Designing Technology to Foster Socioscientific Reasoning by Promoting Internal Values of Learning

Hava Ben-Horin
University of Haifa
hava.abramsky@gmail.com

Carmit Pion
University of Haifa
pion.carmit@gmail.com

Yael Kali
University of Haifa
yael.kali@edtech.haifa.ac.il

Abstract

Learning science in the context of socioscientific issues is an instructional approach for fostering students' active citizenship in social issues involving science. This requires a set of thinking practices called Socioscientific reasoning, which has been found challenging for students. We examined the effect of an existing Web-based Inquiry Science Environment (WISE) module, dealing with the socioscientific issue of Asthma in the community, on students' understanding of the Asthma phenomenon. Findings from an enactment with 8th grade students analyzed by questionnaires and scoring rubrics, revealed improvement in scientific knowledge, but not in students' socioscientific reasoning. Findings also revealed the potential of the module to support students' internal-values of learning, which were not fully exploited. Based on these finding and on the assumption that performing socioscientific inquiry as part of a community that cultivates internal-values of learning may support the development of socioscientific reasoning, we refined the module towards a second enactment. Refinements employ an innovative technology-enhanced pedagogical approach called Knowledge Community and Inquiry (KCI). We explain how the KCI technology-enhanced features can support the development of internal values of learning that can foster students' socioscientific reasoning, which we expect to find in following enactments.

Keywords: Socioscientific reasoning, learning culture, internal values of learning, Knowledge Community and Inquiry, conjecture mapping.

Introduction

Twenty-first century citizens are often required to take an active stand in social issues involving science. This understanding is expressed in modern views of science education, but much less in practice (Hodson, 2002). To address this concern, in the past decade an instructional approach has been developed, which uses controversial social science-related issues, known as socioscientific issues (SSI) as contexts for science learning. Research has shown that when students negotiate SSI, they use a set of thinking practices referred to as socioscientific reasoning (Sadler, Barab, & Scott, 2007).

The high-level conjecture of the current research is that socioscientific reasoning may develop among learners when socioscientific inquiry is performed as a collective endeavor in communities in which internal-values of learning (Sagy, Kali, Tsaushu & Tal, 2016) are cultivated. Specifically, we adopt the Knowledge Community and Inquiry (KCI) approach (Peters & Slotta, 2010), which supports scaffolded inquiry of complex phenomena and the dynamic collaboration within a community of learners.

The research builds upon an existing Web-based Inquiry Science Environment (WISE) module that engages students with the SSI of Asthma in the community (Tate, Clark, Gallagher, & McLaughlin, 2008). This module has been shown to support students' integrated understanding of the scientific aspects of asthma (e.g., oxygen inhalation), and we believe that it can serve as a base to develop socioscientific reasoning.

Theoretical Background

Socioscientific reasoning

In the past decades, a socioscientific instructional approach has been explored, among others, to address the goal of preparing students for their role as future citizens. The socioscientific approach involves students in inquiry of SSI, such as genetically engineered food. Such inquiry engages students in discourse and decision-making processes that are based on knowledge of science as well as knowledge about science. Together, these require skills related to collecting, assessing, and interpreting data, enabling students to critically consider alternative explanations, and appreciate the uncertain nature of science (Sadler, 2009; Tal et al., 2011).

Socioscientific reasoning includes four major practices, grounded in content understanding of the science behind SSI: (1) recognizing the inherent complexity of SSI, (2) analyzing SSI from multiple perspectives, (3) appreciating the need for ongoing inquiry relative to SSI, and (4) employing skepticism about potentially biased information. (Sadler et al., 2007; Romine, Sadler & Topcu, 2016).

The socioscientific approach has been shown to promote students' attitudes towards science as well as their development of higher-order thinking skills (Sadler, 2009), with fewer studies showing its support in science content learning (Sadler et. al., 2016). However, the effect of SSI instruction on students’ socioscientific reasoning has only partially been explored and many challenges have been raised (Sadler et. al., 2016).

