Renewable Energy Resources
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Published in:
Electronic Proceedings of the ESERA 2017 Conference

Publication date:
2018

Document Version
Publisher's PDF, also known as Version of record

Citation for published version (APA):

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PART 8: STRAND 8

Scientific Literacy and Socio Scientific Issues

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*Cushla Dromgool-Regan, Noirín Burke, & Thomas McCloughlin*
STRAND 8: INTRODUCTION

SCIENTIFIC LITERACY AND SOCIO SCIENTIFIC ISSUES

Teachers’ role and skills for developing students’ scientific literacy, often through socioscientific issues were given much interest in many of the papers presented in strand 8. Hence, with a focus on teachers, studies were presented that adds to our knowledge on how in- and pre-service teachers better can organize and promote students’ development of scientific literacy and socioscientific reasoning. Among these, examples of frameworks and models for teaching scientific literacy and socioscientific issues that can be useful for professional development were discussed. To provide tools for teachers to develop a fruitful classroom communication a group of papers described the assessment and analysis of students’ socioscientific discourse. In addition, other studies described the conditions for students’ engagement in socioscientific issues to produce complex and well-grounded arguments.

Scientific literacy and socioscientific reasoning are important skills for all members of society. Hence, these skills can preferably be used without the limitations of the wall of a classroom. A number of papers brought different perspectives on authentic communication to the fore. Here the interaction with stakeholders in society for the purpose to deepen students’ knowledge and perspectives were given attention. Examples to promote students in taking further responsibility for society by engaging in societal discourses were given using diverse issues such as, for example, environmental problems, justice, and research and innovation. Among these, socioscientific issues concerning environmental problems were given much interest.

The following part of this proceeding contains eleven papers from the strand.

The paper by Sakamoto and Yamaguchi investigates how two types of socioscientific issues influence students’ informal reasoning. They found that issues that contain strong dilemmas often led to more emotive reasoning and less rationalistic reasoning than did issues that contain weaker dilemmas. Hüfner, Fiebert and Abels compare 8th grade students’ conceptions on energy resources with that of scientists. To do this, they interviewed students and analysed scientific reports on climate change. They found that there is a way to categorise both students’ and scientists conceptions of energy resources and that similarities and differences in these categories help us to indicate what to address in science education in the future concerning this topic.

The paper by Schenk and colleagues elaborates on the concept of risk and how that concept holds implications for teaching and science education research. One of the main findings is that there is a great variability in terms of how the concept of risk is understood and used, but that this variability may actually be needed. Further the authors argue that risk ought to be included in science teaching.

Vidal, Simonneaux and Levison investigate the place and role of myths in discussions of socioscientific issues among students in England, France and New Zealand. They were able to track the existence of thematic myths in specific issues, and they discuss what these findings mean for practice.
Rydberg, Olander and Sjöström study interdisciplinary teaching of controversial issues. Their findings indicate inherent tensions at different level of complexity in carrying out interdisciplinary teaching around such issues.

Bayram-Jacobs, Henze and Barendsen study how the ENGAGE material can engage students in socioscientific issues interweaving chemical concepts, society and personal life. It was found that students focused more on aspects on society and personal life than on chemical concepts. Baytelman and Constantinou investigate the influence of University students’ content knowledge on their construction of ethical arguments on different health issues. Students’ complex concept maps of content knowledge were found to predict a high quality of socioscientific arguments.

The paper by Motokane investigates students’ knowledge about three hierarchical levels of biodiversity: species diversity, ecosystem diversity and genetic diversity. In particular, the paper stresses the importance of forming relationships between the three levels and to fully understand genetic diversity to grasp the complexity of biodiversity.

Papers by Chadwick, Vidal and Dromgool-Regan examine literacy within context of socioscientific issues.

