Design and Development of a Computer Learning Environment on the Basis of Students’ Initial Conceptions and Learning Difficulties About Chemical Equilibrium

CHRISTINA SOLOMONIDOU*
Department of Education, University of Thessaly, Argonafton & Filellinon st., 38221 Volos, Greece.
* Corresponding author. E-mail: xsolom@uth.gr

HELENI STAVRIDOU
Department of Education, University of Thessaly, Argonafton & Filellinon st., 38221 Volos, Greece.
E-mail: estavid@uth.gr

This paper describes the design and development of an interactive learning environment inspired from the constructivist view of learning and aiming at helping students improve their conceptions about chemical equilibrium. The design of the software was based on data that emerged from research we undertook with 175 Greek students (aged 17–18), in order to detect their conceptions and learning difficulties about chemical equilibrium. The students’ answers to a written questionnaire showed that they had inadequate representations of systems of substances at chemical equilibrium related to the empirical and the atomic level, manifested serious difficulties in conceiving the initial situation of a system at chemical equilibrium and the equilibrium shift, made overextended use of the Le Chatelier principle and applied intuitive personal rules instead of the equilibrium constant law. The aim of this computer application is to help students to create and/or improve their own representations about substances at chemical equilibrium in the empirical, atomic and symbolic level, to establish appropriate links among these multiple representations, and to construct appropriate conceptions about the Le Chatelier principle and the equilibrium constant law. The software contains simulations and visualizations of experiments representing systems at chemical equilibrium, simulations of chemical reactions related to the atomic level, symbolic representations and dynamic graphs, and a step-by-step derivation of the equilibrium constant law.

Keywords: educational software development; chemical equilibrium; students’ conceptions; multiple representations; learning chemistry.

Introduction

Chemical equilibrium is considered to be one of the most difficult topics in the general chemistry curriculum. A considerable number of science education researchers have investigated various aspects of students’ understanding and alternative conceptions about this concept (see reviews by several authors: Banerjee, 1991; Hameed et al., 1993; Garnett et al., 1995; Quilez-Pardo & Solaz-Portolés, 1995; Stavridou & Solomonidou, 2000). But the use of these research results by teachers has little effect on the actual classroom practice (Quilez-Pardo & Solaz-Portolés, 1995).
In several countries, it seems that concepts remain taught by heart, and the development of students’ process skills may be ignored by teachers, who do not require those skills in teaching students factual and conceptual knowledge in science (Fensham, 1988). This fact is also true for Greece, where teacher methodology is focused on the transmission of knowledge rather than on students’ learning with understanding. In Greece chemical equilibrium is mainly taught during the last high school chemistry course (class C of Lyceum) to students having chosen scientific or medical orientations. There are three one-hour periods of theoretical classes per week, from mid-September until end of May. Chemistry teaching is textbook oriented and based on blackboard presentations and on chemistry problem solving using algorithmic strategies. In Greece, as well as in other countries, chemistry textbooks emphasize on quantitative aspects of learning at the expense of qualitative reasoning (Camacho & Good, 1989; Nurrenbern & Pickering, 1987).

Besides, the fact that some educators and researchers reported that teaching students to solve problems is equivalent to teaching the concepts (Sawrey, 1990; Niaz, 1995a), other ones claimed that in order to encourage conceptual understanding science teaching must provide opportunities to promote students’ qualitative reasoning. For example, Raghavan & Glaser reported (1995) that ‘because the prior knowledge and models that students bring to their science instruction are usually qualitative in form, qualitative reasoning is closely connected to that prior knowledge. Thus, qualitative models may be a more effective pedagogical tool for generating conceptual understanding than the premature imposition of their quantitative and formulaic counterparts’.

In order to promote students’ qualitative reasoning and improve their conceptual understanding in chemistry, computer applications may provide new ways to help instructors manage the learning environment. The effectiveness of this educational technology depends on the degree to which pedagogical results about students’ learning and conceptual difficulties are used to guide the development and implementation of this new instructional tool. There are recent examples of computer assisted instructional packages designed to challenge students’ misconceptions in science, previously identified by a research (for example Raghavan & Glaser, 1995; Hameed et al., 1993; Hennessy et al., 1995). Those applications are usually inspired from the constructivist view of learning in science, according to which it is necessary to investigate and study students’ previous ideas and conceptions in order to proceed to the design and development of appropriate computer packages.

The software we have developed is an example of a computer learning environment inspired from the constructivist view of learning, and designed on the basis of research data about students’ conceptions and difficulties on chemical equilibrium. The aim of this software is to help students improve their conceptions, representations and understanding about this science concept.

The present work is about how research on students’ conceptions and difficulties informed the design of the software. More specifically, we describe the research we conducted with Greek students in order to detect their ideas about chemical equilibrium, we present the main results of this research, we describe the software and explain how these research data guided its design and development. Data about students’ misconceptions and difficulties on chemical equilibrium were also considered from a review of the literature on this field.