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Elementary School Students' Emotions when Exploring an Authentic Socio-Scientific Issue through the Use of Models

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ABSTRACT: Despite the belief that emotions are important in the learning process, research in the area of emotions and learning, especially in science, is scant. Modelling and SSI argumentation have shared with respect to the emphasis in recent science standards reports as core scientific practices that need to be part of science teaching and learning. Even though there is evidence supporting the effectiveness of these competences in students' achievement, students' emotions about these have not been explored. The emphasis in this paper is on students' self-reported emotions about a lesson focusing on understanding an authentic socio-scientific issue through the use of student constructed models. Specifically the emphasis is on exploring students' emotions about the learning environment, and on identifying whether their self-reported emotions about the designed activities are positive or negative. The sample for the research study consisted of 19 elementary school students (11-12 year olds), who were interviewed individually at the end of instruction (two months long) with the goal of allowing the students to express their emotions about the learning environment. Findings suggest that students hold both positive and negative emotions about SSI instruction, as well as about the various aspects of the specific learning environment.

KEY WORDS: self-reported emotions, modelling, socio-scientific issues (SSI), elementary science, and collaboration.

INTRODUCTION

Emotions in education are a relatively unexplored, even though they are increasingly becoming an emphasis of study in many disciplines (Zembylas, 2007b). Specifically, during the last decade, researchers have begun exploring students' emotions and anxiety from test taking and achievement (Pekrun et al., 2011; Pekrun, Elliot, & Maier, 2006), whilst other researchers working in a socio-cultural framework have explored teachers' emotions about teaching (Ritchie et al., 2011; Zembylas, 2007a),

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and students' emotions about collaborating in groups (Järvenoja & Järvelä, 2009). According to educational psychologists, emotions are pervasive in learning since they can influence learning, achievement and motivation (Pekrun et al., 2011). For example, the majority of studies in the field of science education report that positive emotions and enjoyment from learning science play a significant role in the learning outcomes and serve as a driving force for self-learning, and retaining knowledge (Alsop & Watts, 2003; Järvenoja & Järvelä, 2009; Ritchie et al., 2011). Despite the aforementioned, the exploration of students' emotions about learning science through participating in authentic contexts is still scarce (Alsop & Watts, 2003), even though we are aware that students' emotions, either positive or negative, can have a significant impact on learning (Goleman, 1996; Järvenoja & Järvelä, 2009). The emphasis of our study is on elementary school students' emotions during a lesson focusing on understanding an authentic socio-scientific issue (SSI) through engaging in the practice of modeling.

The choice of SSI as the authentic context of this study is based on a growing consensus within the field of science education that real world issues should become more central components of science curricula (Cavagnetto, 2010; Driver, Leach, Millar, & Scott, 1996; Kolstø, 2001). Specifically, there is evidence supporting the use of SSI as a context for science education as potentially providing students with meaningful experiences through focusing on socially relevant issues (Kolstø, 2001; Patronis et al., 1999) and also being motivational (Sadler, 2009). Additionally, studies in the area of SSI indicate that placing science in a familiar context raises students' interest and improves their attitudes towards school science (Albe, 2008). SSI are considered as affording a range of emotions and there is also evidence that students involve emotions when discussing SSI (Zeidler, 1997; Zeidler & Keefer, 2003), identify with actors involved in SSI (Evagorou, Jimenez-Aleixandre & Osborne, 2012; Simonneaux & Simonneaux, 2008), or they express emotions about collaborating in groups (Järvenoja & Järvelä, 2009).

Based on the aforementioned, our study focuses on understanding students' self-reported emotions about their participation in the learning environment. The importance of this study lies mainly in the fact that participating in SSI can create a number of emotions in students, especially younger ones. These emotions can either assist or hinder learning (Claxton, 1991) and by exploring students' emotions we can be informed of ways to improve curricula and learning environments.

