Practice and Evidence of Scholarship of Teaching and Learning in Higher Education
Vol. 3, No. 1, April 2008, pp. 57-67

Discovery-based Functional Genomics Laboratory For a Biology Programme

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Abstract

Our current practice at Hong Kong University of Science and Technology, HKUST, in both the Biology and Biochemistry departments is to provide laboratory experience to our undergraduates mostly through large class laboratory courses. The exercises performed therein are often very structured where specific cookbook-like manuals are followed. Students lack the opportunity to conduct or experience independent research until they reach their final year, where their final year project offers them the first hand experience through apprentice-style research activity.

To increase the quality and range of learning opportunities to first and second year undergraduate biology students, we launched a discovery-based molecular genetics course. This type of discovery-based education is unique in Hong Kong. It provides students anticipating a research career the opportunity to have a glimpse of the operation of a research lab. This course enabled our undergraduate students to have hands-on experience on conducting experiments with undefined outcomes. The

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ISSN 1750-8428 (online) www.pestlhe.org.uk

students started with a genetic mutant screen with the nematode, *C. elegans,* looking for a broad spectrum of developmental defects. The use of this simple model organism offered the flexibility for the student to explore a range of biological features. They then characterized the mutant isolates of their choice by developing their own hypotheses, critically thinking of their research foci and strategy with the advice of a team of tutors made up of post-graduates. The students were all enthusiastic and self-motivated about their individual projects. Within a short space of time they learnt different genetic, molecular and cellular techniques, bioinformatics as well as how to conduct scientific literature searches.

Keywords: Discovery-based learning, first year undergraduate research, independent projects

Introduction

Discovery-based science education has been deemed as an effective approach to arouse students' interest in science education (Garrison, 1999; Chen et al, 2005). However, it has not been actively pursued in schools or other tertiary institutions in Hong Kong since the effectiveness of such a programme can only be evaluated over a long period of time and is often viewed as a project that demands both heavy human resources and supporting facilities.

Nevertheless, setting up such a programme is not an un-accomplishable task. Hazel and Baillie (1988) give a good introduction on how to develop laboratory courses in higher education using investigative and project teaching methods to improve the teaching quality. With funding from the Howard Hughes Medical Institute in the US, problem-based courses have been developed since the end of the last century (Garrison, 1999). Successful projects involving a small group of students with one-to-one supervision have made its way into the regular university curriculum at the University of Delaware (Perry, 2000) and the University of Alabama (Powell, 2005).

Indeed, a similar project but on a larger scale has been launched at the University of California, Los Angeles under the support of the UC system and the HHMI (Chen et al, 2005). In that study, close to a hundred students successfully engaged on a genetic research course with a focus on fly eye development which was run throughout the year. We saw that the same model could be adaptable at HKUST, should sufficient interest be identified in the programme development team and the students.

As part of a team in curriculum development, we see that many of our students indeed deserve an earlier exposure to research experience. Such a course would complement the existing teaching laboratory courses run in large classes which use a more conventional cookbook–style approach.

Objectives

For simplicity's sake and to allow flexibility to develop a variety of different projects, we adopted a large scale genetic study initially. Such a genetic screen typically conducted in the research laboratory, using the nematode as the model organism, would offer no restriction on the area to be selected for follow-up experiments. Because *C. elegans* is a widely-used model organism in biological research (it was the first animal species whose entire genome was sequenced) (The Sequencing Consortium, 1988), instructors and interested students would be able to find a wealth of information about this organism, for example, Riddle, Blumenthal, Meyer, & Priess, 1997; Wormbook and Wormbase (A *C. elegans* online database with constant update).

The students could develop their own directions of research interest and gain unique laboratory experience under a confined framework of a biological question. The course offers a broad scope from genetics, cellular and molecular biology, biochemistry, developmental biology, bioinformatics and behavioural science. They develop their own hypotheses and make decisions about the appropriate experiments under the guidance of the instructor and graduate teaching assistants.