*Jan Alexis Nielsen and Mats Lindahl*
INFORMAL REASONING FOR SOCIO-SCIENTIFIC ISSUES CONCERNING DILEMMAS FACED BY GENETIC MEDICAL TECHNOLOGIES

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Individuals’ negotiation of socio-scientific issues (SSI) is often investigated through the framework of informal reasoning. This study aims to examine the impact of SSI dilemma strength on informal reasoning. One hundred and twenty-one university students responded to a questionnaire in which two SSI scenarios (one strong dilemma, one weak dilemma) concerning genetic medical technologies were presented. The participants were required to state their opinions and justifications on each scenario, as well as provide hypothetical counterarguments and rebuttals. To determine the quality of informal reasoning used, students’ written arguments were analysed and classified into three categories based on the types of reasoning displayed: rationalistic, emotive, and intuitive reasoning. A comparison of responses showed that the incidence rates of different informal reasoning patterns differed depending on the SSI scenario. In scenarios with strong dilemmas, emotive reasoning was employed more frequently, while use of rationalistic reasoning was less frequent. This tendency was generally shared regardless of participants’ gender or major. Thus, dilemma strength was found to affect participants’ informal reasoning patterns, such that strong SSI dilemmas disturbed participants’ rationalistic reasoning. This tendency was prominent among the participants who agreed with the presented scenario. This study’s findings may provide suggestions for improving and evaluating the design of SSI-based interventions.

Keywords: socio-scientific issues, dilemmas, informal reasoning

INTRODUCTION

Social issues related to science have become an important issue in science education research. Socio-scientific issues (SSI) are complex social dilemmas that represent applications of scientific principles and practices. SSI are typically ill-structured problems, which are subject to multiple perspectives and involve morals, ethics, personal experiences, and other values (e.g., Sadler & Zeidler, 2005). Examples of SSI include genetic engineering, cloning, local pollution issues, and global climate change. In the last decade, science education researchers and practitioners have made significant advances in using SSI as contexts for transforming science learning (Romine, Sadler, & Kinslow, 2017; Sadler & Dawson, 2012). SSI approaches can be an effective means of supporting learning that are aligned with Vision II science literacy, which focuses on the ways in which students conceptualize and use science content and practices through explorations of complex issues (e.g., Zeidler, 2014). More recently, empirical investigations of SSI-based interventions that focus on students’ reasoning or decision-making in SSI contexts have also increased (e.g., Evagorou, Jiménez-Aleixandre, & Osborne, 2012; Lee & Grace, 2012; Venville & Dawson, 2010; Wu & Tsai, 2012).

Sadler and Zeidler (2005) conducted an SSI based investigation of the informal reasoning of college students engaged in negotiating of controversial and complex genetic engineering issues. These researchers characterized informal reasoning as rationalistic, emotive, and
intuitive. Rationalistic reasoning represented reasoning based on analyses of data or principles, emotive reasoning represented the application of emotions such as empathy and sympathy, and intuitive reasoning represented immediate or gut-level reactions. They found that their participants frequently relied on combinations of these reasoning patterns and tended to employ rationalistic patterns most frequently. Regarding these definitions, Evagorou et al. (2012) pointed out that Sadler and Zeidler’s (2005) selected term, ‘emotive’, only accounted for positive feelings towards others. To deal with arguments based on emotions that were not positive, Evagorou et al. (2012) added a second emotive category, which they labelled as emotive negative or personal. They defined this emotive category as being “consistent with the application of moral emotions. People that use this seem to care about their own well-being rather than that of others or to be driven by feelings of antagonism towards others” (p.414).

Previous studies (e.g., Topcu, Sadler, & Yilmaz-Tuzan, 2010) have suggested that issue contexts affect the informal reasoning processes employed by individuals. The individual contexts of issues likely play a large role in shaping informal reasoning patterns; however, this proposed link has not been explicitly investigated. For example, it is not clear how factors such as the dilemma strength or the application of personal experiences in the relevant context affect an individual’s informal reasoning patterns. Strong dilemmas involving personal morals or ethics may disturb rationalistic reasoning. Examining the impact of dilemma strength on reasoning in SSI contexts may help to elucidate in greater detail the thought processes employed in SSI involving diverse values. These examinations could provide suggestions for SSI-based interventions and evaluations of their effectiveness.