LITERATURE REVIEW

Emotions in Education

Emotions cannot easily be defined, mainly because there is no consensus in the literature on what emotions are. Emotions are defined in different ways based on the theoretical stance of the researcher (Zembylas, 2007a) with four main schools of thought involved . First, according to *evolutionary psychology* emotions are adaptations that help people regulate functions that are essential for their survival (Lewis, Haviland-Jones, & Barrett, 2010). Fear, for example, prevent people from sleeping and help them stay awake and protect themselves. In a similar way emotions can direct attention, learning and motivational priorities (Lewis et al., 2010). From a *cognitive perspective,* emotions are considered as an individual experience, making them internal feelings experienced by a person at the instance when something happens. Parkinson (2012) suggests researchers in this area are only interested in the momentary personal reaction of the person in the situation, and not in the sociocultural context in which the emotion emerged. According to a third school, the *social constructivist approach,* emotions are viewed as sociocultural experiences and "are determined not only or even primarily by internal individual (intrapersonal) characteristics, but rather by relationships. Emotions are grounded in the particular social context that constitutes teachers, students and their actions in the classroom" (Zembylas, 2007a, p.62). In the last theoretical terrain, *interactionism,* emotions are still a sociocultural experience but are not interpreted solely through language, but also through the body, gestures, and expressions (Zembylas, 2007a).

In the present study, we follow the social constructivist approach to measure and analyze emotions, since we view emotions as an expression that is influenced by the social and cultural environment, and not solely by the person expressing them. We measure emotions through self-reports, since students were asked to report their emotions regarding their interaction with the learning environment, the teacher, the other students and the researchers. Self-reporting of emotions, according to Robinson and Clore (2002), the degree to which self-reports are valid varies according to the type of self-report. They claim that self-reports of current experiences are likely to be more valid than those of emotions made somewhat distant in time from the relevant experience. Therefore, we consider that the self-reported emotions by our students are valid, since they concern their current educational experiences.

Socio-Scientific Issues in Education

SSI can be defined as those issues which represent social concerns and problems that are conceptually influenced by science and require the integration of science concepts and processes with issues of moral, ethics, costs and values (Sadler, Barab, & Scott, 2007; Zeidler & Sadler, 2007). SSI are by nature, controversial and ill-structured (Zeidler & Sadler, 2007). In this study we used authentic SSI, and with the term authentic we refer to problems that are real, and of concern to the community that is exploring them (Aikenhead, 2006).

SSI are introduced in science education, amongst others, because they promote informed decision-making; strengthen the ability to analyze, synthesize, and evaluate information; help students engage with moral and ethical issues (Zeidler, 1997) and help them make the connection between science and everyday life (Aikenhead & Ogawa, 2007). A common claim in favor of implementing SSI in science education is that students become more motivated to learn science, develop positive attitudes towards science education, and finally engage in learning (Sadler, 2009). Researchers study the context of SSI (e.g. Albe, 2007; Evagorou, 2011; Simon & Amos, 2011; Simonneaux, 2008) as a motivational stimulus for learning and promoting interest in science. For example, Bulte, Westbroek, de Jong, and Pilot (2006) used a local SSI problem with high school students in exploring the quality of potable water. Their findings suggest that students were motivated, and generally enjoyed the hands-on part of the activity. Similar findings are reported by Lee and Erdogan (2007) in a study with middle and high school students, in which learning about an SSI situation was effective in developing more positive attitudes towards science, and in increasing students' creativity skills.

Models and Modeling in Education

Based on Halloun and Hestenes (1987), we use modeling in the constructivist sense of building and deploying a model of a physical object, a process, or a phenomenon with an aim to gain understanding of the phenomenon. Specifically, we see modeling as referring to collaboratively constructing "scientific models" using real objects. A model, in this case, is an epistemological entity meeting three distinct requirements: (a) *it represents* the essential characteristics or aspects of the phenomenon, (b) *it provides* a mechanism that accounts for the operation of the phenomenon, and (c) uses it to *formulate predictions* about changes and trends in observable aspects of the phenomenon (Nicolaou et al., 2009; Schwarz et al., 2009).

