Socio-scientific Collaborative Inquiry in Astrobiology
– The Design and Implementation of a Digital Learning Environment

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Abstract
In a European project – CoReflect – researchers in seven countries are developing, implementing and evaluating teaching sequences using a web-based platform (STOCHASMOS). The interactive web-based inquiry materials support collaborative and reflective work. The project methodology is based on the idea of design-based research, which seeks to bridge the often disconnected worlds of academia and educational practices. Hence, the teachers are engaged throughout the project. The learning environments will be iteratively tested and refined, first as pilot projects, then during local implementations, and finally during implementations and synthesis work at the European level. All learning environments are focusing "socio-scientific" issues. In this article we report from the pilot of the Swedish learning environment with an Astrobiology context. The socio-scientific driving questions were “Should we look for, and try to contact, extraterrestrial life?” and “Should we transform Mars into a planet where humans can live in the future?” The students are in their last year of compulsory school (16 years old), and worked together in triads. We report from the groups’ decisions and arguments used. A majority of the groups express reluctance towards both the search of extraterrestrial life and the terraforming of Mars.

Introduction
Young peoples’ lack of interest in science and science intense educations and occupations are a big concern for many stakeholders in western societies (e.g. 2005; Sjøberg & Schreiner, 2005; Tytler, 2007). This has led to a call for a renewal of science education, so that more students feel that science is of relevance and importance for themselves, and for the society as a whole. There has also been an increasing acknowledgement of the importance of scientific knowledge among people, to make an active and informed citizenship possible. Hence many science education researchers suggest that work with “socio-scientific issues” should become part of science teaching (Sadler, 2004).

“Socio-scientific issues” can be defined in different ways. They include a scientific dimension, but also other dimensions like economical, aesthetic, ethical and social aspects. We agree with Zeidler et al. (2002) that the term socio-scientific issues take a broader perspective than Science Technology and Society (STS). They state

“STS education, while typically stressing the impact of decisions in science and technology on society, does not mandate explicit attention to the ethical issues contained within choices about means and ends, nor does it consider the moral development of the students” (Zeidler et al. 2002, p. 344).

There is often disagreement within the scientific community concerning scientific questions of relevance for a socio-scientific issue. There is a difference between “socio-scientific issues” where the science community agrees about the scientific dimension compared to those where there are disagreement. The latter are more complex, and Kolsto (2006) states that persons involved (decision-makers) have two main questions to consider.
"First, there is the ethical, personal, or social question related to what scenario to prefer or what actions to take. Second, the decision-maker might need to make a decision on the scientific question involved" (p. 1690).

Research shows that students and people in general (e.g. Ryder, 2002) often do not give high priority to science knowledge when making decisions. One explanation for this is that socio-scientific issues discussed often do not concern “core science”, but “frontier science” on which there is much uncertainty, and no consensus view within the science community (Aikenhead, 2006, p. 101-102).

An individual’s decisions on “socio-scientific” issues depend of her/his values and worldviews. What the right decision is depends on how one thinks about the world we live in, and how one values the costs and benefits. Worldview can be defined in different ways, but here we follow Kearney (1984). His model was adapted to a science education context by Cobern (1991, 1996). An individual’s worldview constitutes a basis for how he or she thinks about and understands specific phenomena, for example phenomena relevant for making a decision on a “socio-scientific issue”. Worldview also lies behind an individual’s judgement on what kind of knowledge that is important:

“Worldview provides a nonrational foundation for thought, emotion, and behaviour. Worldview provides a person with presuppositions about what the world is really like and what constitutes valid and important knowledge about the world” (Cobern, 1996, p. 584)

Examples of such presuppositions are that nothing more than the material world exists, that everything has a meaning, that there are patterns in nature that are possible for humans to understand, that nature is superior humans, and that a god can exist and interfere in the world.

