Educ. quím., **24**(1), 37-43, 2013. © Universidad Nacional Autónoma de México, ISSN 0187-893-X
Publicado en línea el 3 de diciembre de 2012, ISSNE 1870-8404

Inquiry, Chemistry Understanding Levels, and Bilingual Learning

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ABSTRACT
This research followed the teaching and learning processes of the case-based computerized laboratory (CCL) module in bilingual setting — BCCL and unilingual setting — UCCL. The goal of the research was to examine the effect of the CCL module in bilingual setting (Hebrew and Arabic) on developing higher order thinking skills among high school Arab students. The research participants included about 270 12th grade honors chemistry students from thirteen high schools. Research tools included an 'unseen'— a narrative, real-life case study in pre and post questionnaires. These questionnaires served for assessing question posing and inquiry skills. Research results showed that both BCCL and UCCL students improved their question posing and inquiry skills from the pre- to the post questionnaires. In addition, the BCCL students improved their inquiry skills significantly better than their UCCL peers. The research findings have shown that exposure to second language (SL) via gradual translation of scientific learning materials is effective in promoting students` inquiry skills. In the practical domain, the research significance is exemplified in the contribution to chemistry teachers by providing them with tools for overcoming the obstacles while teaching science in second language, and may assist their students in smooth integration into higher education.

KEYWORDS: case-based computerized laboratory, question posing, inquiry, second language, bilingual learning

Resumen (Indagación, niveles de comprensión de la química y el aprendizaje bilingüe)
Esta investigación sigue el proceso de enseñanza y aprendizaje del laboratorio computarizado basado en casos (CCL por sus siglas en inglés) módulo bilingüe (BCCL) y unilingüe (UCCL). El objetivo de la investigación fue examinar el efecto del BCCL (en hebreo y árabe) sobre el desarrollo de habilidades de razonamiento de alto nivel entre estudiantes árabes del bachillerato. Los participantes de la investigación fueron 270 estudiantes de química de grado duodécimo de trece escuelas. La herramienta de la investigación incluyó unos cuestionarios pre y post sobre una narración de un caso real. Los resultados mostraron que tanto los estudiantes BCCL como los UCCL mejoraron su capacidad de hacer preguntas y sus habilidades de indagación de la aplicación previa a la posterior, aunque los BCCL mejoraron sus habilidades significativamente más que sus pares UCCL. Los hallazgos de esta investigación han demostrado que la exposición a una segunda lengua (SL) vía la traducción gradual de los materiales científicos es efectiva para promover las habilidades de indagación de los estudiantes. En el dominio práctico lo significativo de la investigación queda ejemplificado en la contribución de los profesores de química al darles las herramientas para superar obstáculos mientras enseñan ciencia en una segunda lengua y auxilian a sus estudiantes a su integración gradual hacia la educación superior.

Palabras clave: laboratorio computarizado basado en casos, planteamiento de preguntas, indagación, segunda lengua, aprendizaje bilingüe

Introduction

Towards the end of the twentieth century, many researchers reported that the curriculum in sciences is based on memorizing facts and definitions, without enough emphasis on applying knowledge in everyday settings and on higher order thinking skills (Tobin & Gallagher, 1987; Zohar & Dori, 2003). Textbooks were the main tool for learning, and most of them required low order thinking skills and studying and summarizing scientific facts.

One of the main goals of the reform in science teaching is development of higher order thinking skills in general and inquiry in particular (Resnick, 1987; Dori, 2003; Kaberman & Dori, 2009).

Since the 60s Schwab and Brandwein (1962) and Sund and Trowbridge (1967) discussed the importance of teaching

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science as *enquiry* or as we call it today — *inquiry*. In the last decade in Israel, the content and the pedagogy of the chemistry curriculum in high schools have gone through a dramatic change that included emphasis on inquiry-type laboratory activities as a central part of the matriculation examination (final examinations set by the government). These laboratory activities provided students with opportunities to develop their learning and inquiry skills (Barnea, Dori & Hofstein, 2010).

In addition, while learning the Israeli curriculum, students are required to develop their chemistry understandings levels: macroscopic, microscopic, symbolic, and process (Dori & Hameiri, 1998, 2003; Dori & Kaberman, 2012; Gabel, 1993, 1998; Johnston, 1991).