For operation of the project, lab space, basic equipment/facilities and managerial assistance were required. The specific objectives of the project included:

A. Setting up a small functional teaching/research lab facility with research capability for 10-15 undergraduate students and test running this genetics course.

B. Producing an experimental manual with multiple chapters, each of which is dedicated to a specific experimental approach/technique.
C. Understanding specific issues of the operation of this course, to streamline the administration, to solve the problems encountered and to develop a scaled up version for long term implementation in our biology curriculum.

The course involved conducting a genetic screen of a microscopic nematode, *C. elegans,* to identify mutants with specific morphological, developmental or behavioural anomaly. Each student went through the process of discovery by isolating their own mutants in a mutant screen. Since each student had his/her own mutant, this gave them a sense of ownership and enhanced their motivation towards learning and characterizing their own subjects. The students learnt various molecular biology and genetic techniques by doing actual research. Before the running of this course, we did not have a laboratory dedicated for such combined genetics, cellular and molecular studies. Therefore, the test running of this course also served as a pilot scheme to teach genetics in a more integrative approach.

Course Format

Hong Kong University of Science and Technology's BIOL200 molecular genetics course was first introduced as an undergraduate discovery-based laboratory elective course designed for biology first and second year students. There were three parts to the course, starting with BIOL200 A in the first semester, whereby students could choose to continue with 200 B and C in the following semesters (Figure 1). Each student had an independent project. Two credits were assigned for each course with a pass or fail grade. We did not introduce a letter grade here to avoid imposing a strong criteria-dependent assessment of their achievement. Instead, we aimed for the acquisition of the ability to be independent during research, which was monitored through various assessment tools, such as group discussion, literature reading, journal club presentation and discussion, project presentation and instructor-student communication.

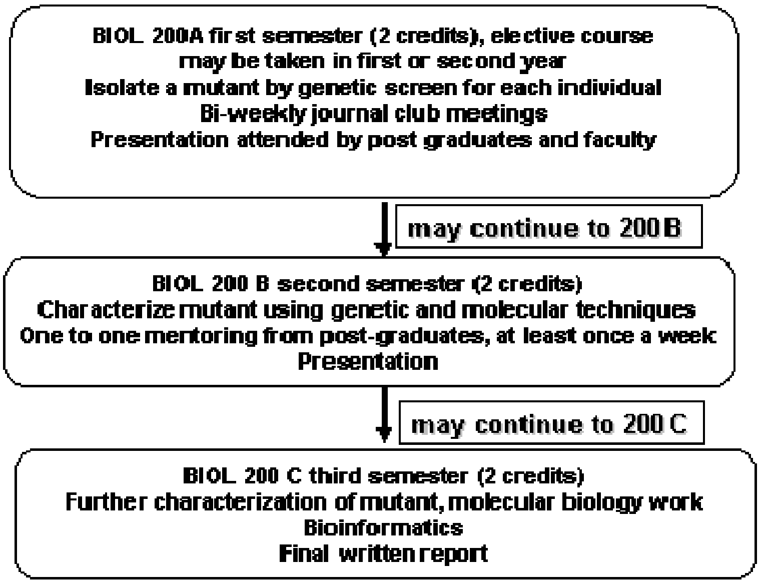

Figure 1 Course structure

The BIOL200 course was run for over a year from the Spring semester 2006 until the Spring semester 2007 (Figure 2). Some students did not continuously take all three courses, because they had to participate in an exchange programme abroad for one semester. This did not affect their research project, however, since the worms were frozen and thawed out again when they returned. The participating students were all biology undergraduates and were initially selected based on their academic performance and this was followed by a brief interview after a prior course briefing session. The purpose of this selection interview was not to identify elite students, but to ensure that all participating students were committed to the course as part of their extra-curricular time. Only 2-5 students were enrolled per course to keep the course manageable.

