Chapter XXXII
A Learning Design to Teach Scientific Inquiry

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ABSTRACT

This chapter reports the authors' experiences of developing a learning design to teach scientific inquiry, of integrating the learning design with learning objects to create online inquiry projects, and of investigating student attitudes following implementation in second year biochemistry units at a major Australian university. We discuss constructivism, problem based learning (PBL), and inquiry learning as the philosophical and pedagogical approaches informing the learning design, and highlight how critical components of each approach were transformed into a learning design. We specify the learning design and highlight its important features. The claimed efficiencies of the learning object approach were evaluated during the development phase. Outcomes reported here indicate that reuse was most cost effective if many, elaborate learning objects were reused. Little benefit was gained by the reuse of many, simple learning objects. Finally, student perceptions indicate benefits from the inquiry projects that warrant their inclusion in a traditional teacher-centred course.

INTRODUCTION

The learning of science is not only about the acquisition of knowledge regarding scientific principles, theories, and concepts, but constitutes an understanding and appreciation of the scientific method of inquiry—how science is accomplished. The laboratory has traditionally been the primary domain for teaching methods of science. In the 1970s, the promotion of scientific thinking and the scientific method was considered to be one of the five major goals of laboratory teaching (Shulman & Tamir, 1973). Hofstein and Lunetta (2003) have since pointed out that the "uniqueness of the laboratory lies principally in providing students with the opportunities to engage in processes of investigation and inquiry" (p. 203).

However, with regard to teaching scientific inquiry, it is still not clear precisely what features of laboratory learning promote student understanding of these processes or, more importantly, whether understanding actually improves following laboratory experiences. In the past, research studies that compared the effects of practical work in the laboratory with other teaching approaches such as discussion groups, demonstration groups, computer simulations, and filmed chemistry experiments found no significant differences in student achievement, attitude, critical thinking, and in knowledge of the processes of science (see review by Hofstein & Lunetta, 1982). Significant improvements, however, were found in the development of laboratory manipulative skills.

Hofstein and Lunetta (1982) are critical of prior studies for poor control of variables, small group size, limited validity of the instruments chosen to measure effect, failure to consider teaching behaviour, and low quality of laboratory manuals. Nevertheless, when viewed with caution, the studies point to the fact that the major strength of laboratory work may lie in the teaching of technical skills (e.g., handling and operating equipment) and practical abilities (e.g., report writing), rather than achieving more abstract learning objectives such as the conceptual understanding of scientific inquiry processes.

The personal experience of one of the authors, who has taught science to tertiary students for over 15 years, tells a similar story. Despite regular sessions in the laboratory, students find it difficult to grasp the notion of a process that guides the progression of scientific inquiry, and which may include: making observations, defining research questions, gathering information, forming hypotheses, performing experiments, collecting, analysing, and interpreting data, drawing conclusions, and communicating results. With little or no understanding of this iterative process, students have difficulty recognising which stage of the process they are undertaking or identifying the next step in the investigation. Therefore they rely heavily on direction from educators or written laboratory manuals.

Along with an understanding of science facts and an understanding of the scientific method of inquiry, a third goal of learning science is the development of intellectual skills necessary to perform competent investigations. Also referred to as "problem solving skills," "science process skills," "scientific thinking," the rationale behind developing these skills is to provide training for would-be scientists (Zachos, Hick, Doane, & Sargent, 2000). In terms of the learner, the distinction between the latter two goals of science education is, in the first case, knowing the sequence of steps to take to perform an investigation, and second, having the cognitive skills to perform them.

Within the context of his work on technological advances in inquiry learning, de Jong (2006) noted that, "[s]tudies of young students' knowledge and skills indicate that many students in large parts of the world are not optimally prepared for the requirements of society and the work place" (p. 532). In Australia, this concern has been expressed about science students at tertiary level, "few students appear to have developed expert problem solving skills that enable them to cope effectively with learning independently and effectively in the sciences" (Hollingworth & McLouglin, 2001, p. 32). The concern that many tertiary-level science students lack the higher order thinking skills (e.g., problem solving) to enable them to carry out competent investigations, is reiterated by the authors.

Given the problems outlined above, there is an argument for the use of formats other than the