Not only every individual but also all knowledge systems, for example science, are built upon presuppositions that are not possible to prove within the system itself (Cobern, 1991; Cobern, 1996; Trusted, 1991). There are partly different views within the science community concerning which presuppositions that science builds upon. But even though different scientists have slightly different views on this there is also what Cobern (1991) calls a “lived worldview”. This lived worldview consists of presuppositions that are taken for granted by most scientists in their daily work. Poole (1998) states that presuppositions shared by most scientists are

- “human reason is generally reliable,
- there is regularity and order in the universe,
- humans can discover and understand something of that order,
- there is a basic uniformity in the behaviour of the natural order, in space and time” (Poole, 1998, p. 186)

In a similar way Cobern & Loving (2000c) describe a “metaphysical minimum for science” and state that science take a starting point in that “the possibility of knowledge about nature”, “that there is order in nature” and “causation in nature”. However, these presuppositions are not always shared by the students and the students do not always or easily see that these presuppositions are associated with science (Hansson & Redfors, 2007). This is a possible problem for students about to learn science. For example if you do not know that science takes as a point of departure that there are order in nature, and that the theoretical models we construct are valid over time and space, it is difficult to in a meaningful way understand scientific models of how the Universe develops over time, or how stars are “born” and “die” (Hansson & Redfors, 2007).

How can this be handled in the science classroom? In the teaching of science the focus is often on different phenomena and models linked to these. According to a worldview perspective (Cobern, 1991, 1996) one also has to work with a more profound level of the students’ thinking – that is the presuppositions that the students have about the world. These have to be related to the presuppositions that underpin science:

“the strategy and tactics of science education need to be formulated as an analog to the macrolevels (worldview or level of fundamental presuppositions) and microlevels (conceptual level) of a everyday thinking” (Cobern, 1996, p. 591).

In this way more students can get knowledge about the presuppositions underpinning science, which makes it possible for them to understand also the specific models taught in the science classroom.
To include “socio-scientific issues” in the teaching of science prepares youths to deal with questions that they will meet as citizens in a democratic society. It is also a way to make science relevant for greater numbers of students. Yet another strategy to make science more appealing, and promising for meaningful learning, is to integrate new technologies (ICT) in the teaching. This article is a report from a pilot study within the European project, CoReflect (www.coreflect.org). Within this design-based project (Barab & Squire, 2004) the researchers together with teachers design digital learning environments about different socio-scientific issues. The web-based learning environments in this project are used to scaffold collaborative settings. The researcher-teacher groups in the different countries design one learning environment each, on different socio-scientific issues. In the first phase of the project we are piloting the learning environments in our own countries. In this article we report from this piloting phase in Sweden. In a later phase of the project we will implement the learning environments in other countries and study this implementation phase too learn about what changes that have to be done to accommodate different school systems, cultures and traditions.

The Swedish group have chosen to design a learning environment dealing with the scientific content area of Astrobiology. Astrobiology is a relatively new area of research that deals with questions related both to biology, astronomy/cosmology/physics, and chemistry. At the most profound level Astrobiology questions are questions like “Does life exist outside Earth?”, but to come closer to an answer to that question one tries to answer questions about the physical and chemical conditions for life, and how to establish whether or not a distant planet harbour life. Astrobiology researchers therefore try to detect planets that could be similar to the Earth, and try to understand more about the conditions for and origin of life on Earth. The possibility to detect planets orbiting other stars is a rather new one, and has made the research area of Astrobiology expand. These results have also reached the broad public, since they have been reported in daily newspapers. Astrobiology questions are of existential value for many people, and Astrobiology is also an area that we believe fulfils many of the things that young people today are interested in: much of it is unknown, it raises philosophical questions, which has been shown by ROSE (Sjøberg & Schreiner, 2006) to be of interest to many youths.

Rationale
The first aim of this article is to describe the learning environment and the thoughts behind. The second aim is to describe the results of the students’ decisions concerning the socio-scientific driving-questions, together with what kind of arguments the students use and value as important.

Methods
The data that this article builds upon comes from the implementation of a pilot version of a digital learning environment focusing socio-scientific issues in the context of astrobiology, designed within the European project CoReflect. We will first briefly describe the digital learning environment, the implementation, and after that the kind of data collected and analysis performed.