Knowledge Community and Inquiry (KCI) approach and culture of learning

The KCI instructional approach blends core ideas from "knowledge-building communities" (Scardamalia & Bereiter, 2006) and "scaffolded inquiry" (Krajcik, Blumenfeld, Marx & Soloway, 2000). KCI designs include scaffolded scripts of collaborative inquiry and knowledge-building activities that facilitate a culture of collective inquiry while addressing science learning goals. Students engaged in these activities work collectively to create a knowledge-base that is accessible as a resource for their ongoing inquiry as well as for editing and improvement by all (Lui & Slota, 2014). KCI designs include complex forms of interaction such as scripted collaborations within and between groups. Students involved in KCI designs engage in reflection, critique, discourse, or design activities performed individually, in groups, or in the whole community (Slotta, Tissenbaum, & Lui, 2013). Technology can support the aggregation and visualization of students' ideas within the knowledge-base (Lui & Slota, 2014). KCI affords ongoing inquiry of complex scientific phenomena, examination of different perspectives and integration of scientific knowledge.

Research shows that fostering the development of an inquiry culture in learning communities requires to: (1) Support deep, multiple-perspective exploration of the problem; (2) Provide opportunities for participants to explore data together and engage in open dialogue; (3) Create a safe environment for exploration, where mistakes are seen as opportunities for learning; (4) Create a process of exploration in which the collective knowledge-base of the inquiry community can grow (Dillenbourg, 1999; Dowd, 2005; Littleton et al., 2005). Research shows that students' deep learning of scientific content and their development of expert-like scientific discourse requires a learning environment that promotes internal values (Sagy et al., 2016; Tsaushu, Tal, Sagy et al., 2012). The Culture of Learning Continuum (CLC) framework delineates learning culture on a continuum ranging from internal-value-based to external-value-based cultures. Three dimensions in the CLC framework are particularly relevant to socioscientific reasoning: (1) Attitude toward authority (external values are characterized by learners' relying exclusively on what they believe to be authoritative sources of information while internal values are associated with considering various sources) (2) Knowledge judgement (accepting knowledge without contestation versus treating new knowledge critically), and (3)

Attitude toward uncertainty (intimidation by uncertainty versus viewing uncertainty as an opportunity for learning and self-growth).

Methodology

This study uses a design-based research (DBR) methodological approach, in which multiple iterations of design-enactment-analysis lead to refinements of the design as well as to advancement of theoretical aspects about the kind of learning supported by the designed environment (e.g., Barab & Squire, 2004).

In order to demonstrate the connections between our intervention and its desired outcomes, we used Sandoval's (2014) mapping technique, which represents the various types of conjectures typically made in DBR (Figure 1): The *high-level conjecture* is embodied into design features that, according to *design conjectures*, support the emergence of mediating processes. These mediating processes produce, according to *theoretical conjectures*, the desired outcomes of the intervention.

The high-level conjecture described above, was embodied using technology-enhanced features that employ the KCI approach, to support students' inquiry of the asthma problem and the various aspects involved (i.e., transportation' effect on air pollution). Our design conjecture was that the resultant design will facilitate the emergence of an internal-value-based learning culture. That is, by participating in collaborative inquiry activities, students will critically consider various sources of information regarding the Asthma problem and acknowledge uncertain aspects of it such as its main environmental contributors. Our theoretical conjecture was that this emergent learning culture will mediate the development of the four dimensions of socioscientific reasoning. In other words, students will become more aware of the complexity and the multi-perspective nature of the Asthma problem, develop an understanding and appreciation of the ongoing inquiry involved, and develop their ability to employ skepticism about potentially biased information. (Figure 1).