The purpose of the current study was to examine how the strength of SSI dilemmas affected university students’ informal reasoning. To this end, we developed an assessment task in which the strength of SSI scenarios was manipulated. We compared the patterns of informal reasoning that emerged from each SSI context. We also examined the impact of participants’ gender and major on informal reasoning. In addition, for each scenario, the arguments provided for and against the scenario were compared in terms of informal reasoning patterns.

**METHODS**

**Participants**

A total of 121 undergraduate students participated in the study. Participants reported their age, sex, major, year of study, and any science-related classes they had taken in high school. The participants consisted of 75 males and 46 females. Among these, 28 participants were science majors and 93 were humanities majors.

**SSI argument tasks**

We presented two scenarios: one involved a designer baby and the other involved a baby with Huntington’s disease. Both scenarios addressed SSI related to genetic medical technologies, but we manipulated dilemma strength by introducing human survival as the main issue in the strong dilemma. Our designer baby scenario was a Japanese version of the one created by Venville and Dawson (2010). The Huntington’s disease scenario—our stronger dilemma—was based on Sadler and Zeidler’s (2005) SSI scenario and Zohar and Nemet’s (2002) Cystic
Fibrosis scenario. In this scenario, following antenatal testing, the parents decided not to deliver a child who carried the genes responsible for Huntington’s disease. For each scenario, participants were required to state their opinions (for or against the presented scenario) and justifications, and then to construct hypothetical counterarguments and rebuttals to them.

Procedure

We used a questionnaire to survey the students while we were lecturing the students.

Analysis

Based on the Venville and Dawson’s (2010) framework, descriptions of justifications and rebuttals were categorised into three reasoning patterns: rationalistic reasoning, emotive reasoning, and intuitive reasoning. Table 1 illustrates the participants’ entries, and the categories and descriptions to which they were assigned.

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<th>Description</th>
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<td>Rationalistic</td>
<td>Logical thinking, uses scientific understanding and language, reasoned-based calculations, weighs risks, benefits, advantages and disadvantages</td>
<td>Since certain characteristics are considered preferable in human society, I think acceptance of designer babies will cause adverse results. Similar genes will be propagated, which is risky. For instance, loss of gene divergence will impair survival in case of environmental change. In addition, people will lose their individuality and sense of personality, which will make personal identification difficult.</td>
</tr>
<tr>
<td>Emotive</td>
<td>Emotional response towards stakeholders, shows care, empathy, sympathy, and concern for plight of those affected</td>
<td>It would be a pitiful scenario, where children have to live in constant fear of acquiring the disease, and the parents have to live in a continuous state of worry that their children might acquire the disease at any time.</td>
</tr>
<tr>
<td>Intuitive</td>
<td>Considerations based on immediate reactions to the context of scenario, often exhibits a negative response, and often precedes rational or emotive reasoning</td>
<td>I think one should not terminate a life even if the baby is destined to have the disease. Modifying the human body using our limited human intellect is a blasphemy against God.</td>
</tr>
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RESULTS

To determine the extent of participants’ knowledge on the selected themes, we examined the biology-related classes participants had taken in high school. Thirty-six percent of participants had taken Basic Biology, eleven percent had taken Advanced Biology, thirty-two percent had taken Biology I (Basic), and seven percent had taken Biology II (Advanced). Number of classes taken was as follows: fifty-eight percent had taken one class, fourteen percent had taken more than two classes, and twenty-eight percent had taken no classes. Participants in the third group,
who had not taken any biology-related classes, reported that they had taken physics-related or chemistry-related classes.

Figure 1 shows the distribution of opinions among participants. There were significant differences in approval rates between the scenarios ($p<.05$, exact test). In the weak dilemma, more participants opposed the use of genetic medical technologies. In both scenarios, no differences were found in agreement rates based on participant gender, major, or number of biology-related classes taken in high school. Fifty-four percent of participants were consistent in their opinions across the two scenarios.