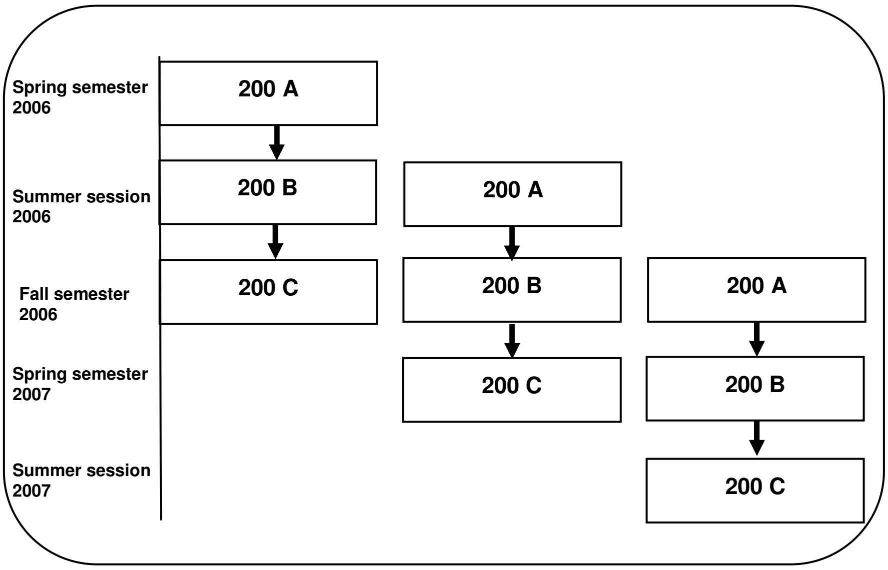

Figure 2 Course schedule

After students have screened and identified a mutant, they had to characterize the mutant with help from their post-graduate teaching assistants (TAs), instructor and PI in charge of this project (Figure 3).

In the lab, they are required to do basic lab routines including seeding and pouring of plates and culturing worms. They use dissecting microscopes to sex and identify the different stages the worms and to recognise the different phenotypes.

Figure 3 Students working in the lab trying to identify their favourite mutants.

In the genetic screens, five students generated 50 mutants after two rounds of screening. After obtaining a mutant, they had to think about what to do with it. This was quite challenging for them. The students had to do a literature search with the help of the TAs about their mutants first, before they could characterise them. The students were not expected to get results for a publication, but were expected to go through the process of learning how research is done and how to think critically.

A laboratory manual was written to aid them in designing their experiments. The instructor was based in the laboratory and helped with the technical problems. Advice was given from TAs for the direction of research from preparation and planning to gathering data, documentation, evaluation, interpretation and finally an oral presentation. The TAs did not give instructions, but only facilitated the learning process. A weekly discussion was initiated between the mentor TA and student pairs. Journal club was held bi-weekly in which the students in the first semester were given topics for discussion from journal papers which were related to genetics in general. In the second semester students were allowed to pick any topic of their choice to broaden their scope of reading in science. At the end of each semester, students had to present their results in an oral presentation session, and post-graduate students, professors from the department, the Dean of Science and evaluators from CELT (the Centre of Enhanced Learning and Teaching) were invited to attend. At the end of the 3 courses, a formal written report was required for documentation, and more importantly for enhancing their scientific writing skills. In the final report, students were also asked to reflect on their learning experience, which collectively provides a summative feedback on this exercise.

Feedback from the students

In general, the students commented that they had developed a totally new perspective in research after the course. Students learnt how to be patient, focusing on the subject of study, asking precise scientific questions, learning to think critically, how to cope with problems and frustration and come up with a solution. One remark made by a student was,

> *"It was amazing to have my first hands-on experience as a researcher. I have to admit that I was frustrated throughout the whole process. However, I began to think that this frustration is actually*

good. It helps us to realize the situation, and makes us think what is going wrong…".