The learning environment
The web platform used to set up the learning environments within the CoReflect project is STOCHASMOS (Kyza & Constantinou, 2007). This platform is made up by two environments. The teacher authoring environment supports teachers in building or customizing and managing multi-modal, web-based inquiry environments and enables them to get asynchronous access to their students work. The learning environment allows students to collect and value information and arguments, explain their thinking, construct, and finally communicate their argumentation concerning a socio-scientific issue.

The teacher’s asynchronous access to their students’ work means that a teacher can review a group’s work and add comments to their workspace pages, thus providing feedback the students can view and use at the beginning of their next lesson. Furthermore, the history log of the tool can give teachers information on which inquiry environment
The students have visited and the time between accessing each of the web-pages stored in the STOCHASMOS system.

Learning environments of STOCHASMOS consist of different parts – “the inquiry environment” and the “work space”. In the inquiry environment the missions are presented, and the students can also find information that they could use developing their arguments. In the workspace students are asked to work with different activities, and also to gather information and arguments relevant for the missions. There is also a Chat, a Notebook and a Forum; these tools are accessible from both workspace and inquiry environment. Through the chat it is possible to communicate with one peer-group. It is also possible for the students to share pages in the workspace with this peer-group. The students were introduced to STOCHASMOS by working with a detective story – as detectives, solving a theft of computers in a school. The detective story introduces them to the uses of the STOCHASMOS features. It also helps to focus on the role of evidence in argumentation.

**The missions**

In the inquiry environment two missions were given to the students. The second mission was not shown to the students from the beginning. Both missions have socio-scientific driving questions, which include a scientific, but also economical, social and ethical issues are relevant.

- **Should we look for, and try to contact, extraterrestrial life?**
  - **Scientific aspect:** e.g. Probability to find life/intelligent life? What are the requirements for life? Where should we be looking?
  - **Social aspect:** e.g. Safety if we establish contact – for us, for them?
  - **Economical aspect:** e.g. How shall economical resources be spent?
  - **Ethical aspects:** e.g. How should we be looking for life? From Earth or through sending things out in space? Should we be leaving footprints? Interfere in the natural order?

- **Should we try to transform Mars into a planet where humans can live in the future?**
  - **Scientific aspect:** e.g. Probability to accomplish the project? What kinds of changes of Mars are necessary? How can it be done?
  - **Social aspects:** e.g. If it was possible to transform Mars, and humans could not survive on Earth – who will be allowed to go – who will decide?
  - **Economical aspect:** e.g. On what should economical resources be spent?
  - **Ethical aspect:** e.g. What kind of interventions should we do in our Solar System? Interference in the natural order?

In the first case the mission begin with a youth expressing concerns about possible life on other planets. The text is adapted from an actual blog in Swedish. The trigger for her/his thoughts is the publication of the first optical picture ever of an exoplanet, a planet outside our own solar system, see figure 1.

![Figure 1. The first tab of the STOCHASMOS Inquiry Environment](image-url)
The second mission starts up with an interview with the first Swedish astronaut Christer Fuglesang where he describes his thoughts about space travels and the possibility that humans can live on Mars in the future.

Framework and scaffolding

The STOCHASMOS inquiry environment consists of ten tabs besides the two mission-tabs. There the students find information about the origin and development of the universe, the solar system, exoplanets, life and conditions for life, how to get information about the universe (pictures, spectra, space travels), terraforming, security issues, economy and ethical issues. The last tab is about lab work and describes the lab work the students are asked to do. There are two sessions in the laboratory. The first is connected to distances in the Universe and the student practice the direct method of triangulation. The second is connected to the analysis of element abundances in stars and galaxies. The students get to observe spectra – continuous spectra as well as absorption and emission spectra.

There is also one tab “On Science” which contains a text on the Nature of Science (NOS). The focus is on presuppositions, theories and models. Including this is a consequence of the worldview theory. Cobern states that

“the strategy and tactics of science education need to be formulated as an analog to the macrolevels (worldview or level of fundamental presuppositions) and microlevels (conceptual level) of a everyday thinking” (Cobern, 1996, p. 591).