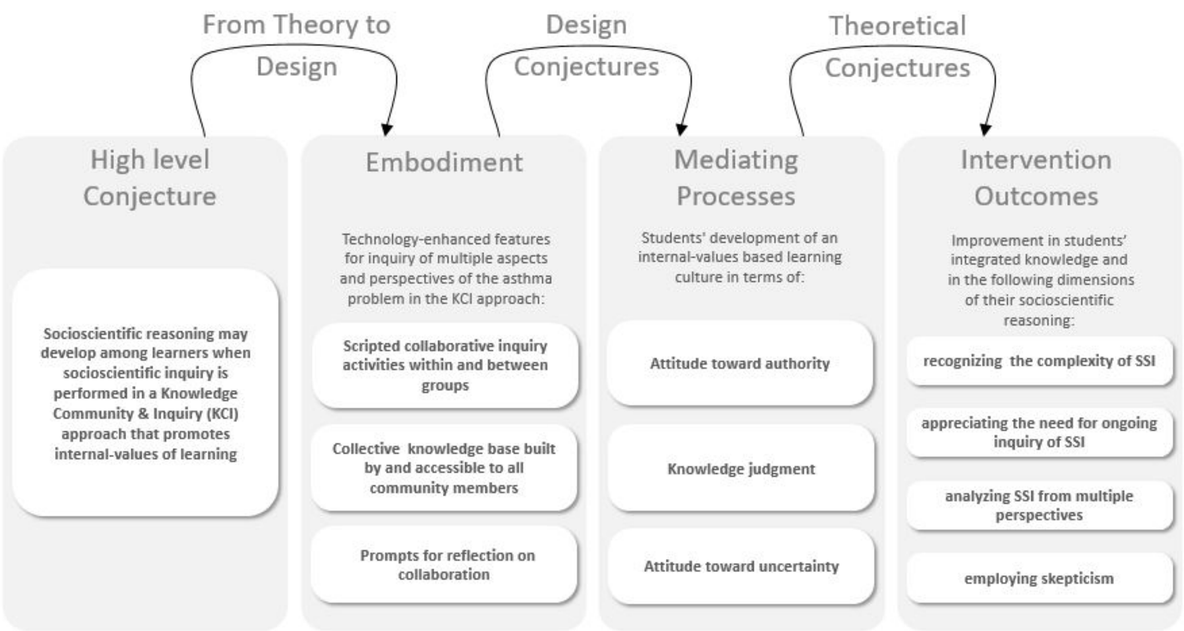

Figure 1. Conjecture mapping of the current research using Sandoval's (2014) technique

Design and enactment of the first iteration

The original 'Asthma in the community' module (Tate et al., 2008) allows students' participation in a decision-making process for the resolution of the asthma problem in their community, and ongoing inquiry of this issue from various aspects. Its pedagogical design was based on the Knowledge Integration (KI) framework, which enables students to build upon their repertoire of ideas, create meaningful links between these ideas and integrate them to create coherent knowledge (Linn & Eylon, 2011).

For the first iteration of this study, we translated the module to Hebrew and refined it to allow for cultural adaptations (e.g., adding relevant local information) as well as better alignment with the socioscientific approach (e.g., expose students to different perspectives regarding asthma phenomenon). Students were able to add data and ideas to an individual knowledge-base which consisted of Google maps and an 'evidence basket' in which they documented their insights throughout their learning with the module. We avoided adding KCI or collaborative inquiry features at this stage. This enabled us to examine the way this original version of the module supported students' learning, and identify possible gaps in its potential to promote socioscientific reasoning. We implemented the module during the 2015/6 school year for six weeks (twelve hours) in two 8th grade classes (65 students) and examined: (a) students' integrated understanding of the scientific aspects of the asthma phenomenon before and after the intervention (b) their socioscientific reasoning before and after the intervention, and (c) the learning culture that characterized students’ work with the module.

Data collection and Analysis

Data about students’ socioscientific reasoning and integrated understanding of Asthma was collected and analyzed based on existing questionnaires and scoring rubrics as described in Table 1.

Table 1. Data sources and analysis

Parameter examined	Data collection	Data analysis
a) Integrated scientific knowledge	Knowledge Integration (KI) questionnaire, consisting of 5 open-ended questions (Liu, Lee, Hofstetter, & Linn, 2008) - administered before (pre) and after the program (post).	Use of a scoring rubric for Asthma KI questionnaire (Liu et al.,2008)
b) Socioscientific reasoning	Socioscientific reasoning questionnaire (based on Sadler et al. 2011) - administered before (pre) and after the program (post). This questionnaire presents a socioscientific scenario, followed by a series of 2 close and 4 open-ended questions. Two different (equivalent) scenarios were used for the pre and post questionnaires	Use of a scoring rubric for socioscientific reasoning (Sadler et al., 2011).
c) Learning culture	Learning experience reflective questionnaire (post) with 3 open-ended questions (post)	Content analysis and use of Sagy et al.'s (2016) CLC rubric

Preliminary findings

Integrated scientific knowledge: Students significantly improved their integrated understanding of the asthma phenomenon, the factors affecting it and the mechanism of allergic immune response. However, no significant improvement was found in understanding of the processes involving oxygen inhalation (Figure 2).