Gilbert (1991) suggests that for students to understand the nature of science and scientific knowledge they should participate in modelling-based instruction in order to develop an awareness of the artificial nature of models and, therefore, the tentative nature of science.

The close relationship between models and scientists' activities support the view of science as a process of constructing models for prediction purposes (Gilbert, 1991). Accepting that science is the process of constructing and deploying scientific models helps students understand that knowledge is a human product (Grosslight et al., 1991), since despite the fact that they challenge the artificial nature of knowledge, they support, according to Gilbert (1991), that models relate to artificial knowledge. Involving learners in working with models and modeling is also grounded in the premise that models can make abstract entities visible for students (Justi & Gilbert, 2002) and simultaneously act as an intermediate agent between their ability to describe the phenomena and accounting for the observable data deriving from them (Acher, Arca, & Sanmarti, 2007).

To our knowledge, students' emotions about models and modeling have not been the subject of research, at least in science education, while the aforementioned literature results indicate that using SSI as the context of instruction affords a number of different emotions to students, which aspects the SSI instruction afford specific emotions has not been explored in detail. Moreover, it is not clear whether modeling promotes negative or positive emotions to students, or whether there any other characteristics of the learning environment that promote specific emotions to students?

In order to address this gap, the research question guiding this study is stated as: Which characteristics of the learning environment create positive or negative emotions to the students?

METHODOLOGY

Context of Instruction

The learning environment was designed based on project based learning (Krajcik, Blumenfeld, Marx, Bass, & Fredricks, 1998), sociocultural theories of learning (Rogoff, 2003) and what was already known regarding how young students construct models (Constantinou, 1999; Louca, Zacharia, & Constantinou, 2011) plus talk about SSI (Evagorou, 2011). The driving question guiding all lessons was 'What solution(s) do you propose as appropriate to deal with the excessive mosquitoes in your area?' Based on the aforementioned, a learning environment was designed aiming to engage students in the exploration of SSI using modeling as a tool. Based on the issue, the teacher along with the researchers prepared a proposed structure for the curriculum. After each lesson, the teacher and the researchers discussed emergent issues and restructured the next lesson based on this discussion. The structure of all 14 lessons were developed and implemented as described below:

<u>Lesson 1</u>: The teacher introduced the mosquito issue to the class, and during a whole classroom discussion they talked about the biology of mosquitoes. Then the teacher asked the students to describe, individually, a proposed outcome for the issue (40 minutes).

Lesson 2: The teacher facilitated a whole class discussion in which the students discussed their proposals. Then the groups were presented with a list of possible solutions, namely

- chemical spraying to kill the mosquitoes at any of the stages of their life cycle,
- biological spraying to kill mosquito larvae,
- introduction of new species that are fed on mosquitoes (i.e. Gambusia Affinis fish and bats),
- planting eucalyptus trees to drain the salt lake, and
- genetic modification of mosquitoes to stop them from reproducing.

Only a short description of each was presented, without any reference to the effects of each on the environment. The students were instructed to decide (in groups) which one of the potential solutions is the best and explain their reasoning in their notebooks. They were also instructed to note down any questions they had regarding their proposal (40 minutes).

Lessons 3-5: Since the issue was associated to a nearby salt lake, the students visited the salt lake to study the ecosystem of the area and gain information. During the visit, they collected various data (i.e. temperature of the salt lake, wind, occurrence of mosquitoes around the lake), they represented the salt lake on paper, took pictures of the lake and its surroundings, and investigated what types of organisms live in and around the salt lake. After returning to their class, the students had various questions regarding the organisms of the lake, and therefore the teacher suggested that they report their questions in their notebooks and search online to find the information, either at school or at home (120 minutes).