**Figure 1. Distribution of opinions for each scenario**

**Impact of SSI dilemma strength on informal reasoning**

Figure 2 displays the rates at which each reasoning pattern was employed by participants in their justifications and rebuttals for each scenario. Cochran’s $Q$ tests showed that there were overall significant differences in the incidence rates in each scenario (justifications for the weak dilemma, $Q=58.018$; rebuttals for the weak dilemma, $Q=90.830$; justifications for the strong dilemma, $Q=84.483$; rebuttals for the strong dilemma, $Q=71.402$; all $dfs=2$, $ps<.001$). The results of post hoc tests showed that, in justifications for the weak dilemma, rationalistic reasoning was employed significantly more often than emotive or intuitive. In rebuttals for such dilemmas, rationalistic reasoning was employed more often than emotive reasoning, and intuitive reasoning. In both justifications and rebuttals for the strong dilemma scenario, emotive reasoning was employed more often than rationalistic reasoning, and intuitive reasoning.

The comparisons of the incidence rates of each reasoning pattern between scenarios found similar significant differences. In both justifications and rebuttals, rationalistic reasoning appeared more frequently for scenarios with weak dilemmas than scenarios with strong dilemmas ($Z=13.754, p<.001$; $Z=19.184, p<.001$), and emotive reasoning appeared more frequently for scenarios with strong dilemmas ($Z=30.947, p<.001$; $Z=29.469, p<.001$). Intuitive reasoning in the justifications appeared more frequently for scenarios with weak dilemmas ($Z=8.828, p<.01$).

We also compared the incidence rates of reasoning patterns according to participants’ major and gender. Science majors showed significantly higher rates of rationalistic reasoning than humanities majors in rebuttals for strong dilemmas (71.4% vs. 44.7%; $p<.05$, exact test); however, no other comparisons, including the number of biology-related classes taken, resulted in any significant differences.
Impact of participants’ opinions about the scenarios on informal reasoning:

Figure 3 shows the rates of different patterns of reasoning based on participants’ opinions for weak dilemmas, and Figure 4 shows rates of reasoning patterns based on participants’ opinions for strong dilemmas. Results of chi-square tests demonstrate that for justifications and rebuttals in both scenario types emotive reasoning was used more frequently by proponents than opponents (weak dilemmas, $\chi^2(2) = 12.835, p < .001$; $\chi^2(2) = 10.084, p < .001$; strong dilemmas, $\chi^2(2) = 41.852, p < .001$; $\chi^2(2) = 4.388, p < .05$) and rationalistic reasoning was used more frequently by opponents than proponents (weak dilemmas, $\chi^2(2) = 6.116, p < .05$; $\chi^2(2) = 2.495, n.s.$; strong dilemmas, $\chi^2(2) = 26.663, p < .001$; $\chi^2(2) = 7.142, p < .01$). In the case of justifications, intuitive reasoning was employed more frequently among opponents than proponents (weak dilemmas, $\chi^2(2) = 8.700, p < .01$; strong dilemmas, $\chi^2(2) = 9.788, p < .01$). Almost no instances of intuitive reasoning were found in rebuttals.

Additionally, opponents’ reasoning and proponents’ reasoning were analysed separately. Cochran’s Q tests and post hoc tests showed that opponents employed rationalistic reasoning more frequently than emotive reasoning in justifications for strong and weak dilemmas and in rebuttals for weak dilemmas, but not in rebuttals for strong dilemmas. Among proponents, on the other hand, emotive reasoning was used more frequently than rationalistic reasoning in strong dilemmas. In fact, almost all proponents (94.5%) relied on emotive reasoning in making justifications. In weak dilemmas, rationalistic reasoning was employed more frequently than emotive reasoning for rebuttals, and both were employed to the same degree for justifications.
DISCUSSION

