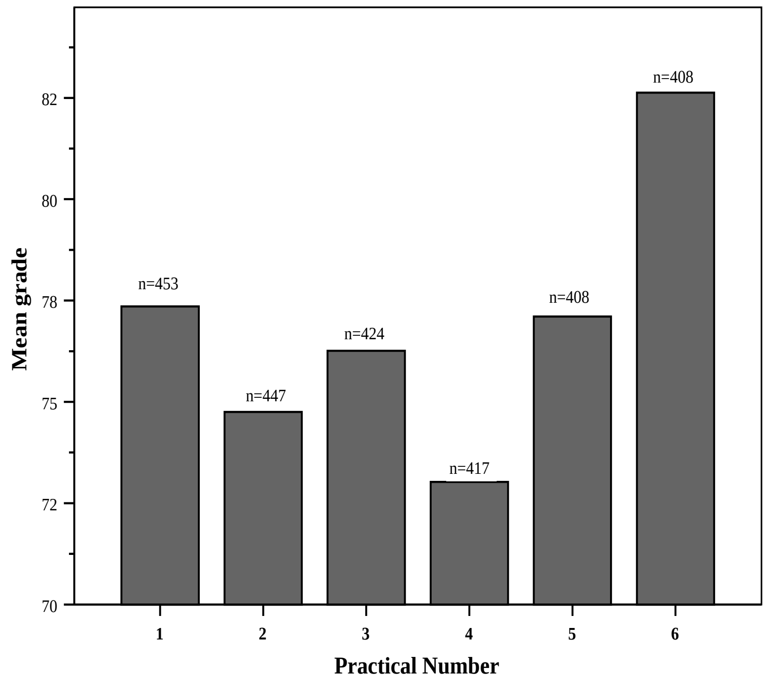

Figure 1. Mean mark for each of six practical laboratory reports from the first year semester topic Biology 1101: *Evolution of Biological Diversity* during 2007

The results from the student surveys are outlined in Table 2. The survey comments used were from a question specifically asking students to comment on how they experienced the report writing process for each exercise and was not specifically addressing the content of the exercises; however we have provided examples of students' comments in Table 2 to illustrate the pertinence of the comments for this purpose. Like responses were grouped into three categories reflecting different levels of engagement with the exercise. A student was considered to be highly engaged during the practical exercise if a comment related exercise content directly to learning experience. Responses indicative of engaged students had a task orientated focus and did not reflect on learning. The responses of non-engaged students were those that were general, unrelated, negative or superficial. Online survey results indicate that a higher percentage of students during the fighting fish exercise (FF – Practical 6) were highly engaged or engaged (33.3% combined) than during the animal diversity exercise (AD – Practical 3) (11.6% combined). Comments from the Student Evaluation of Topic - Practical Component (SETS) were categorised in the same way as the online survey results and are included in Table 2. These comments were in response to a question specifically asking students to provide feedback on the fighting fish exercise in the laboratory. A high proportion of responses reflect high student engagement (47.5%) during the exercise. On further analysis we also observed some other themes were repeatedly included in student comments on the SETS (Table 3).

Table 2. Students comments from surveys regarding the fighting fish [FF] and animal diversity [AD] exercises, and student evaluations of topic (SETS) were categorised based on three categories reflecting engagement level. Examples of comments fitting each category are provided.

Engagement level	*Percent of responses* FF n=66	AD n=43	SETS n=40	*Descriptor*	*Example comment*
Highly Engaged	*12.1*	*2.3*	*47.5*	*Focus on learning experience: illustrates that student has related to task and reflected on how it has influenced learning.*	'I found the write up for the [FF] practical challenging but rewarding – it was clear how other research could be discussed and related to our results, which helped to put the experiment into a broader context.' 'This prac was brilliant. It really helped me understand the responses of animals and how their behaviour can be affected by communication, in this case visual.'
Engaged	*21.2*	*9.3*	*30*	*Focus on task: illustrates that student has related task to achievable academic outcomes.*	'Setting out the phylogenetic tree in part D [of the AD practical] was very rewarding.' 'I understood this practical [FF], it was easier to understand, and I felt that I was on the ball the whole practical, whereas in previous practicals, I felt overwhelmed and not exactly sure what I was studying/ and why etc.' 'I appreciated having control of the experimental design process.' [FF]
Not Engaged	*66.7*	*88.4*	*9*	*Comment is superficial/general/not related to task/negative*	'It was awesome!' [FF] 'a bit too long' [AD] '[the AD practical was a] little confusing, too much content to write about'