Lessons 6-8: The questions from the previous session were discussed during a whole classroom discussion at the beginning of the lesson. These were mostly questions about the biology of the different organisms found in the salt lake – i.e. the brine shrimps (Artemia Salina) and how they survive during summertime when the salt lake was drained. The students were then asked to work in their groups and, based on the data, drawings and information gathered during the field study, to construct a three dimensional physical model of the salt lake using material of their choice. After this initial modeling experience, each group presented their model justifying the choice of materials and representations (120 minutes).

Lessons 9-10: The students worked in their groups, using their model as a visual aid to help them understand the effects of the proposed solutions For each proposed solution, the students needed to argue either for or against and register their arguments in their notebooks. At this stage, the groups were provided with information regarding the effects of each solution, but only if they requested for this information. Finally, each group was asked to choose the best possible solution, apply the solution to their physical model to show possible changes over time, and prepare an argument to justify their choice (80 minutes).

Lessons 11-12: The students prepared the final group argument to justify their decision for the solution. Finally, each group presented their model, justifying the choice of the proposed solution, and had the opportunity to challenge other groups' solutions. Moreover, they discussed implications arising from each proposed solution. It is important to state that there was no optimal solution (80 minutes).

Lessons 13-14: A municipal councilor visited the class. Each group presented the proposed solution through their models showing possible effects, justifying their choice. After the presentations, the municipal councilor asked questions about the effects of each solution. Students had the chance to enquire about the processes applied by the local authorities regarding this problem, and the councilor informed them of the actions taken (80 minutes).

The Role of the Teacher

The teacher, the third author of this paper, is an experienced science teacher with 20 years of experience. She is familiar with recent trends in science teaching, and holds a PhD in Science Education with an emphasis on argumentation and SSI. Based on pre-observations in her class, she is following an inquiry-based teaching approach placing an emphasis on the experimental process. She focuses on students communicating their findings and feelings of the learning process. Our pre-observations were consistent with her teaching practice. During all lessons, the teacher's main role was to coordinate and scaffold the group discussions and coordinate whole classroom discussions whenever necessary. When students requested information the teacher either provided evidence cards with information (i.e. information regarding the effects of the solutions), or suggested searching for the information online.

Participants

The participants of the study were 19, 6th grade students (10-12 years old) from an urban school in a European country, nine girls and ten boys. Based on the school's curriculum, these students were taught science for two periods (40 minutes each) every week. They usually engaged in discussions and experimentation of scientific topics. They had no previous experience with modeling and SSI. They were not used to undertaking group work in other subjects, but for their science class they were assigned to groups of four or five. The same class structure was applied during the implementation of the project. One of the students was not a native speaker, and the teacher characterized the majority of them as average achievers.

Data Collection Process

The learning environment was implemented over a period of two months and all group interactions and whole classroom discussions were video recorded by the two researchers (the first and the second author) who were present in all lessons. Additionally, both researchers kept research journals during all lessons, which were used when necessary during the data analysis. The students kept notebooks in which they recorded: their arguments, notes from the field study, and any information relevant to their proposed solution. The researchers collected all notebooks after the end of the instruction, along with photographs of the models that were created by each group. After the end of all lessons, the students were interviewed. All students knew the interviewer beforehand, as she was a member of the research group, and present during the implementation. This contributed to the establishment of the rapport necessary for the students to trust the interviewer and therefore to feel free both to express their emotions in a comprehensive way and to raise doubts about the questions they were being asked.

For the purposes of the present research study, only the data from the interviews were used to answer the research question. The *semi-structured interviews*, based on the interview schedule applied by Zembylas (2004) had a duration of 10-15 minutes and consisted of questions aiming to examine students' self-reported emotions about the learning environment and their interaction with the learning environment, the teacher, the researchers and the other students. The interview protocol was included in the Appendix.

Data Analysis Process

The following steps were followed in order to address the research question, "which characteristics of the learning environment create positive or negative emotions to the students?"

<u>Step 1</u>: The interviews from all 19 students were transcribed and then open coded individually by the three authors, with the aim of identifying characteristics/aspects of the learning environment that created either positive or negative emotions for the students. After the initial open-coding, the main categories were identified and agreed. The coding categories, along with representative quotes, were as presented in Table 1.