Comparing arguments for the two types of SSI scenarios revealed that informal reasoning pattern rates differed depending on the scenario. In strong dilemmas, emotive reasoning was used more frequently and rationalistic reasoning was used less frequently, than in weak dilemmas. This tendency was shared by all participants regardless of gender or major. Comparing the arguments provided for and against scenarios revealed that participants’ opinions about the scenarios affected their informal reasoning patterns; opponents generally relied on rationalistic reasoning, while proponents tended to use emotive reasoning. Our findings show that constructing arguments against issues might promote logical thinking to resolve the dilemmas. There were more proponents of the strong dilemmas, which may have resulted in more emotive reasoning in this type of scenario.
In summary, the strength of the dilemma in a scenario tended to affect university students’ informal reasoning regarding SSI. Even if students were capable of rationalistic reasoning in scenarios with weak dilemmas, when faced with a scenario containing a strong dilemma, students mostly relied on emotive reasoning. This tendency was prominent among the proponents, that is, the participants who agreed with the presented scenario.

CONCLUSION

Our findings may provide insight for improving the design of SSI-based interventions and evaluations. Empirical investigations of SSI interventions (e.g., Evagorou et al., 2012; Lee & Grace, 2012; Venville & Dawson, 2010) have often evaluated students’ reasoning or decision-making in SSI contexts as a learning outcome, but used assessment tasks with only one scenario. Based on our findings, we suggest using evaluation tasks with various scenarios or contexts in SSI-based interventional research. Participants’ opinions about the scenarios should also be taken into account in analysing the outcomes of SSI interventions. Overall, these findings provide important guidelines, which can be used to analyse SSI-based curriculums.

In the future, we plan to examine the consistency of students’ opinions and reasoning patterns across scenario types, and to carefully analyse the arguments provided in each scenario type, in order to identify any factors that students may use to resolve these dilemmas.

ACKNOWLEDGEMENT

This research was supported by JSPS KAKENHI 26282036 and 15K12381

REFERENCES


Wu, Y. T., & Tsai, C.-C. (2012). The effects of university students’ argumentation on socio-scientific issues via on-line discussion in their informal reasoning regarding this issue. In M. S. Khine (Ed.) Perspectives on scientific argumentation: Theory, practice and research (pp. 221-234). Springer.


RENEWABLE ENERGY RESOURCES: HOW CAN SCIENCE EDUCATION FOSTER AN APPROPRIATE UNDERSTANDING?

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The increasing use of energy and its impacts on the atmosphere, the oceans, the soil and the biosphere is one of the main arguments that have been put forward for the Anthropocene age. The energy transition from non-renewable to renewable energy resources is a core strategy to avoid greenhouse gas emissions that contribute to the human-induced climate crisis, which the UN considers a major challenge for politics and society. To become scientifically literate citizens, students need to actively engage with this topic. To effectively implement the energy transition in science education, we need to know about students’ learning demands. Using the model of educational reconstruction, we gathered and compared conceptions of 8th-grade students and scientists concerning non-renewable and renewable energy resources. For this, we conducted guideline-based, problem-focused interviews with 27 students and analysed sections of two scientific reports for scientists’ conceptions. Our results indicate that students’ and scientists’ conceptions can be structured in six categories (availability, consequences of use, producibility, conservation, naturalness, and costs). These categories can be helpful to design interventions for science classrooms.

Keywords: energy education, sustainability education, student’s conceptions

INTRODUCTION

Humans’ rising hunger for energy is strongly connected to the age of the Anthropocene and contributes to anthropogenic effects on earth systems (Steffen, Broadgate, Deutsch, Gaffney, & Ludwig, 2015). Due to increased greenhouse gas emissions, we have already exceeded the planetary boundaries relating to climate change (Steffen, Richardson, et al., 2015). The transition from non-renewable to renewable energy resources is a core strategy to contain the human-induced climate crisis, which the UN considers a major challenge for politics and society (UN, 2015). In order to foster scientific literacy in terms of active participation in societal communication and opinion making, it is important to address the topic of the energy transition in science education as well. To identify students’ learning demands, we need to inquire about their preconceptions and contrast them with scientific conceptions.