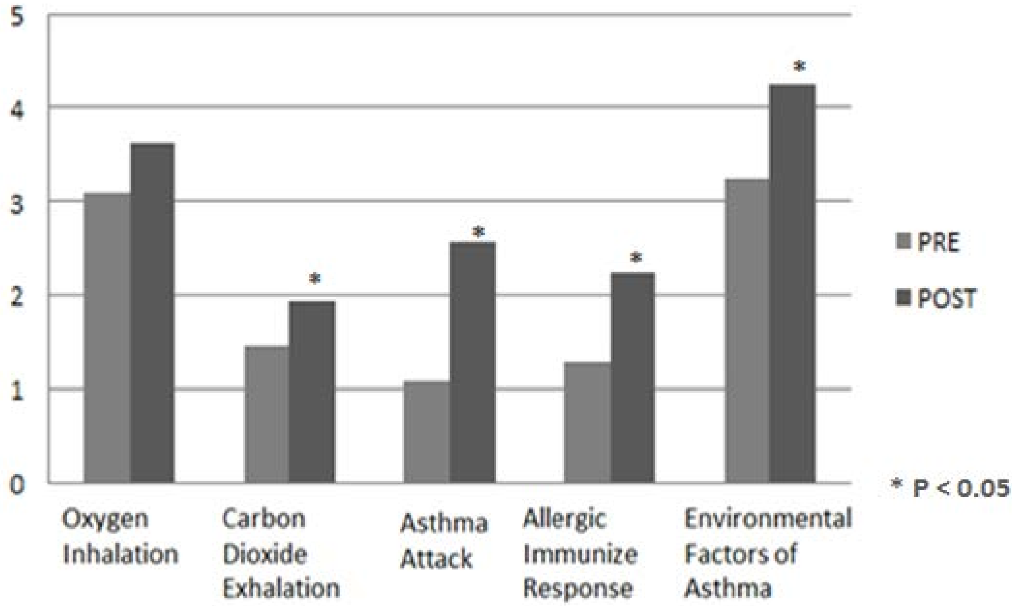

Figure 2. Students integrated understanding of the asthma phenomenon (pre/post)

Socioscientific reasoning: No significant change was found in students' socioscientific reasoning in the three dimensions of socioscientific reasoning that were measured: complexity, perspectives and inquiry.

Learning culture: The content analysis of students' answers to the questions of the learning experience questionnaire yielded three categories of experiences. Students positively described these experiences in terms of: (a) the independent nature of the learning in the module (55% of the students' answers), (b) the interest they found in it (36%) and (c) the increasing sense of self-efficacy students felt due to the learning experience they had in the module (27%). The analysis of these answers using the CLC rubric indicates that 59% represent internal values, and 41% represented external values. These findings indicate that the module has the potential to increase internal values, but that this potential was not fully exploited in the first iteration.

Implications for the design of the second iteration

Following the above findings, and in order to improve the intervention outcomes (in terms of students' understanding of the Asthma phenomenon and their socioscientific reasoning), we made the following design revisions, employing our conjectures (Figure 1):

- *Scripted collaborative inquiry activities within and between groups*: Inquiry activities that were conducted in pairs in the first iteration, were redesigned as collaborative scripts. That is, they were revised to support data collection and representation by regional 'expert' groups, and discursive activities within and between groups, targeted for collaborative knowledge-building and knowledge integration. Figure 3 illustrates the instructions for learners that guide the collaborative process of inquiry.

