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Twenty Years of An Inquiry-Based Lab: Does It Work?

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Extended Abstract

Can large numbers of first-year students design and implement their own experiments in biology? Twenty years ago we developed a lab program where cohorts of 600 to 1,000 students are guided through an inquiry-based approach to answering biological questions. Our goal is for students "to apply the scientific process and to develop and practice scientific thinking". We guide students to think like scientists by having them pose hypotheses, design and modify their own experiments, and analyze and interpret their results in a biologically meaningful manner.

Inquiry-based educational experiences in science are set in a variety of contexts and are structured with different levels of support (for example, D'Costa and Schlueter, 2013). Undergraduate research experiences (URE) where students are integrated with research labs can accommodate relatively small numbers of students (Heitz and Giffen, 2010, Lopatto, 2010, Wood, 2003). Guided-inquiry experiences in class may be more structured and implemented for larger numbers of students. We developed a course-based research experience (CURE) that was not content based but rather focused on the process of experimental inquiry (Hanauer and Dolan 2014). One of the implicit goals of the course was to appreciate the Nature of Science (NOS) by "doing" Science.

In the intervening years there has been a growth in the scholarship of teaching and learning with teacher practitioners publishing their in class action research regarding the importance of inquiry in the form of commentaries, reports and research (Heitz, 2013, Wallace et al., 2003, Wood, 2003). In parallel there has been increasing interest and motivation to enhance STEM education (Fairweather, 2008). In general there is a movement to increase an awareness of the NOS, especially the tentative aspect of scientific knowledge that is continuously evolving. Students who experience inquiry-based labs will have the opportunity to practice thinking like a scientist; early exposure to inquiry-based labs forms the basis for more sophisticated scientific thinking in subsequent years of study (Derting and Ebert-May, 2010).

In our course we introduce students in the first year of the undergraduate program to experimental design. Despite the large numbers of students we provide a structured "authentic" experience within the real limitations of time, space and equipment. Initially students become familiar with one of three local ecosystems to inspire questions about the response of organisms to changes in the environment. Student research groups, typically of four students, are randomly assigned to investigate one of six common species from that environment. Following instruction on experimental design and data analysis the groups decide on a factor that is relevant to their species and design an experiment based on one of two templates, either a 'measured-response' or a 'choice' experiment. The students then request the equipment, materials and organisms necessary to implement the experiment for two separate three-hour lab periods. Using basic statistics, the students determine whether their results show significant effects of their factor and provide a biological explanation of their results in both written and oral format.

Table 1. Sequence of inquiry-based lab activities within a 12 week course.

Week	Lab activities	Writing and assessments
1	Introduce ecosystem variation in abiotic factors assign and observe experimental animals	Paragraph describing their experimental animal
2	Review experimental design and equipment practice manipulating their animal brainstorm and develop question	Peer review paragraphs
3	Present proposal for experiment revise plan, develop outline of experiment, order equipment	Introduction to experiment
4	Trial 1	
5	Trial 2, review data analysis	
6	Tutorial on group data analysis	Methods and Results
7	Exam	
8	Oral presentation of experiments	Final compiled report with discussion

Does it work? To answer this question we surveyed the students for their perceptions, measured student learning gains using concept inventories and looked to the literature. At the end of each term students provided their opinions on the value of the course through course evaluations. In addition to knowing more about how abiotic factors affect their research organism (97% agree), students indicated that they learned how to conduct scientific experiments (91%), think more analytically and critically (70%) and know more about the process of scientific research (80%). We also held three focus groups where students told us that although they learned a lot, the course was too much work especially in comparison with lecture courses and it was too much effort for so few credits. However, when we encountered students that had taken the course previously and were in their senior year of study, they expressed appreciation for the research and experimentation skills they had learned in their first year.

In addition to course assessments, learning gains were measured using two concept inventories: the *Experimental Design Concept Inventory* (BEDCI) (Deane et al., 2014), and the *Results Analysis Concept Inventory* (RACI) (both are available through Q4B, Questions for Biology http://q4b.biology.ubc.ca/). The student cohorts that completed the concept inventories indicated a significant overall learning gain in both experimental design and analysis of results. We are not alone in finding that inquiry-based laboratory experiences are effective. Other science educators have also found that inquiry-based lab experiences promote scientific thinking (Derting and Ebert-May, 2010, Haury, 1993, Heitz and Giffen, 2010, Hofstein and Lunetta, 2003, Lopatto, 2010, Wallace et al., 2003).

The course has evolved over the last 20 years and we have learned many lessons. In order to deliver an inquiry lab experience to large numbers of students we need a dedicated teaching team. To counteract student resistance to the work involved in undertaking a research project we need to be explicit about the course goals and the skills they will learn. When students understand the reasons for our pedagogical choices they are willing to accept that inquiry-based lab experiences are of value. This course is one step in achieving the goal of helping students develop critical thinking and inferential skills and become scientifically literate.

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