Table 1 Description of coding categories for characteristics of the learning environment based on students' emotions

Coding category and description	Example of a Quote
SSI aspect: Instances in the interviews were coded as SSI when students:	
1. Referred to the importance of the issue because it is real and concerns their community,	*1. I was proud because we dealt with a real problem, a problem of our community!* (Student 15, positive emotion)
2. Referred to the uncertainty of the proposed solutions for the problem as something negative,	*2. I did not like the fact that we did not reach to a solution and just presented our ideas to the councilor* (Student 12, girl, negative emotion).
3. Referred to the need of an expert to confirm their solution,	*3. I liked that the councilor came and helped us decide which solution to implement.* (Student 11, positive emotion)
4. Referred to their input to the community stakeholders as something positive/negative.	*4.1. I really liked that we had the chance to express our opinion about the issue to the town councilor* (Student 10, boy, positive emotion). *4.2. I was anxious when the town councilor visited us, because I did not know what to expect* (Student 13, girl, negative emotion).
5. Referred to the process of decision making as something pleasant.	*5. I liked the fact that we were free to find our own solution* (Student 4, girl, positive emotion).
6. Referred to the process of decision making as elimination of solutions as not feasible.	*6. It is impossible to decide when there are so many solutions. I didn't like this* (Student 12, negative emotion)

Table 1 Description of coding categories for characteristics of the learning environment based on students' emotions (cont'd)

Modeling aspect: Instances in the interviews were coded as modeling when students talked about either the process or the product (actual model) of the modeling procedure.	*1. I was very happy and proud building our own model, because it was something creative and was totally our creation* (Student 17, boy, positive emotion). *2. I was sad because our model was not as good as the models presented by the other groups* (Student 6, boy, negative emotion).
Collaboration: Instances in the interviews were coded as collaboration when students referred to interactions between group members during the activities.	*1. I really liked the fact that we tried all together to find the best solution and we worked in groups* (Student 16, boy, positive emotion). *2. I felt anger with the other group members, because they didn't want to help in the process of collecting material for the model* (Student 9, boy, negative emotion).
Other aspects	
Knowledge acquisition: Instances in the interview were coded as knowledge acquisition when the students talked about learning something new.	*1. I liked our lessons very much because we learned so many things about mosquitoes* (Student 3, girl, positive emotion).
Breadth of activities: Instances in the interview were coded as types of activities when the students talked about the different activities, or how these differed from their usual classes.	*1. I enjoyed the fact that we did many activities different from the usual* (Student 15, boy, positive emotion). *2. It was not a lesson from a book; it was great that we studied the theme in depth; we discussed many details for each organism* (Student 14, girl, positive emotion).

Step 2: Two researchers, based on the emerging categories, coded the interviews independently. Inter-rater reliability reached 95% and any disagreement was resolved after discussion.

Step 3: Even though the interview specifically referred to a number of different emotions (e.g. anxiety, happiness, excitement, anger etc.), aiming to help students express the breath of their emotions on students' responses, were grouped as "positive" or "negative". This grouping was based on the main aim of our study, which was to identify which characteristics of the learning environment create positive and which created negative emotions, as opposed to what kind of emotions did each characteristic promote.

Step 4: Based on the coding categories in Table 1, the number of students expressing either positive or negative emotions about each of the learning environment aspects, were recorded and presented.

FINDINGS

Table 2 summarizes the findings from the interviews. The first column of the table presents the aspects of the learning environment that afford an emotion (either positive or negative) and the second part presents the students' emotions towards the different aspects of the learning environment, as reported in the interviews.