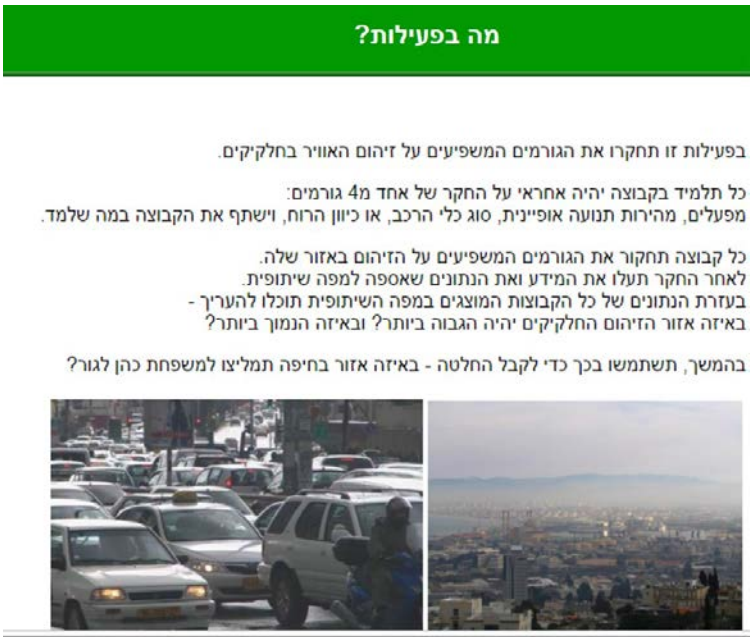

Figure 3. General instructions for collaborative inquiry in the second iteration

- *Collective knowledge-base built by and accessible to all community members*: We implemented technology-enhanced tools that enable students to collaboratively build, improve and use a collective knowledge-base. This knowledge-base consists of a 'public evidence basket' and a collaborative Google map that aggregates data contributed by the different teams. Both are intended to serve as resources for students' inquiry and decision-making processes. Figure 4 illustrates the evidence basket that allows students to aggregate their own pieces of evidence, while choosing which items to contribute to the public basket, or adopt for their own use.

Figure 4. The private and public evidence basket in the revised module

- *Prompts for reflection on collaboration*: We embedded scaffolds for reflections of each member of the community through the learning process (e.g., analyzing their responses and posts in the discourse, analyzing each contribution to the group's ongoing inquiry (Figure. 5).

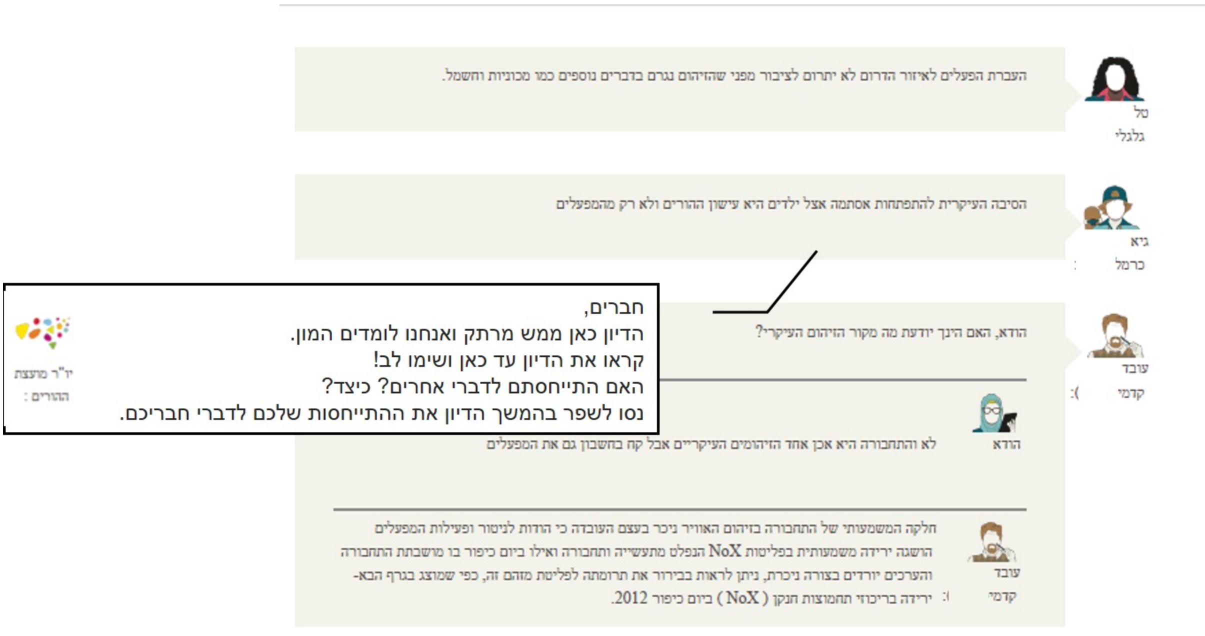

Figure 5. Prompt for reflection on learners' responses in a collective discourse during a digital role-playing game (to-be education.co.il)

Concluding remarks

The first iteration of the research revealed that the "Asthma in the community" module supported students in developing integrated understanding of most aspects related to the scientific aspects of the asthma phenomenon. However, although the topic deals with a SSI, our finding show that the module in its original (culturally adapted) version, does not support students in developing socioscientific reasoning. The findings also indicate that the original module does not fully exploit its potential to support a learning culture that is characterized by internal values. We strongly believe, as described in on our conjecture mapping (Figure 1) that the refined design with KCI features will foster an internal-values based learning culture, and subsequently, will result in improvement of students' scientific knowledge and socioscientific reasoning.

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