Developing and validating a web-based learning environment for helping 6th grade students appreciate subjectivity and uncertainty in science

Georgia Michael[1], Nicos Papadouris[1], Eleni A. Kyza[2], Constantinos P. Constantinou[1]
[1]University of Cyprus, P. O. Box 20537, Nicosia, 1678, Cyprus,
[2] Cyprus University of Technology, P.O. Box 50329, 3603, Limassol, Cyprus
georgia3m@gmail.com, npapa@ucy.ac.cy, Eleni.Kyza@cut.ac.cy, c.p.constantinou@ucy.ac.cy

Abstract: This study reports on the development and research validation of a web-based learning environment (LE) for helping students, ages 12-14, to appreciate uncertainty and subjectivity in science. The environment was implemented once and the research results are used for revising it to better address the learning objectives. Results in relation to students' understanding of subjectivity and possible emerging modifications of the LE are discussed.

Aim of the Study

The tremendous progress witnessed in the fields of science and technology tends to bring about dilemmas on a range of socio-scientific issues (SSI), such as global warming. Science education aims at preparing students to engage with such SSIs in an informed manner. One of the resources underpinning this ability is awareness relating to the nature of science (NOS) (Sadler et al., 2004). However, evidence suggests that students and lay adults do not possess informed ideas. Clearly, there is a need for developing teaching innovations, especially for elementary grades (Lederman, 2007).

This study draws on the paradigm of design-based research (Barab, 2006). It seeks to design a learning environment (LE) dealing with certain aspects of NOS, and refine it on the basis of the data collected during its implementation in classroom settings. In particular, we have developed a LE for helping students aged 12-14 appreciate the subjective and uncertain nature of science and develop simple criteria for evaluating the validity and reliability of scientific claims. Empirical data from the first enactment of the LE were collected and analysed so as to inform its refinement. Due to space limitations, we only report data on students' understanding of subjectivity and present how these results are used for refining the LE.

Methodology

Participants

Thirty eight students from two 6th grade classrooms (19 students in each class) of a public school in Cyprus participated in this study. Students were working in pairs or triads. The implementation lasted 10 weeks (24 40-minute sessions).

The learning environment

The LE was hosted on the STOCHASMOS web-based platform. The context of the investigation is a topical SSI, namely the bovine tuberculosis problem in cattle in the UK. Each group of students assumed the role of scientists who represent relevant organizations, as a means for illustrating that scientists' agendas may lead to different scientific claims on the same issue. Students' goal was to study the data and construct scientific claims on how the problem could be best solved. The learning sequence provided students with multiple opportunities to construct and evaluate scientific claims and it systematically engaged them in explicit reflective discourse on relevant epistemological ideas such as the role of uncertainty and subjectivity.

Assessment task

A task for assessing understanding on subjectivity focused on the extent to which students are able to appreciate that scientists studying the same phenomenon might subscribe to different interpretations and to identify possible reasons for this. Students were presented with simplified versions of the man-made and natural theory regarding the global warming causes and a dialogue between two students who argued whether scientists can disagree. Students needed to agree with one of the two positions stated in the dialogue and explain their reasoning. The task was administered prior to and after the implementation. Thirteen students (34%) also participated in interviews (pre, post) for additional insights into their reasoning.

Results and consequences for the refinement of the learning environment

Students' responses were analyzed in order to identify qualitatively different categories of responses (Table 1). Only justified responses are included in this table. Interestingly, fewer students justified their responses in post tests (N_{pre}=27, 71%, N_{post}=19, 50%). Examining the responses without justification, both the number of students believing that scientists can disagree (N_{pre}=8, 21% overall, N_{post}=12, 32% overall) and of those believing that they need to agree (N_{pre}=0-0% overall, N_{post}=5-13% overall) increases. Although there are no interview data from these students, the fact that more students believe scientists need to agree has probably emerged as a byproduct of their interaction with the LE: Students judged claims that were at variance with available data as invalid, as this was the validity criterion they were guided to develop. Incidentally, students ended up with just one valid claim. This might reinforced the belief that scientists eventually agree on the same claim. This suggests the need to modify the LE so as to increase the likelihood for multiple valid claims and, hence, facilitate discourse on subjectivity.