Table 2 Summary of Students' self-reported emotions towards different aspects of the learning environment

Aspect of learning environment	Students referred to (the aspect) as creating		
	Positive emotions	Negative emotions	both positive and negative emotions
1. SSI Aspect	*18*	*9*	*8*
2. Modeling Aspect	*15*	*1*	*0*
3. Collaboration	*4*	*5*	*3*
4. Other aspects			
Knowledge acquisition	*9*	*0*	*0*
Breadth of activities	*7*	*0*	*0*
Field study	*10*	*2*	*1*

As evident in Table 2, some students expressed both positive and negative emotions for some of the categories, while some others did not talk about their emotions for these categories. Based on the findings, three tendencies among students' self-reported emotions towards the aspects of the characteristics of the learning environment were present:

Finding 1: Students have contradicting emotions for the same aspect:

Table 3 indicates, for some aspects of the learning environment (namely SSI, collaboration, field study), eight students who expressed both positive and negative emotions; three students expressed contradicting emotions about the collaboration aspect of the environment, and one about the field study.

In order to identify why there was this discrepancy in students' emotions for the same aspect of the environment, students' profiles about their self-reported emotions were analyzed and presented in Table 3.

It is evident from Table 3 the positive emotions are mostly associated with (1) the importance of the problem because it is real and concerns their community; or (2) their input to the community stakeholders. For example, Student 12 (girl) stated, "I felt really good during these lessons, as it was the first time that we investigated a real issue; something that affects our lives. We had to think of real solutions to that issue." On the contrary, the negative emotions were mostly associated with the uncertainty of the solutions, the fact that nobody was certain as to how effective a solution could be. The same student (#12) said during the interview, "I did not like the fact that we could not be sure whether any of our solutions was correct."

With regard to the collaboration aspect, positive emotions related mostly to working together to find a solution, or to the fact that group members were helping each other. Negative emotions related mostly to the disagreements within the group. A representative example was the response of student 2, a boy, who expressed his contradicting emotions in the following way: "I didn't like the fact that we were fighting with the rest of the kids in the group, but, at the same time, I liked that we shared ideas and collaborated towards the same goal".

Another aspect of the learning environment that created mixed emotions was the field study. As mentioned in our methods, students visited the nearby salt lake to collect data and make observations that would constitute the basis for their model. Twelve of the 19 students expressed positive emotions, two students gave a negative position and six did not mention this activity at all. The sum of these responses was not 100% as one of the students (#7, boy) expressed both positive and negative emotions about the field study: "Going to the lake was cool, I loved it but I didn't like walking there. I got tired".

Finding 2: Students have either positive or negative emotions for the same aspect

A second finding suggested that for the modeling aspect of the learning environment some students expressed positive emotions only, and others

Table 3 Students' self-reported emotions towards different aspects of the learning environment

Student #	SSI Aspect										Modelling		Other Aspects							
	Importance of Problem		Uncertainty of Solution		Need Expert		Contact Stakeholders		Decision Making				Knowledge Acquisition		Breath Activities		Collaboration		Field Study	
	Students talked about it (the aspect) as creating																			
	P	N	P	N	P	N	P	N	P	N	P	N	P	N	P	N	P	N	P	N
1	1	0	0	1	0	0	1	0	0	0	1	0	1	0	0	0	1	1	1	0
2	1	0	0	1	0	0	1	0	0	0	1	0	0	0	1	0	1	1	1	0
3	0	0	0	0	0	0	1	0	0	0	1	0	1	0	1	0	0	0	0	0
4	0	0	0	1	0	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0
5	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1
6	0	0	0	1	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1
8	0	0	0	1	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0
9	0	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0	1	1	0
10	0	0	0	1	0	0	1	0	0	0	1	0	1	0	1	0	0	0	1	0
11	0	0	0	1	1	0	1	0	0	0	1	0	1	0	0	0	1	0	1	0
12	0	0	0	1	0	1	0	1	0	1	0	0	1	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	1	0	0
14	0	0	0	0	0	0	0	1	0	0	1	0	1	0	1	0	0	0	0	0
15	1	0	0	1	0	1	1	1	0	0	0	0	1	0	1	0	0	0	1	0
16	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
17	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	1	0
18	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
19	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0
Total	**5**	**0**	**0**	**11**	**1**	**2**	**12**	**6**	**1**	**1**	**15**	**1**	**9**	**0**	**7**	**0**	**4**	**5**	**10**	**2**

P=positive emotions, N=negative emotions, negative emotions only. In their interviews, most students mentioned that they enjoyed constructing and deploying their models. A representative example was student 9 (boy) who said, “I really enjoyed building the model. It was creative.” Only one of the students, student 6, expressed negative feelings about the modeling process. Specifically he said, “I was not sad, but stressed that the models we created were not good enough.”