With the text on presuppositions together with an activity we want to focus the students’ attention to the presuppositions of science. In teaching about the Universe and extra-terrestrial life you often encounter question from the students on the relationship between Science and Religion. Therefore, a text on Science and Religion is included and the students get to discuss this relationship. This is also linked to the presuppositions that are associated with science.

Scaffolding is important to make it possible for more students to engage in reasoning on an appropriate level. The student work in the workspace is of course scaffolded by the teacher in the classroom, meeting the students face to face. The student work is however also scaffolded directly by the design of the learning environment. For example, to scaffold the students learning in the inquiry environment, the texts includes questions for the student groups to discuss. An example of how questions are included is shown in figure 2, showing the main text under the tab “On Science”.

**Figure 2. The On Science tab with challenging questions.**
Another way to scaffold the students work is through designed activities. There are activities on the presuppositions associated with science, Drake’s equation\(^1\), and habitual zones\(^2\). In addition to this the workspace of STOCHASMOS includes templates to help students structure their work and focus on relevant questions. In the workspace the students do all their work, but the reading part – they gather arguments and write conclusions. The students can create new pages using a predefined list of templates. There are templates to help students

- keep track of their chosen path through the materials (*All the tabs*)
- make notes on their discussion (*Group discussions*)
- work with the activities and the labs (e.g. *Drake’s equation*)
- gather and fine tune their arguments (*Concluding arguments*)
- formulate their final standpoint (*Final standpoint*)

In the work space the students can access images of data, texts and figures taken earlier with the camera tool, and they can insert a number of things in their pages, e.g. textboxes, “stickies”, arrows, images and links to pages that they have created earlier in the workspace. They are also asked to share their pages with a pair-group. There is a “History” feature which allows the students to view old versions of their pages.

The students are first introduced to the *All the tabs* template where they keep record of their progress through the learning environment. The template *Concluding arguments* is of special importance, see figure 3.

![Image of the workspace](image)

**Figure 3: The template *Concluding arguments***

It helps the students to consider all four aspects of the socio-scientific driving questions. It also helps the students to recognise arguments in both directions concerning each aspect. It has been shown that evaluating different positions is central for effective decision makers (Lee, 2007). By continuously working with this template the

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1 Drake’s equation is used to estimate the number of current civilisations in the Milky Way.
2 Habitual zones are spherical zones around a star where conditions for life, as we know it, are met.
students are given the possibility to enhance the basis for their final arguments, reported in the template Final standpoint no matter what path they have chosen to take through the learning environment.

The implementation

The learning environment was implemented in a student group that attend the last year of compulsory school (the year most of the students turn 16). Swedish students study science (including physics, chemistry, and biology), and the schools (and teachers) can choose whether the science subjects are integrated, or studied separately. The student group that worked with the pilot version of the learning environment studies the science subjects integrated. They were also used to non-teacher centred work – in groups and individually. There were 30 students in the group. The number of lessons was 13 including three lessons with the detective story. The students were working together in triads (groups with three students) in front of a computer.

Data collection and analysis

All computer activities were logged by STOCHASMOS. The arguments and decisions that the students have written in the templates of STOCHASMOS are therefore available for all student groups. Written pre- and post-instruments tested for students’ knowledge and inquiry-skills, worldviews, and motivation. In addition to this data was collected through audio-recording 6 of the 10 student groups throughout the teaching sequence. Follow-up interviews of single individuals were performed by the researchers.

During the implementation there were 1-2 researchers present in the classroom, managing video/audio recording and taking field notes. The researchers were trying not to take part in the teaching, even though some “teacher-like” answers to questions were given.

The analysis that this article builds upon is focusing students’ decisions and argumentation in their final statements of the groups. We are interested in what kind of arguments that the students tend to value as important.

Results

We will begin by describing the decisions and arguments of all ten student groups, and after that focus on the description of the work, argumentation, and decisions of one of the groups.

