Scientific inquiry: Where is it in the educational technology landscape?

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This paper describes some of the challenges facing science educators at tertiary level. It subsequently introduces a project supported by the Australian Learning and Teaching Council (formally Carrick), which aims to investigate the effective use of educational technologies to promote understanding of scientific inquiry and development of skills necessary to conduct successful investigations. The project will use a qualitative research framework to examine current practice and to determine best practice in teaching scientific inquiry skills to bioscience students. Study findings are expected to provide guidance on developing skills in the next generation of bioscientists.

Keywords: scientific inquiry, scientific method, scientific inquiry skills, problem solving skills, educational technologies

Background

Concerns have been raised that students studying science subjects at tertiary level in Australia have little understanding of the overarching process that guides the progression of scientific inquiry. Moreover, many students appear not to have sufficiently developed the skills necessary to conduct competent investigations (Elliott, Sweeney, & Irving, 2008; Hollingworth & McLouglin, 2001). The process by which scientific endeavour is achieved is known historically as the scientific method and generally involves: Recognising and defining a problem, Formulating hypotheses, Collecting data (through observation and/or experimentation), Testing hypotheses, Drawing conclusions and Communicating results (Bunge, 1967). Although debate is ongoing as to the exact nature of scientific practice, including different models of scientific inquiry (Wong & Hodson 2008), for the purpose of this paper we will use the definition of scientific inquiry outlined above.

Traditionally, the laboratory was the primary domain for teaching methods of science and because of the opportunities the laboratory afforded for students to engage in processes of investigation it was assumed that they would develop scientific inquiry skills during laboratory teaching sessions (Hofstein & Lunetta, 2003). More recently, it has become clear that exposure to limited views of investigative science in the laboratory can lead to misconceptions by students about the way investigations are conducted (Windschitl, Thompson & Braaten, 2008). Furthermore, calls continue to be made for more authentic science education experiences that share commonalities with the real world practices of the scientific community (Wong & Hodson 2008). Given these challenges in science education, there is an argument for investigating alternative pedagogical approaches to promote understanding of the scientific method of inquiry and to develop skills necessary to conduct successful investigations.

The purpose of this paper is twofold. We wish to inform the ascilite community about a project *Educational technologies: Enhancing the learning of scientific inquiry skills for bioscience students in Australian universities*, supported by the Australian Learning and Teaching Council (formally Carrick), which will investigate issues outlined above. Secondly, we would like to invite participation in the project from interested bioscience educators in the community.

Project aims

The project will examine current pedagogical approaches used by science educators, to determine best practice in promoting understanding of scientific inquiry and development of related skills. Because of project members' experience as practicing bioscientists, the investigation will be framed within science disciplines dealing with biological aspects of living organisms (e.g. agricultural sciences, botany, biochemistry, pharmacology, zoology). To ensure a broad range of educational contexts are examined, the project brings together members from four major Australian universities: The University of Melbourne, Monash University, LaTrobe University and the University of Queensland.

The primary aim of the project is to identify the role that specific educational technologies play in effectively enhancing the learning and teaching of scientific inquiry skills, and to determine the educational context of their use. Furthermore, an evaluation framework will be developed to assist educators in determining the effectiveness of specific educational technologies.

Educational technologies to teach scientific inquiry skills

For many years computers have been used to create environments that engage students in scientific inquiry activities. There are many examples of how computers are used for scientific inquiry activities including: computer simulations that present natural phenomena or processes for manipulation; support tools that help students gather, organise, visualise and interpret data; collaborative tools that allow students to communicate and to share data and ideas; and computer-based modelling tools that allow students to express their theories as models. More recently, efforts have been made to develop scaffolds or cognitive tools for computer environments, which support students through the inquiry process.

The design of many of these applications are informed by principles of inquiry learning, for example, the Knowledge Integration Environment (Linn, 2000) and Hiking across Estonia (Pedaste & Sarapuu, 2006). Inquiry learning focuses on the use of real world inquiry activities for students and is described as the process of solving a problem through exploration of the natural world: asking questions, making discoveries, rigorously testing these discoveries in the search for new understanding (National Science Foundation, 2000). Supported inquiry learning has been shown to be an effective mode of learning (van Joolingen, de Jong & Dimitrakopoulou, 2007). Another approach to the design of educational technologies to teach scientific inquiry skills is to integrate Problem Based Learning (PBL) procedures (Elliott, Sweeney & Irving, 2008). PBL also focuses on the use of real world inquiry activities for students, and uses authentic problems as a context for small student groups to acquire factual knowledge, learn problem solving skills, and develop self-directed or lifelong learning strategies (Norman & Schmidt, 1992).