Finding 3: For some aspects of the learning environment students have only positive emotions

For some aspects of the learning environment, students expressed only positive emotions. Specifically, during the interview nine students talked about knowledge acquisition, and highlighted their enjoyment of the lessons because they gained deep knowledge, learned a lot about the topic, and wanted to find out more information on their own. A representative quote from student 14 (girl) explained: “I liked the lesson because we learnt a lot. We opened it up. Every time after the lesson, I wanted to search online to find out more. The more we learned, the more I wanted to know.”

Additionally, during the interview seven students expressed positive emotions towards the fact that they engaged in a number of different activities and also activities that differed from their usual practice: “It was not a lesson from a book. It was great that we studied the theme in depth; we discussed many details for each organism” (Student 14, girl).

It could be important here to state that the “knowledge acquisition aspect” could be considered part of the SSI aspect, but it was not however unique for SSI. For example, positive emotions referred to the knowledge that students’ gathered about the mosquitoes and the ecosystem (see Table 1 for quotes), a characteristic that could be attributed to any other inquiry-based lesson. For this reason, the “knowledge acquisition aspect” was included in the “other aspects” of the learning environment, and not under the SSI aspect. The SSI component was, however, a unique socio-scientific aspect of the issue that the students were discussing (see Tables 1-3 for quotes).

DISCUSSION AND IMPLICATIONS

Engaging students in the learning process and promoting positive emotions towards science could be considered important aspects of science education. In this study, we explored students’ emotions about various characteristics of a specially designed learning environment combining modeling and SSI. The overall findings indicated that:

a. some aspects of the learning environment create both positive and negative emotions for the same students; namely the SSI aspect of the problem, collaboration and the field study,
b. some aspects of the learning environment create positive emotions to some students, and negative to others (i.e. modeling), and
c. some aspects of the learning environment created only positive emotions to the majority of the students; namely the, knowledge acquisition and breath of activities.

Part (c) is in line with results from previous studies (Bulte et al., 2006; Evagorou, 2011), which identified that the open-ended nature of the tasks, and working towards discovering new information on their own was rewarding for students. The preference for the open-ended structure of course might be explained by the fact that it was a different structure than usually applied in elementary school classes, and was a hands-on approach since students were working with materials.

Our findings also suggest that modeling is something affording positive emotions (only one student named modeling as something that caused him negative emotions). This is a contribution of our study considered valuable since, based on our reading of the literature, there is no published study exploring students' emotions towards modeling. Our hypothesis accounts for this finding is that students, especially younger ones, prefer hands-on activities to help them visualize and better understand the ecosystem under study.

SSI can create both Negative and Positive Emotions

Our analysis indicated that most of the students expressed contradictory emotions about the SSI aspect of the learning environment. To better understand why this happened, we broke down the different aspects of the SSI environment, based on how students talked about them during the interviews. This detailed analysis revealed that positive emotions were mostly expressed about the authentic nature of the topic under study. On the other hand, presenting the outcomes to the authorities was perceived by some students as positive, and by others as negative, mainly because of the stress that the students felt about talking to someone they did not know, and their disappointment because the councilor could not provide a definite solution to the problem. Specifically, students expressed positive emotions about investigating a problem that was part of their everyday life, since according to them it made them feel that they could contribute to their local community. This finding agreed with published work according to which using SSI or everyday life issues as context for learning produced positive learning outcomes (Aikenhead, 2006; Sadler, 2009).