The decisions and arguments of the groups

During the work in the learning environment with the two driving questions the students collected arguments concerning scientific, social, economical and ethical aspects of the issues with the help of a template. With the starting point in those collected arguments the students were supposed to decide upon their views concerning the driving questions and formulate this view in a final statement for each of them. Looking at those decisions of the ten student groups concerning the two socio-scientific driving questions we can see that the most common answer is that we should not search for extra-terrestrial life, and we should not try terraforming Mars, see table 1.

Table 1. The groups’ decisions concerning the driving questions

<table>
<thead>
<tr>
<th>DRIVING QUESTION</th>
<th>YES (# of groups)</th>
<th>NO (# of groups)</th>
<th>NO STATEMENT (# of groups)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Should we look for, and try to contact, extraterrestrial life?</td>
<td>2</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Should we try to transform Mars into a planet where humans can live in the future?</td>
<td>1 (not possible)</td>
<td>7</td>
<td>2</td>
</tr>
</tbody>
</table>
In the final statement the students were also asked to describe their arguments. There are differences as well as similarities in the arguments put forward by the groups in the statements. The arguments included in each one of the final statements were analysed, and the arguments were categorised based upon their content. The categories that were emerging from the analysis are presented in table 2.

Table 2. Categories of student arguments

<table>
<thead>
<tr>
<th>Searching for life</th>
<th>Transforming Mars</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RISKS</strong></td>
<td></td>
</tr>
<tr>
<td>- safety during space travels</td>
<td>- dangerous for people (e.g. if the suits brake we will not cope)</td>
</tr>
<tr>
<td>- conflict between humans and the other intelligent species that we find</td>
<td>- we can bring back bacteria or other organisms that could cause illness on Earth</td>
</tr>
<tr>
<td>- we can bring back bacteria that could cause diseases</td>
<td>- we can bring organisms to Mars that can endanger indigenous life forms</td>
</tr>
<tr>
<td><strong>COSTS, RESOURCES, PRIORITISING</strong></td>
<td></td>
</tr>
<tr>
<td>- we should spend the money on other things (e.g. the environment on the Earth, people in developing countries, medical research)</td>
<td>- we should spend the money on other things (crises in the world, pour people, rebuild after war and nature catastrophes, education, medical research, environment, global warming)</td>
</tr>
<tr>
<td>- maybe the money will be spent in vain</td>
<td>- maybe we will not figure out how to do it</td>
</tr>
<tr>
<td><strong>CHANCE OF SUCCESS, PRACTICAL PROBLEMS</strong></td>
<td></td>
</tr>
<tr>
<td>- believe/do not believe that life exists elsewhere</td>
<td>- Mars lacks things that we need (water, food, too cold, nature, oxygen)</td>
</tr>
<tr>
<td>- believe life exists somewhere because the universe is large</td>
<td>- we'll have to wear astronaut cloths, change the temperature and atmosphere</td>
</tr>
<tr>
<td>- low chance of finding life (planets are far away, takes a long time to go there, the universe is large we can’t look everywhere…)</td>
<td>- takes a long time to go there</td>
</tr>
<tr>
<td>- Have only found planets where life cannot exist</td>
<td>- takes too long time to transform Mars</td>
</tr>
<tr>
<td><strong>CURIOSITY</strong></td>
<td></td>
</tr>
<tr>
<td>- we are curious</td>
<td></td>
</tr>
<tr>
<td><strong>ENVIRONMENTAL ASPECTS</strong></td>
<td></td>
</tr>
<tr>
<td>- CO₂ pollution by space travel</td>
<td>- space travels are bad for the environment</td>
</tr>
<tr>
<td>- important not to litter other planets</td>
<td>- should not ruin more planets</td>
</tr>
<tr>
<td><strong>TECHNOLOGICAL, DEVELOPMENTAL ASPECTS</strong></td>
<td></td>
</tr>
<tr>
<td>- could lead to higher intelligence and improved technology</td>
<td>- the Martians might have technology that can help</td>
</tr>
<tr>
<td>- natural resources, new fuel, help us learn how to live in space</td>
<td>- what use is it for us?</td>
</tr>
<tr>
<td>- not right for us to create better living conditions if the Universe must suffer</td>
<td></td>
</tr>
</tbody>
</table>

