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Abstract

Teaching subjects traditionally perceived as “difficult” by students, such as genetics, is particularly challenging when the lectures are only a small part of a larger module taught by different lecturers. This teaching intervention combined research-based learning techniques with group work in order to increase the motivation and participation of MSc students in learning about the application of genetics in aquaculture in a series of four lectures. Theoretical lectures were combined with a practical based on real data in order to enhance the learning of key concepts. Results of the exams indicated that the key concepts were best understood by the students when theoretical lectures were combined with a practical approach instead of being used on their own. However, results from feedback questionnaires from the students revealed that genetics was still perceived as a difficult subject.
Introduction

Research is central to teaching in the Biosciences, yet in most cases it is not explicitly embedded in the curriculum (Sears & Wood 2005). Although its potential is widely recognized (Jenkins et al. 1998), the integration between research and teaching seems to be more a desire than a reality (Gibbs 2001). In many cases, difficulties in implementing research-based teaching arise from the students' lack of knowledge of basic concepts, so that these need to be introduced by the teacher at the same time as the basic research skills (Kirschner et al. 2006). The fact that many modules are taught by a number of different lecturers with different styles and that the time available is limited in some of the shortest modules often makes it difficult to apply research-based methods. Most teaching in higher education still relies on traditional lectures, where more information can be conveyed to the student in less time.

However, it is becoming clear that - given the opportunity - students actively participate and engage in their own learning process and that of their peers (Harper & Quaye 2008). Although students' preferences and enjoyment in terms of types of learning do not necessarily reflect an improvement in their knowledge acquisition, there is a general positive relationship between the students' perception of their own learning and the actual learning achieved (Prosser & Trigwell 1990; Race 2005).

This could be particularly relevant for subjects that are perceived by the students as "difficult", especially in the area of Science. In general, students (including those coming from a science background in secondary school) tend to remember science concepts poorly (Alters & Nelson 2002) and find subjects, such as Genetics, that include mathematical ideas particularly challenging. As a consequence, students tend to avoid these subjects if possible and repeatedly question their relevance to their general topic of study (e.g. Genetics for Marine Biology) leading commonly to poor understanding of evolutionary (and genetic) principles (Alters & Nelson 2002). Genetics is a core subject in Biosciences and the challenge remains to be able to
engage students in its learning. One of the main difficulties of students in understanding arithmetic concepts (used widely in genetics) seems to be the memorization of rules and equations (Hativa 2001) and an effort is required from the teacher to make them understandable by the students. Teaching effectiveness can be further increased by including laboratory and field practices in the curriculum (Lauer 2000), and by explaining learning outcomes and procedures to the students in advance (Ramsden 1992).

Student participation has proven to be effective in improving understanding and delivery of mathematical concepts, and most importantly in changing the attitude towards mathematics-related subjects (Springer et al. 1997). Small group teaching is the ideal teaching environment for student participation in that it allows a wider range of teaching practices than is possible in large groups (Race 2005; Lorenzo & Juste 2008). This encourages active learning (Prince 2004) and the development of the necessary analytical and evaluative skills for understanding challenging concepts (Cottrell 2001). Student-student and student-lecturer interactions are also more likely to develop in small groups, and when appropriately moderated these types of interactions have proved particularly useful for understanding scientific concepts (Nelson 1994; Dotterer 2002).

In this teaching intervention I explored the idea of using research-based techniques in order to introduce two basic genetic concepts (perceived as difficult for the students) in a very short space of time (4 hours), taking advantage of the small size of the group to encourage active participation of the students in the learning process.

Learning Outcomes

The main learning outcomes of the intervention were:

1. To engage students in active participation in their own learning process by interactive small group teaching
2. To introduce the students to the concept of research-based learning, making them familiar with the end use of the key concepts
3. To change students’ attitudes towards Genetics through the better understanding of the relevance of genetics concepts to any subject in Biology

Methods

The intervention took place as part of a MSc course in “Aquaculture and the Environment” over 4 consecutive years (2007-2010). Student numbers were 6, 6, 4 and 2 for the last year. An attempt to apply the same methodology to a larger group of 3rd year undergraduates was made last year (2010) and will be repeated this year (2011) but it is not yet possible to make comparisons with the smaller group. The course consisted of a series of lecturers each giving a limited number of lectures on topics of “Advanced techniques in Aquaculture”, and the central topic of the four lectures of the present intervention was “Managing small captive populations”, involving understanding the fitness consequences of losing genetic diversity and the different ways of maintaining genetic diversity in captive populations. The two key concepts were Effective population size, Genetic diversity and their interactions.