Table 3. Thematic student comments from SETS regarding the fighting fish [FF]. Examples of comments fitting each category are provided (n=40).

Comment theme	*Percent of responses*	*Descriptor*	*Example comment*
Visual component	*35.0*	*Comment indicates that the visual component of practical contributed to engagement or learning*	'Most interesting practical for the year. Much was learned and it was very exciting to observe actual behaviour, due to our own actions. Stimulated learning in ethology.'
Live animal	*40.0*	*Comment indicates that the use of live animal contributed to engagement or learning*	'This practical was to say the least really, really, really fun! On an academic level, it was very interesting to understand the behaviours noticeable from a live subject and how stimuli would affect behaviour. Considering that I came to this practical with a toothache, this was one of the best practicals in this semester.'
Learning	*50.0*	*Comments include specific reference to learning experience*	'The Siamese fighting fish practical was crucial in understanding the mechanisms behind innate behaviour. By observing live fish a good understanding was obtained through careful observation.'

We observed that students found certain aspects of the fighting fish exercise particularly engaging (Table 3). Forty percent of students commented positively about the opportunity to use live specimens within the laboratory and 35% percent of students recognised the importance of being able to observe behaviour directly, suggesting that students recognise the importance of this type of engagement to their learning experience. This is also supported by the 50% of student comments that specifically addressed aspects of learning in relation to the fighting fish exercise, indicating a high proportion of students relating the fighting fish exercise to their own learning.

Conclusion

Practical laboratory experiences are unique to the sciences in that they allow students to gain hands on experience with the subject matter and clearly provide students with an opportunity to become highly engaged in the process. Hofstein and Lunetta (2003) stated that a significant factor that continues to reduce learning in the laboratory is the ‘recipe-book’ style that limits students’ opportunity to experience ownership, creativity or development of deep learning. With this in mind, the addition of inquiry to practicals adds considerable value with respect to student engagement, motivation and ultimately an enhanced learning experience. In addition, inquiry based practicals offer students a more realistic experience where the answer is not always predetermined and which requires students to come up with their own ideas for their observations. Although potentially more expensive and less predictable for academic and technical staff (Sunberg et al. 2000), this style of practical development will potentially outweigh its costs in that it has the potential to increase retention of students in courses that incorporate it.

The results presented above clearly demonstrate that practical design is extremely important in determining the level of engagement and the subsequent attitude and grades obtained in assessment. The clear benefit of inquiry based learning demonstrated in this paper will help the authors promote a cultural change in practical development at Flinders University. As most practicals within the school are similar to the animal diversity practical, being contemporary and incorporating hands on learning, they clearly do not provide students with the opportunity to develop ideas or to engage highly with the exercise. These practicals or ‘recipe-book’ approach to learning is widely accepted as being less effective with respect to student learning and engagement (Zion and Sadeh 2007). The fighting fish practical on the other hand, allowed for real inquiry and creativity. The higher results achieved in the fighting fish practical we believe were primarily due to students not being able to complete the exercise without engaging with the task both academically and visually; beginning with designing the experiment and developing testable hypotheses, by visualising and predicting possible outcomes, to observing and interpreting the behavioural responses of test subjects. Essentially the students were able to ‘take ownership’ of the exercise, which is well demonstrated by the following survey comment from a student: ‘The fighting fish practical was fun.......I even named my fish, which was fun but now I want to keep it which is heartbreaking because I know we can’t’.

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