THEORETICAL BACKGROUND

The history of energy transitions is closely intertwined with the history of mankind (Bithas & Kalimeris, 2016). The transition to the utilization of fossil energy resources becoming the predominant resources for the energy supply was accompanied with the massive growth of the world’s population and other socio-economic trends. This led to an exponential increase in all of these trends since the 1950s, which triggered the process in which humans altered the earth systems in an irreversible way leading to the age of the Anthropocene (Steffen, Broadgate, et al., 2015). The first demonstration that this path taken, concerning the world’s energy supply,
has its limitations showed itself in the peak oil debate in the late sixties and the oil crises in 1973 and 1979 (Bithas & Kalimeris, 2016). These crises fell together with the time when the term ‘renewable’ was first used in reference to energy resources (Harper, 2018). Hence, the growing usage of the expression ‘renewable energy’ is closely linked to the availability of energy resources and the attempt to overcome the shortage of fossil energy resources. In the age of the Anthropocene the focus shifts from the availability of fossil energy resources to the confinement of the negative consequences of their use. From a natural scientist point of view the transition to alternative energy resources is necessary to massively decrease the emission of greenhouse gases and avoid the security risks of nuclear power plants and nuclear waste (WBGU1, 2003, 2011). Therefore, when we talk about energy transition we refer to a transition from fossil and nuclear energy resources to renewable energy resources.

Concerning the term ‘renewable energy’ there is a common agreement that energy resources derived from the sun (indirectly including wind, hydropower, biomass), geothermal heat and tidal action are labelled renewable (e.g., Ellabban, Abu-Rub, & Blaabjerg, 2014; WBGU, 2003, 2011; Spellman & Bieber, 2011). In contrast to this, other definitions of ‘renewable energy’ based on scientific criteria seem to be difficult to formulate. One example for a vague definition is renewable energy resources being characterised as ‘naturally replenished’ (e.g. Spellman and Bieber, 2011: 8). This is debatable because it could be claimed that fossil fuels are also naturally replenished, although this process takes billions of years. Furthermore, the sun is considered to be a renewable energy resource though its nuclear processes will come to an end sometime in the far future. Twidell and Weir (2015: 3) focus even more on the dynamics of the energy system and define renewable energy as a ‘naturally repetitive and persistent flow of energy’ in contrast to the non-renewable ‘static stores of energy that remain underground’. In this definition without a specific timescale it is difficult to categorise biomass since it is a chemical store of energy, only most of it decomposes over time and is so less stable (a very small amount of it entering the process of becoming fossil fuels). Therefore, Twidell and Weir (2015) use the localisation of the storage (‘underground’) as the telling point that allows a differentiation between renewable and non-renewable energy resources when it comes to biomass. Some other publications simply avoid the definition problems by implicitly assuming a common shared understanding of ‘renewable energy resources’ (WBGU, 2003, 2011).

From a linguistic point of view the term ‘renewable’ could be confusing, since the prefix re- and the suffix -able imply that a subject has to actively do something to make something ‘new’ again (Wehling, 2016). What makes it so difficult to talk about energy resources in general is that this expression does not only refer to substances like coal, crude oil or natural gas but also to immaterial systems that contain a valuable amount and form of energy. In these systems, substances are also involved, e.g. water in a dam. Nevertheless, in the literature often just the energy carriers are referred to (e.g. named as wind) meaning the system (Ellabban et al., 2014; Twidell & Weir, 2015). Before the conversion into forms intended for usage (e.g. electricity) these ‘naturally occurring’ forms of energy are called primary energy (WBGU, 2011: 111).