During the first year (2007) the concepts were delivered mostly as a traditional lecture, trying to engage the students in the genetic concepts by using animated slides with a small number of equations which explained the basic ideas, rather than their mathematical development. Real examples were used, some of them from the lecturer’s own research, in an attempt to encourage questioning and discussion and increase motivation (Jenkins et al. 1998). Students were told that they would be provided with the slides used in the presentation in order to be able prepare for the exam and consequently most of them did not take notes. The results of the two compulsory exam questions indicated that:

- 66% of the students (4/6) did not understand the measurements of genetic diversity
- 33% of the students (2/6) did not answer the effective population size
question
• Marks for the two questions were below 40%

Thus, in the following year a substantial change was introduced in the delivery of the four hour lecture:

• The expected learning outcomes were made explicit at the beginning of the first lecture.
• The traditional lectures were reduced from 4 to 2 hours, in which the basic concepts of Effective population size and Genetic diversity were explained, based mostly again in real examples, some from the lecturer's own research (Appendix I).
• A practical session of 2 hours was introduced, where the students applied the newly learned concepts to a hypothetical problem of paternity assignment in aquaculture using genetic software (Appendix II). The objective was not for them to learn the use of the program but to understand the potential end use of the key genetic concepts. At the end of the practical a short assessed assignment was introduced to evaluate the degree of understanding of the key concepts. In order to encourage the students to take notes they were told that they could use their own notes for answering the assignment questions. Students were encouraged to work in pairs in order to do the practical work with the program, although the assignment questions had to be completed individually. This allowed both for student-student interactions and for individual assessment, essential to evaluate the success of the intervention.

In order to evaluate the effectiveness of the teaching intervention, the correlation between the scores of the practical assessment and the final marks of the exam questions was measured. Results of the exams were compared among successive years. All statistical analyses and graphs were performed using SYSTAT 11. In addition, as a qualitative measurement of success, a simple questionnaire was given to the students to fill in during 2009 and 2010.
Results

Exam marks

Marks were available from a total of eighteen students over four consecutive years. Given the small number of students in the later years, average marks were pooled in the years 2008-2010 (post-intervention) and compared with those in 2007 (pre-intervention). Marks after 2007 were significantly higher (mean 55.0 SD=17.2) than in 2007 (mean 36.7 SD=17.8; Mann-Whitney U=14 P=0.038). Marks by year are detailed in Table 1.

Table 1. Descriptive statistics for MSc student marks for genetics exam questions over four successive years.

<table>
<thead>
<tr>
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<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
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<tbody>
<tr>
<td>N of cases</td>
<td>6</td>
<td>6</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Minimum</td>
<td>15</td>
<td>20</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Maximum</td>
<td>60</td>
<td>75</td>
<td>70</td>
<td>65</td>
</tr>
<tr>
<td>Mean</td>
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<td>50.83</td>
<td>60.00</td>
<td>57.50</td>
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<tr>
<td>Standard Dev</td>
<td>17.80</td>
<td>23.11</td>
<td>9.13</td>
<td>10.61</td>
</tr>
</tbody>
</table>

Results from the practical assignment were positively correlated with those from the exams (Spearman rank correlation test $r=0.84$ $P=0.005$), indicating that those students that best understood the concepts during the practical, also performed better in the exam (Figure 1).
Figure 1. Relationship between marks obtained by 12 MSc students in exam questions and assignments related to genetics.

Feedback questionnaires

Feedback questionnaires were received from 6 students. They were asked to answer to 5 questions related to the content and distribution of the lectures and practicals and were provided space for further feedback (Figure 2). None of the students provided additional feedback.