As we can see from table 2 there are arguments concerning risks, possible achievements, costs & resource prioritizing, chance of succeeding and practical issues, environmental issues, and curiosity. Not all kinds of arguments were present in all student groups. For example, while most groups include economical arguments and arguments about risks, only one of the groups put forward arguments about curiosity. Possible development is not mentioned frequently either. Ethical arguments are seldom mentioned explicitly in the groups’ final statements. One group states that it is not right of us to try to form a life that is more convenient for us if it has negative consequences, and one group mentioned that we should not destroy more places than we already has.
Conclusions and Implications

Most student groups decided that we should not look for extraterrestrial life, and neither should we try terraforming Mars. We have seen that the students in their statements put forward arguments of different kinds. Many of the students’ arguments are related to science, for example risks, chances of success and practical problems related to the missions. Economical arguments seem to be central and present in many of the groups. The same is valid for social aspects. Mostly this concerns arguments relating to different kinds of risks, but also arguments about the possibility that establishing contact with other life forms could lead to different kinds of development here on Earth. On the other hand ethical aspects are rarer. Aikenhead (2006) states that research shows that students are not able to thoughtfully make decisions on controversial issues before the age of 15 or 16 years old (p. 104). The investigated students are in that age where they could begin to handle controversial issues. This means that there probably are many students in the group that have difficulties with this. Economical aspects are more familiar and easier for the students to handle, compared to ethical aspects. Economy and resource prioritising are often more explicitly discussed in the society than ethical issues are. In a study by Hansson & Lindahl (2007) where older students (18-19 years old) were interviewed about whether we should try to transform Mars into a planet where humans could live in the future, it was rather common that the students mentioned ethical issues, associated to their worldviews. There are students in that study that find it problematic to interfere in another planet which could then be spoiled. They claimed that humans should not/are not allowed to interfere in nature in that way, maybe because they are older and more familiar with ethical considerations. In that study the students also only stated their individual views, they were not asked to agree with others. Ethical arguments is harder to agree upon in a group because of their heavily dependence on worldview.

That the students seems to prefer or choose to use arguments concerning science, risks, chance of success, and economical arguments rather than ethical ones could also be strengthened by the context. The Astrobiology context is an area that many students are curious and interested in (Sjöberg & Schreiner, 2005). However, it is also a research area that is not highly prioritised by Swedish adults (Public & Science, 2009). Hence the area seems to be considered interesting, but not very important. This is a possible reason for the influence of economical arguments.

Concerning the science aspect of the issues most student groups include arguments in their final statements concerning that. Analysing the arguments that are included we have seen that many of them are related to science. Obviously there are arguments about the probability of success – Does extraterrestrial life exist? Could we go there? But science also constitute a background for arguments about what kind of risks we are prepared to take – for humans and for possible extraterrestrial life. Science therefore constitutes a background also for ethical and social aspects of the issues. Much of earlier research on students’ reasoning on socio-scientific issues has shown that the students mainly focus on other aspects than science in their decision making (e.g. Ryder, 2002). This is not obvious from our analysis.

We will continue to analyse the students discussions during the teaching sequence to see how much science reasoning that really are present, and to find out how important science aspects are for their understanding and decision making on the issues. So far we can only conclude that they to a rather high extent include science related arguments in their final statements. Continuing the work we will analyse how the students’ worldviews can be related to their argumentation during the teaching sequence. We will also in the near future analyse the time spent on talking about the different aspects of the driving questions. We will also analyse in what ways and how the teacher scaffolds the students throughout the work with the learning environment. These results will be published elsewhere in the near future.

Acknowledgement

CoReflect (contract: 217792) is funded by the European Commission's FP7 Science in Society program. Any opinions expressed herein are those of the author and do not necessarily reflect the views of the funding agency.
A paper presented at the European Science Education Research Association 2009 Conference
Istanbul, Turkey
August 31 - September 1, 2009

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