Web-based learning environments supporting socio-scientific decision making

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Abstract

In recent years, the rapid progress in science and technology tends to bring about dilemmas on a range of socio-scientific issues. Thus, science education needs to prepare students to deal with such issues in an informed manner. In this paper, four learning environments (LEs) addressing topical socio-scientific issues (i.e. biotechnology, climate change, the impact of fog on human life and nicotine addiction) are presented. The data-rich environments are hosted on the STOCHASMOS web-based teaching and learning platform which offers adjustable scaffolding tools for students' inquiry. Each of the LEs was designed and implemented in authentic classroom settings of public and private schools of Cyprus' (n=121) and Israel's (n=40) secondary education and of Greece's primary education (n=53). Data collection tools included pre-post tests and observations. Results from the implementation of these LEs are also presented.

Keywords: problem-based learning, web-based learning environments, inquiry, socio-scientific topics

Introduction

One of the most important goals of science education is to contribute to fostering students' dealing with socio-scientific issues that preoccupy modern societies (Zeidler et al., 2005). In this paper, we present four LEs addressing socio-scientific issues (i.e. biotechnology, climate change, the impact of fog on human life and nicotine addiction) and targeting to promote related conceptual and epistemological understanding as well as reasoning skills. The LEs are hosted on the STOCHASMOS web-based teaching and learning platform (Kyza & Constantinou, 2007), which provides a series of specific tools for scaffolding students' reflection and collaboration (http://www.stochasmos.org/). Each environment was implemented locally in authentic classroom conditions and improved through successive iterations. Aspects of the classroom implementation of web-based LEs for inquiry-oriented science teaching and learning, such as the teachers' role, are systematically investigated. The LEs and results indicating their effectiveness in the elementary and high school context are presented.

The "*Biotechnology*" learning environment

This LE focuses on biotechnology, genetic engineering and Genetically Modified Organisms (GMOs) and is catered to 10-12th grade high-school students (15-18 years old). The socio-scientific issue that is addressed is GM plants' cultivation from the perspective of health, environment and economy: Are GM plants' cultivations safe for human health? Environmentally-friendly? Profitable? Ethical? Beneficial? Students are asked to provide an evidence-based answer to the following problem: Would you allow the growing of GM plants in your country?

Learning objectives

By the end of the intervention students are expected to: a) demonstrate an understanding of concepts such as biotechnology, genetic engineering, GMOs, b) evaluate the credibility of evidence by applying specific criteria, and c) make evidence-based decisions to address the socio-scientific dilemma, considering three perspectives: the environment, economy and health.

Enactments

Two enactments were carried out in successive school years in two 11th grade classes in a public high school in Cyprus (year 1 n=12; year 2 n=21). Both enactments were taught by a biology teacher who was part of the Local Working Group who designed the LE. The enactments lasted for eleven and eight 90-minute lessons, respectively.

Results

To assess students' learning gains in year 1, we compared their pre- and post-tests, using the Wilcoxon signed ranks non-parametric test because of the small sample size. The analysis indicated a statistically significant difference $z(12)=-2.91$, $p<.01$, and an effect size of 0.59. Students' performance increased from a mean of 16.58 (SD=5.02) in the pre-test to a mean of 24.17 (out of 38) (SD=6.13) in the post-test. To assess students' learning gains in year 2, we compared their pre- and post-tests using Paired samples t-test. The analysis indicated a statistically significant difference $t(17)=-5.36$, $p<.01$. Students' performance increased from a mean of 15.72 (SD=5.69) in the pre-test to a mean of 20.89 (SD=5.51) in the post-test. Results indicated the effectiveness of the two interventions.

The "Climate Change" learning environment

Climate change is a topical issue that is the subject of extensive debate worldwide. The LE is designed to expose 16-17 year-old students to this issue and to the main positions that are being debated within the scientific community about the causes of the corresponding phenomena. Students need to address two driving questions: Is climate change a man-made or a natural phenomenon? Which technology should be used in combination with the existing oil-fired power stations to cover our future needs for electricity: natural gas, wind turbines or solar cells?

Learning objectives

By the end of the intervention students are expected to: a) demonstrate an understanding of the greenhouse effect, b) develop argumentation skills (be able to provide evidence-based arguments and counter-arguments), and c) develop a specific optimization reasoning strategy for dealing with decision making situations.