Some students, however, expressed negative emotions, mostly associated with the uncertainty of the solutions, and specifically the fact that nobody was certain as to how effective any solution could be, or what was the answer to the problem they were investigating. Several reports provide evidence of student interest in SSI and engagement in SSI learning experiences (Albe, 2008; Zeidler, Sadler, Applebaum, & Callahan, 2009) but these findings were reported through observations by students, and not by the students' self-reported emotions. In our study, we recorded students' emotions regarding the use of SSI contexts, as these were expressed by the students. Therefore, a second contribution of our study, especially important for SSI instruction, was that using SSI as the context of instruction could potentially create negative emotions to some students mainly because of the ill-structure nature of the issue, and the uncertainty of the proposed solutions. This finding might be explained by the fact that science was usually presented in a final form in the science classroom and the use of SSI contradicted this way of presenting science, since it introduces uncertainty. An implication arising from this finding was that there was a need to explore how uncertainty could be introduced in the science curriculum, especially with younger students, since developmental constraints might also be related to the negative feelings that students of this age had when introduced to ill structured-problems. Furthermore, the strain between introducing SSI to motivate students, and the negative feelings that were afforded by the uncertainty should be considered when designing a SSI related curriculum.

Collaboration can create both Negative and Positive Emotions

According to our findings, some students expressed positive and others negative emotions regarding the collaboration in their groups, whilst 3 students held both positive and negative emotions. We hypothesized that positive emotions were related to students being able to contribute to group work and being appreciated by the other members of the group because of their contribution. To our reading of the literature this is third contribution of the current study, since research on students' emotions about collaborative work is scarce (Järvenoja & Järvelä, 2009). Studies in collaborative learning in the past have focused on establishing parameters for effective collaboration (e.g age, sex, cognitive ability of the students in groups). For example a number of studies suggest that groups of learners with similar abilities seem to learn better than groups of widely varying abilities (Hogan, Nastasi, & Pressley, 1999). More recent studies are instead moving towards understanding the conditions under which collaborative learning is effective (Webb, 2009). The second aspect of our finding is that for some students, collaboration creates negative emotions, since according to them there is a lot of fighting in the groups. This finding is in line with results from previous studies according to which friendship groups are better in collaboration than groups assigned by teachers, because there is no fighting (Alexopoulou & Driver, 1996; Järvenoja & Järvelä, 2009), or that collaborative work creates mixed emotions because of the power issues in the groups (Järvenoja & Järvelä, 2009). It is important to note that students who reported negative emotions about collaboration are in mixed-sex groups in which one of the students is trying to be in charge of the discussion.

What we have essentially presented in this study is that students have different emotions about SSI instruction, and different emotions about the various aspects of the specific learning environment. The data reported in this study provide useful insights that could inform teachers' in-class instructional efforts. Implications include respecting individual students' identities during instruction, designing learning environments, and appreciating that certain aspects of SSI, plus collaboration, might be negatively perceived by students. Finally, in SSI instruction there is a need for scaffolding and introducing students to the aspects of SSI related to uncertainty.

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APPENDIX

Emotion Interview Protocol

Introduction

I would like to ask some questions about your feelings and emotions during the implementation of our research program, for example, whether you felt happy, sad, and angry and so on. Before I start with the questions, is there anything that you would like to ask or make a comment?

1. How did you feel during our lessons? Can you describe these feelings?
2. Why did you feel ___________ ?
3. I am going to show you a list of feelings (see below). Is there a word that you do not understand in this list? Did you experience any of these emotions during our lessons? If yes when and why? Explain.
4. Which of the emotions in this list you do not like? Did you experience any of those emotions during our lessons? When?
5. Did you like participating in this research program? What did you like the most? What did you least like?
6. Was this learning environment different from the classes you usually have? In which ways? How did that make you feel?

List with Emotions

Happiness, Sadness, Anger, Fear, Stress, Anxiety, Excitement, Pride, Boredom, Contented, Shame, Desperation