Justified responses suggest a decrease in the number of students who discussed disagreements in relation to how productive they are (category 3, N_{pre}=9, 34%, N_{post}=3, 16%) and in students attributing disagreements to scientists themselves because, as human beings, they have the right to disagree (category 2, N_{pre}=17-63%, N_{post}=7-37%). Interestingly, while no students considered the role of data in relation to subjectivity (category 1), 9 students (47%) gave such post responses. This category is thought to be more informed than categories 2 and 3 because students take into account the role of data in science. However, no students referred to the possibility of having different claims due to different interpretations. This fact may also be connected to certain aspects of the LE: Even though students were scaffolded to appreciate the distinction between data and their interpretation (by asking them to separately refer to these constructs when reporting scientific claims), they did not seem to make this distinction to a satisfactory extent. It is possible that explicit discourse on this distinction and comparisons of different interpretations could help them recognize the possibility of having various claims due to different interpretations.

Table 1: Students' pre & post justified responses in relation to subjectivity and typical student responses

	PRE		POST	
	N=27	%	N=19	%
1.Disagreements in science are attributed to the variability of the information that was reviewed.				
Scientists can disagree because they rely on different information. *"It is possible for scientists to disagree because they might have different information."* (D17)	0	0	9	47
2.Disagreements in science are attributed to scientists (as persons and to the way they work).				
Scientists can disagree because they have the right to have different opinions. *"Many scientists disagree with each other many times when they are on new research because each person has its own opinion."* (D32)	16	59	7	37
Scientists need to agree because they work in groups. *"It is not possible to disagree because this would mean that they are against the other group."* (D12)	1	4	0	0
3.Disagreements in science depend on how productive they are.				
Scientists can disagree because disagreements are useful for the progression of scientific knowledge. *"It is possible to disagree with each other because this is a way to find more solutions to their problems."* (D36)	1	4	0	0
Scientists can disagree because this stimulates further research. *"If scientists did not disagree with each other, then there would be no reason to work more on a subject. But now they work more on a subject, their answers are more certain."* (D31)	2	7	0	0
Scientists can disagree because it enables them to recognize fallacies they might have run into. *"It is possible that scientists disagree with each other because if they agree they might be both wrong (and then we are left with no claim on an issue)."* (D24)	1	4	0	0
Scientists need to agree because disagreements hinder scientists from achieving their goals. *"Scientists make research in order to find a solution. It is not possible to disagree."* (D39)	5	19	3	16
4.Mixed responses				
Scientists may have different information and different opinions. *"Every scientist has his/her own opinion and his/her own information on a subject."* (D2)	1	4	0	0

The LE sought to help students appreciate that scientists' objectives might influence the data collection and/or interpretation as sources of subjectivity. This perspective addresses the role of both scientists (category 2) and data (category 1) in constructing claims and, thus, this kind of responses were coded as mixed (category 4). There was only one such response in the pre-tests but the student referred to the role of scientists and data separately. Even though there were not any written mixed responses after the enactment, such responses were discerned in the interviews, as shown in the next quote [Student (D2)].

> "Each group of scientists will collect the data that relate to what they represent or think. Scientists who thought that temperature increased due to some gases, tried to find data to prove this. On the contrary, the others tried to find supporting evidence for their position. Each group might have studied the same data but focused on parts fitting their position. […] this is sometimes unintentionally done depending on the goals and beliefs of the group you belong to."

However, not many such responses emerged and this also has implications for the revision. For example, more activities may be added so as to facilitate students' adoption of their role. The LE could also be enriched with explicit discourse in relation to existing interpretations of data of other topical SSIs so as to give more opportunities for discussing this learning objective.

Conclusions

This study contributes to existing knowledge on elementary students' initial ideas on uncertainty and subjectivity in science, the difficulties they encounter when trying to understand about these aspects and the extent to which it is possible to impact through the use of inquiry-based LEs. Although the results show that students can learn about NOS aspects with such LEs with embedded explicit discourse in the context of SSIs, the LE has limits and weaknesses. For instance, we discerned difficulties that were not anticipated during the design, while some learning objectives were not achieved to a satisfactory degree. These suggest the need for refinement through multiple cycles of design-evaluation-revision until an effective LE is established (Andersson, 2004). The study also provides insights into how empirical results can be used for further refining the LE.

References

Andersson, B., & Bach, F. (2004). On designing and evaluating teaching sequences taking geometrical optics as an example. *Science Education*, 1-23.

Barab, S.A. (2006). Design-based research: A methodological toolkit for the learning scientist. In R.K. Sawyer (Ed.), *The Cambridge Handbook of the Learning Sciences*. Cambridge, New York: Cambridge University Press.

Lederman, N. G. (2007). Nature of science: Past, present, and future. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of Research on Science Education* (pp. 831-879).

Sadler, T. D., Chambers, F. W., & Zeidler, D. L. (2004). Student conceptualizations of the nature of science in response to a socioscientific issue. *International Journal of Science Education, 26*(4), 387-409.