Enactments

The LE has been implemented twice in Cyprus with 49 11th grade students overall. A third enactment with a group of 39 pre-service teachers from the Department of Educational Studies also took place. The enactments lasted for 16 90-minute sessions.

Results

Data analysis revealed significant learning gains with respect to argumentation and decision making skills. The analysis of pre- and post-chats within pairs of students, with respect to whether climate change is a man-made or a natural phenomenon, indicated improved argumentation skills. Specifically, after the enactment, students were able to provide more informed arguments and counter-arguments (to weaken or critique arguments in favour of the alternative position or address criticisms raised by other students against their own arguments). In a similar manner, data analysis suggested improvement in students' ability to effectively cope with the reasoning task of comparing rival solutions in socio-scientific decision-making and synthesizing the available data to identify the optimum solution.

The "Clearing the fog for helicopter landing" learning environment

This LE is addressed to primary school students of the 5th-6th grade (10-12 years old). It is a design-oriented project: students have to design a solution to the problem of eliminating radiation fog in a limited area and for a short time period. The space and time constraints are determined by the realities of helicopter landing. It is an open-ended problem and students have to produce as many well defended design proposals as possible.

Learning objectives

By the end of the intervention students are expected to: a) demonstrate an understanding of the structure of fog, the relative size of molecules, water droplets and other selected small entities, evaporation and condensation b) demonstrate snapshots of the way their design will work using microscopic quantities (molecules and water droplets), and c) use a model of water droplets taking into account both incoming and outgoing molecules in order to argue about the efficiency of their solution.

Enactments

Two enactments have been conducted thus far in Greece. The pilot enactment in three different 5th grade classes (located in a village, a town and a city, respectively) led to changes which were implemented in the second enactment. In the second enactment the participants were one 5th grade (n=16) and one 6th grade (n=11) class in the city of Volos. The enactments lasted for 13 90-minute lessons.

Results

Data from the second enactment is currently being analyzed. Students in both classes, working collaboratively in groups of three, produced snapshots of their design including the evolution of droplets and some dynamics of molecules. They also used the targeted model of the water droplets in their explanations. Moreover, they showed improvement in the understanding of the structure of fog and the relative sizes of water molecules and droplets and, to a lesser degree, in the molecular explanation of evaporation and condensation. We recorded heated discussions among students arguing on the merits of their explanations. Finally, their teachers reported being happily surprised by the quality of students' argumentation in the environment.

The "Health Sciences Nicotine Addiction Cessation" learning environment

This LE, catered to grades 10-12 (15-18 years old), focuses on nicotine addiction cessation covering topics from neurobiology and health sciences. It addresses the socio-scientific issue of patient health care decisions. Specifically, how to choose among treatment alternatives based on effectiveness, risks and individual characteristics. Using clinical data, students construct an evidence-based recommendation of which of four pharmacological smoking cessation aids a patient should choose.

Learning objectives

Students are expected to: a) demonstrate a basic understanding of the neurophysiology of addiction, and of health science research methods (e.g. placebo use), b) interpret and synthesize graphs (bar, line) in order to solve a problem, and c) employ a rational decision making model, and be able to back claims and counter arguments with evidence.

Enactments

Two enactments were carried out in successive school years in a 10th grade class in a private Arabic speaking high school in Israel (year 1 N=22; year 2 N=18). Both enactments were taught by a biology teacher who was part of the Local Working Group design team.

Results

One challenge for students was the need to use effect size to normalize findings to a common scale when synthesizing graphs depicting results of different operationalizations of the same variables. This skill is not covered in typical science curricula. We did not provide guidance for this process in year 1. In year 2, we provided guiding questions, some drawing attention to key or unusual points and some depicting the conceptual sub-tasks of graph analysis. In year 1, students did not recognize the need for normalization and consequently reached flawed conclusions. In contrast, in year 2, students showed greater awareness for the need for normalization and showed some facility in applying the procedure correctly. These outcomes seemed strongly mediated by the teacher.

Conclusions

Pedagogically significant results indicate the effectiveness of these LEs for the development of primary and secondary students' inquiry skills and conceptual understanding of the subject-matter. These LEs are available for use by educators interested in enacting them in their classrooms. Each LE is available in English and in two other languages out of Arabic, Dutch, German, Greek and Hebrew.

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