Chapter 24

The Effectiveness of an Inquiry-Based Computer-Simulated Lesson in Physics

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ABSTRACT

Robust as they are, the existing instructional design prescriptions (Reigeluth, 1983; 1999) which are content-based, expository- and individual-oriented, and generally technology-free are of little use when the task is to design inquiry-based computer-simulated lessons for teaching scientific thinking skills in cooperative learning environments. Thus, the aims of this study were to design a computer-based simulation lesson employing currently available PC and internet software and investigate its effectiveness in various learning situations. The heart of the lesson was the utilitarian Gas Law Simulation program developed by Abraham, Gelder, and Haines (2002) that was incorporated into a hypertext interface display with active links to related notes and worksheets and a superimposed Microsoft Excel table and chart-plotting facility. This package allowed students to review the concepts involved and see relationships between the variables in graphical forms when a selected independent variable was manipulated and all the corresponding values were keyed into the Excel table. A science process skill and HD thinking worksheet was drawn following Lawson’s (1995) prescriptions and the questions and activities were further modified to fit the local syllabus and physics texts. A pilot study was conducted to evaluate and refine the lesson and field testing was conducted using a 3 x 2 factorial design. The first factor was the inquiry-based computer simulation lesson with three modes of cooperative learning, namely, heterogeneous-ability cooperative learning (HACL) group, friendship-based cooperative learning (FCL) group, and traditional group work (TGW) group. The HACL and FCL group were trained following the Kagan (1994) Cooperative Learning Structure while the TGW group which was essentially another friendship-based learning group was not instructed on the Kagan (1994) Cooperative Learning Structure.
The Effectiveness of an Inquiry-Based Computer-Simulated Lesson in Physics

The second factor was student reasoning ability, namely, empirical-inductive (EI) and hypothetical-deductive (HD) abilities. The sample consisted of 301 Form Four (16-year-old) science students. The results showed that students in the HACL group significantly outperformed their counterparts in the FCL group who, in turn, significantly outperformed their counterparts in the TGW group in scientific thinking and conceptual understanding. The study found that the inquiry-based computer simulation program was effective in enhancing scientific reasoning and conceptual understanding of students of all reasoning abilities but for maximum effectiveness cooperative learning groups should be composed of students of heterogeneous abilities.

INTRODUCTION

Computer simulations are computer-generated dynamic models that present theoretical or simplified models of real-world components, phenomena, or processes. They can include animations, visualizations, and interactive laboratory experiences. Learners can observe, explore, recreate, and receive immediate feedback about real objects, phenomena, and processes that would otherwise be too complex, time-consuming, or dangerous to follow. Computer simulation programs are available for classroom use but they are either within proprietary softwares or offered as bits and pieces of presentations within some websites. Either way, their pedagogical value is unclear as the teacher has no control over how they are used and how the students navigate or choose the learning paths to explore the ideas presented. In developing his or her own computer-based lessons, a teacher who is usually not an expert programmer may spend ninety five per cent of his or her effort on software issues and only five per cent on pedagogical issues. A quick solution for the teacher is to use hypertext documents (HTML files) to integrate the computer simulation packages and offer a the path of learning employing easily available interactive graphic interfaces, three dimensional buttons, arrows, and labels with a minimum of time effort. The use of hypertext documents lets the teacher concentrate on the conceptual or pedagogical issues.

A major pedagogical oversight in the teaching of science with technology or with computer support is the use of expository methods of delivery while science concepts are better learned using inductive methods. One inductive method for teaching science is the use of the learning cycle (Lawson, 1995). The Learning Cycle approach is an inquiry-based teaching model derived from constructivist ideas of the nature of science and Piaget’s (1970) theory of cognitive development. The Learning Cycle approach begins with students identifying the possible variables at work, generating causal questions and suggesting alternative hypotheses in their attempt to explain an event, and then to design and conduct scientific experiments to test the proposed hypotheses. The second phase includes the introduction of a new term such as in the case of Boyle’s Law which refers directly to the mathematical relationship discovered during the exploration phase. The formal terms will be introduced by the teacher but students are expected to intuitively identify as much of the new pattern as possible from the follow-up investigation before another new term is introduced. During the concept application phase, students apply the new terms to additional contexts. After the introduction of Boyle’s Law, for instance, concept application might involve the learners having to explain the event presented based on the relationship between the variables. These processes are completely absent when expository methods are employed and only partially attended to when simulation programs are used. Roth & Roychoudhury (1993) argued that inquiry-based science experiences that are conducted in relevant and meaningful contexts could develop higher order thinking skills in students. This study,
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