In this paper, we describe a study of learning via inquiry in computerized environments where high school students and their chemistry understanding levels will be presented. The learning environment of this study (Dori & Sasson, 2008), combined computerized and inquiry-based laboratories (Kaberman & Dori, 2009) with cased-based approach (Herried, 1994; 1997) and will be abbreviated as CCL — cased study and computerized-based Laboratory module.

Students have difficulties in understanding particulate nature of matter, structures of variety of compound, and interpretation of chemical symbols (Chandrasegaran, Treagust, & Mocerino, 2007). Most of the students find it difficult to create the required connection between the elements' and compounds' symbols, their structures and chemical processes. This difficulty stands from the abstract obstacle when students attempt to solve problems in various subjects (Dori & Barak, 2001). Chemists and chemistry teachers usually use both virtual and tangible models in attempt to create a connection between the symbols and the microscopic and macroscopic nature of matter. The study will provide a teaching, learning, and assessment approach in which the CCL learning environment can serve for either a bilingual teaching approach of Arab chemistry students (who studied chemistry in a gradual translation from Arabic to Hebrew) or a unilingual approach — Arabic only (Abed & Dori, 2007). The term 'bilingual learning' in this paper means, the use of Arab students' home language, and culture, along with Hebrew, the language in which the majority speaks. The CCL in the bilingual setting will be referred to as BCCL while the unilingual approach will be referred to as UCCL.

The two approaches were implemented and their benefit in improving students' understanding and fostering their posing question and inquiry thinking skills was investigated. Students improved their ability to ask questions and solve inquiry problems, which required transition between the four levels of understanding — macroscopic, microscopic, symbol and process. In addition, it was found that the BCCL approach that was characterized by faded scaffoldings over time, in both learning materials and language of instruction, allowed students greater responsibility over their own learning, and encouraged students who studied chemistry in a gradual translation from Arabic to Hebrew to perform better than their peers who studied in the UCCL environment.

Theoretical Background

In this paper, the research background includes a short discussion on case studies as a tool for developing higher order thinking skills such as question posing and inquiry. Following, we will describe the four levels of chemistry understanding and the need to combine means of demonstration such as computerized inquiry laboratories in chemistry teaching, to assist students in making transitions between the levels of understanding.

Following, we will describe a learning environment for minority students in Israel, whose mother tongue language is Arabic while most of the textbooks are written in Hebrew.

Computerized laboratories have developed in Israel in the last few years since the decreasing use of chemical laboratories due to safety and health risks associated with some of the experiments, as well as the experiments being of high costs and time consuming. Integrating information technology in laboratories as well as the development of appropriate curriculum enabled conduction of experimental studies in which the computer serves as a tool for collecting, processing and displaying real-time data. Throughout the experiment, students formulate inquiry questions, speculate, take part in the actual experiment, collect data retrieved by sensors which is graphically displayed on computer screens, explain the experiments' results and come to conclusions.

Inquiry concerns authentic ways in which learners can investigate the natural world, propose ideas, ask questions, and sense the spirit of conducting scientific experiments in the laboratory (Hofstein & Lunetta, 1982, 2004; Lazarowitz and Tamir, 1994).

Researchers have found that student-centered inquiry laboratories provide excellent language and content learning for students learning in second language medium (Thomas & Collier, 1995; Nieto, 2000). Participating in inquiry-based science activities may benefit students by better understanding of science concepts and developing higher order thinking skills.

According to Resnick (1987), it is difficult to define higher order thinking skills, but it is possible to identify them when they occur. Resnick claimed that higher order thinking is not algorithmic and that thinking patterns are unclear and may not be predicted in advance. Thinking patterns often result with multiple solutions, each with pros and cons, but there is no single definite solution. Higher order thinking skills include, among others, posing questions, inquiry, drawing conclusions following experiment, graphing skills, solving problems, critical thinking, reasoning, modeling, decision making and taking a stand (Bodner, Hunter, & Lamba, 1998; Dori & Herscovitz, 1999; Dori & Kaberman, 2012; Dori & Sasson, 2008; Dori & Tal, 2000; Zohar & Dori, 2003; Zohar & Nemet, 2002; Zoller, 1987).

Various approaches aimed at encouraging development of