Another student remarked that

> *"Through hands-on experience, I have the knowledge of how mutations are transmitted to next generation. A connection is established between the real world and content in the textbooks".*

Another one claimed,

> *"This project is an independent work. It is also a group work. We can get the help with our classmates. We teach each other and learn from each other. No one can learn everything, but everyone can be a teacher."*

They all indicated that they had made a significant improvement over the course of this project coping with various hurdles which demanded much independence, organizational skills, literature research, communication/presentation skills, and most importantly time management. Time management was an important factor since they had to fit the research work into their schedules. During the examination periods, it was quite difficult to spend the desired amount of time on their research projects. Outside these times, however, the students felt they were quite self-motivated and wanted to engage in the experimental work in the laboratory as much as they could.

The exposure to research literature has also opened up their minds in terms of the needed preparation of basic knowledge and the demand of both the depth and breadth of understanding. The bi-weekly journal club helped tremendously to enforce this aspect and brought about encouraging results. The end of semester oral presentations as well as the lab report were important for the students to learn how to convey scientific information in a succinct manner with sufficient elaboration.

As a result of the project experience, all the students have enjoyed their research experience so much that they have all selected to join research labs in their final year.
Indeed, it was a learning experience for the TAs as well, since it was the first for many of them to act as mentors. They learnt how to lead the student to think instead of giving out the answers straight away. This experience enabled the TAs to appreciate what education was about from a totally different perspective and to have a better

understanding of the student and mentor relationship. The experience evidently offers them a good opportunity in their personal growth as well as some essential skills to enhance their own career development should they be considering a research or a teaching career.

Problems Encountered

No project in its first trial would run smoothly without encountering some difficulties. This project indeed had to overcome major hurdles. Finding lab space dedicated to undergraduate research and setting up a new laboratory took over 8 months.

It is conceivable that when the course develops over time, the continued supply of TAs with the appropriate background knowledge to act as mentors could be a problem since each student is developing their own project, which does not necessarily match with the specialty of the graduate student TAs of this course. Recruitment of permanent TAs who have worked on different genetic model organisms used in this course would be an ultimate solution. This issue should be considered in the next phase of development of this project. Having senior undergraduates to participate in the mentoring process of juniors would also be beneficial.

Development of discovery-based course

Due to the success of the course and the convincing educational rationale behind it, the project has been well recognized by the university, and has been incorporated into the new BSc Molecular Biomedical Sciences (MBMS) undergraduate programme. This new operation represents an elite programme for students who wish to have a career in research. This discovery-based genetics course will give these students a head start to conduct research in their first year. To sustain the course and to further develop the programme to include diversity of exposure, additional modules using other organisms are planned. Apart from the worm module, yeast and zebra fish modules will be developed as an extension package. Therefore, other members of the Biology, Biochemistry and Chemistry Departments will be involved. This new programme has an initial intake of 11 students in this academic year (2007/08). They are taking part in this project course now, and we hope to expand this operation to have a larger cohort of around 20-25 for the next academic year. In terms of support, more TAs, financial aid as well as more laboratory space would be required. Discussions at the departmental and university level committees are in progress to secure funding for implementing the expansion.

As a summary, we have shown that it is feasible to set up a discovery-based course with limited resources to nurture a small cohort of students with research interest. These students at the early university years can engage in active research driven by their own interest, instead of serving as followers. The sense of ownership of the project certainly provides a strong driving force for their pursuit of knowledge and to equip themselves. While this discovery-based course is unique in Hong Kong's tertiary education, we strongly believe in the effectiveness of this pedagogy to bring about the scientific curiosity and the best out of our students. We hope that with its success, more discovery-based courses in the future in our university as well as other universities in the region will be developed.

Acknowledgements

This work was supported by the Teaching Development Grant (project code 00387S) from the Centre of Enhanced Learning and Teaching (CELT), School of Science and the Department of Biology. We would also like to thank Bonnie Tsang and Michael Chau of CELT, and the team of teaching assistants from the Chow Lab for their support throughout the course development.

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