Within the context of higher education in Australia, the extent to which bioscience educators explicitly teach scientific inquiry skills (and related generic skills) to their students is currently unclear. While there are examples of educational technologies being used to support the teaching of scientific inquiry skills and problem solving processes (Elliott, Sweeney & Irving, 2008; Galea, Stewart & Steel, 2007), more evidence needs to be collected on the effectiveness of tools and how widespread their use is in bioscience disciplines.

Skills for bioscience research

The focus of this project is on the acquisition of skills required to conduct scientific investigations within bioscience disciplines. While many essential skills have been identified (Zachos, Hick, Doane & Sargent, 2000), of major importance is proficiency in the scientific method of inquiry, as defined within the scope of the project. This is a specific procedure for handling scientific problems and generally involves the following components: (1) Problem analysis (i.e. defining a research question), (2) Hypothesis formulation (i.e. a suggested explanation of a phenomenon), (3) Prediction of logical consequences of hypothesis (4) Inquiry planning (i.e. how to test for logical consequences), (5) Hypothesis testing (i.e. performing experiments, collecting, analysing and interpreting data), (6) Drawing conclusions and (7) Communicating results (Bunge, 1967). Although this description suggests a linear progression, scientific inquiry is cyclic in nature. In fact, an entire cycle can be thought of as the gradual accumulation of scientific knowledge over time, often requiring repeated experiments by multiple research groups across the globe. The global nature of scientific inquiry underscores the importance of communication between individual scientists and the wider scientific community.

Project methods

The project will employ a qualitative research framework and will begin by conducting semi-structured interviews with tertiary educators in a range of bioscience disciplines. Rich information sets will be collected that detail: pedagogical approaches used to encourage skill development (e.g. case-based and problem-based learning, inquiry learning, discovery learning); specific educational technologies used to encourage skill development; specific skills educators are expecting to develop in students; activities and tasks used in pedagogical approaches; tools or resources used to support teaching; how closely teaching supports are integrated into the curriculum; size and type of student cohort, and; evidence of improved outcomes for students. Observational studies of laboratory or classroom sessions will be conducted to identify tacit expert knowledge that educators do not express in the interviews, but may be evident in their teaching.

In the second phase of the project, learning designs of effective pedagogical approaches will be created from descriptions given by educators in interviews. Learning designs will describe critical components of pedagogical approaches and will demonstrate if and how technology and pedagogy are integrated. During this stage, identified technologies will be critically analysed to determine beneficial features, such as, flexibility, accessibility, multi-mode representation of information. The reason for this focus is to allow future users to judge the value of using a particular technology in their own educational context. This point might be particularly relevant, if for example, a large group educator is considering using a technology that has only previously been used with small tutorial groups.

In the third phase, the project will build on existing learning evaluation models (e.g. Reeves & Hedberg, 2003) to develop an evaluation framework to assist teachers in determining the effectiveness of a chosen educational technology in their own educational context. The evaluation framework will primarily focus on measuring changes in students' knowledge and skills following the use of an intervention in a classroom activity. It will have both a quantitative and qualitative component and will be validated using technologies identified earlier in the project.

An objective of the project is to disseminate the findings to the wider community of bioscience educators in higher education. As such, potential users of project outcomes will be identified and involved in the project at all phases. For example, during the interview phase, educators from collaborating institutes will be made aware of the intended outcomes of the project and how they might make effective use of them. Following this phase, a set of recommendations will be made available to educators and round table discussions will be held to obtain their feedback and reflections. Further strategies to promote the transfer of knowledge and tools developed in the project include, conducting a series of workshops for educators, creating a project website from which educators can access practical tools and resources, and writing a handbook of recommendations and guidelines that is freely accessible from the project web site.

Conclusions

The project's approach is to identify best practice in teaching scientific inquiry skills, particularly the effective use of educational technologies to promote understanding of the scientific method of inquiry and to develop skills necessary to conduct successful investigations. Through the pedagogically sound use of proven educational technologies it is expected that bioscience graduates will enter the workplace better equipped with the skills to conduct investigative research.

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