Although the results were difficult to interpret due to low number of students from different cohorts, in general they provided moderately good feedback for the general appreciation of the course (Figure 3). Most students did not feel that the content of the lectures was difficult, although they considered that the delivery of the lectures could be improved (more slides with less content and examples). Practicals were considered clear and informative by half of them but only informative and not clear
for the other half and the combination of practicals and lectures only increased the interest in genetics of half of students (Figure 3).

**Figure 2.** Feedback questionnaire.

GENETICS & AQUACULTURE – Feedback Questionnaire

1. How difficult did you find the content of the lectures:
   a. Easy
   b. Moderate
   c. Difficult
   d. Very difficult

2. How did you find the balance between information and number of lectures?
   a. Too much information per lecture
   b. Enough information per lecture
   c. Too little information per lecture

3. How did you find the practicals that supported the lectures:
   a. Clear & informative
   b. Informative but not clear
   c. Not informative & not clear

4. Rank in order of preference possible improvements for the lectures/practicals:
   a. More student participation
   b. More examples
   c. More detailed methods (i.e. equations)
   d. More slides with less content per slide

5. How did the combination of lectures and practicals affect your interest in genetics for aquaculture?
   a. Not affected
   b. Increased interest
   c. Decreased interest

6. Further comments & suggestions
Figure 3. Results of feedback questionnaires about genetics in aquaculture.
Discussion

Integration of lectures and practicals, in which students can combine the learning of theoretical concepts with their practical application and may have the chance to work in groups, is used to encourage motivation, participation and student interaction (Kneale 1996) (Objective 1). In this teaching intervention, practical work was introduced in combination with theoretical lectures with the intention of engaging the students in active research (Objective 2), knowledge acquisition and group work (Sears & Wood 2005) and also to increase students’ interest in an area traditionally perceived by field-orientated biologists as “difficult” (Genetics) (Objective 3). In addition, the use of examples from the lecturer’s own research was intended to motivate student interest by generating questioning and discussion. Student participation and discussion was also encouraged by group working. Working in pairs was promoted to induce discussion within the pairs and also with the whole of the class (possible in a small class), with the objective of increasing confidence in contributing (Lyman 1981). Student participation and response, as well as student-student interactions during the lectures, increased when practical sessions were introduced. It was expected that the effectiveness of the strategy would be maximized by the introduction of the learning outcomes and procedures during the first lecture (Ramsden 1992). Students were told what concepts they were expected to learn and how they would be assessed on them. After the assessed practical was introduced, students actively took notes during the theoretical lectures and shared them during the practicals, in contrast with passiveness of the first year. They also engaged more actively with questions and were encouraged to discuss the answers among each other. The general environment of the class became more participative.

The exam and assignment marks indicated that students understood the two key concepts better with the combination of practicals and lectures than when only traditional lecturing was used. However, the responses from the questionnaires indicated that the perception of the students of their own learning was different. Only half of the students felt that the lectures had increased their interest in the topic and
they still considered genetics difficult. Some students also thought that there was need for improvement in the lecturing style/performance, although no specific comments were provided. Student perception of the effectiveness of a particular teaching strategy and their enjoyment of the learning process does not necessarily reflect the real learning progress, and in general perception and learning correlate best in deeper learners (Prosser & Trigwell 1990). Considering the small number of students assessed by the questionnaires, it is difficult in this case to evaluate the correlation between perception and real learning, especially because the students belonged to different cohorts. However, exam results and class participation suggested that the substitution of theory by more practical sessions was at least benefiting the acquisition of key concepts and the class environment. On this basis, a similar approach was used in a larger group (25 students) of third year undergraduates in Marine and Freshwater Biology for the first time last year. A simplified practical, similar to the one used with MSc students, was introduced in the lectures of fish genetics of the 3rd year module on Fish Biology with the intention of reinforcing key concepts. Results will only be comparable after this year but the larger number of students will allow more robust statistical comparisons.

A disadvantage of the approach that could be raised is that in terms of contents the intervention involved a reduction in the amount of information provided to the students in exchange for a reinforcement of the two main concepts. Future developments, particularly in the undergraduate module, would involve the combination of practicals with theoretical lectures in other key topics (e.g. quantitative genetics) and the use of student pairing to encourage scientific reading that would introduce key concepts that would later be reinforced in the practicals.