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1 WBGU is the German acronym of the German Advisory Council on Global Change of the German government.
Additionally, the concept of energy itself is difficult to understand. Students often think of energy as a substance (e.g. Wernecke, Schwanwedel, & Harms, 2017). However, from a physicists’ point of view energy is an abstract concept that can only be indirectly defined or described by overall principles (Feynman, Leighton, & Sands, 2011). According to Duit (2014) there are four strongly interrelated basic ideas concerning energy that foster a scientifically appropriate understanding: transformation, conservation, transfer and degradation. Other authors add another basic idea of energy forms, and consider energy transfer and transformation to be one idea (Neumann, Viering, Boone, & Fischer, 2013). Although learning about energy seems to be complex and non-linear (Yao, Guo, & Neumann, 2017), research has shown that for students the concept of energy conservation seems to be most difficult to understand (e.g. Neumann et al., 2013; Tatar & Oktay, 2007; Yuenyong, Jones, & Sung-Ong, 2011). There seem to exist quite similar problems concerning the conservation of matter. For example, when students struggle to explain what happens with substances after a chemical reaction, e.g. when burning a substance and the products of this reaction cannot be perceived with the senses (Löfgren & Helldén, 2008). When it comes to the connection of energy and the cycling of matter, students are often not able to see this relation, especially when living and non-living systems are involved (Jin & Anderson, 2012; Lin & Hu, 2003). In the specific context of the energy transition to renewable energy resources most students do not understand that renewable energy resources produce fewer greenhouse gas emissions and how this relates to whether they are carbon-based (Cheong, Johari, Said, & Treagust, 2014).

Due to the vagueness of technical terms it is not surprising that there are studies that suggest that students are having problems with defining the phrase ‘renewable energy source’ in a scientifically appropriate way or with correctly assigning energy resources like natural gas or geothermal heat to the categories ‘renewable’ or ‘non-renewable’ (e.g., Bodzin, 2012; DeWaters & Powers, 2011). In his study, Menthe (2006) let students explain why certain energy resources are categorised as renewables or fossil fuels. He found three categories of conceptions of fossil fuels (they cause pollution, are limited, cease to exist after usage) and two categories concerning renewable energy resources (are natural, are reusable). Since the terms ‘renewable’ and ‘non-renewable’ are used to classify energy resources it remains to be researched which conceptions lead students to assign different energy resources to one of these categories. The model of educational reconstruction (MER) stresses that considering both students’ conceptions and the clarification of a specific science-related content are crucial starting points for effective learning sequences (Duit, Gropengießer, Kattmann, Komorek, & Parchmann, 2012). Within the MER, students’ conceptions are contrasted with the scientists’ conceptions. From these comparisons a suitable structure of the scientific content for education can be derived. In the case of energy transition these steps are especially relevant. As potential obstacles for understanding the scientific reasons and circumstances of the shift from non-renewable to renewable energy resources lie in the students’ conceptions as well as in difficulties related to the definitions of energy and renewable energy resources. In our research, we therefore aim to answer the questions about how students and scientists conceptualise renewable and non-renewable energy resources. From the comparison of these mental

2 Throughout this paper, we refer to a moderate constructivist point of view of learning and teaching. Therefore, by the term ‘conceptions’ we mean a mental construct of a phenomenon.
constructs we want to derive the learning demands of the students. Based on these results we generate recommendations about how to structure the content for science education.

**RESEARCH QUESTIONS**

The aim of the study is to provide recommendations for science education about how a scientifically appropriate understanding of the energy transition from non-renewable to renewable energy resources could be fostered. Based on the theoretical background and the MER presented above the following research questions were derived:

1) How do secondary school students conceptualise renewable and non-renewable energy resources?

2) How do scientists conceptualise renewable and non-renewable energy resources?

3) Which differences and similarities can be derived from the comparison of the students’ and scientists’ conceptions of renewable and non-renewable energy resources?

4) How can renewable and non-renewable energy resources as a content for science education be structured to foster an appropriate understanding?

**METHOD**

Our research design is based on the MER (Duit et al., 2012). Due to the explorative character of this study qualitative methods are appropriate. To investigate the learners’ conceptions, we decided to conduct problem-centred interviews, because this allows us to start with very open and general questions, influencing the students as little as possible and on the other hand allowing us to encourage the students to explain and specify their conceptions. An interview guideline developed from the theoretical background assured us that the interviews were conducted in an equivalent way and the same main questions were asked (Niebert & Gropengießer, 2014). The first author conducted all of the interviews herself, interviewing 27 students from different school types in northern Germany. For our sample we chose students from the 8th grade, since we wanted to gather conceptions the students hold after learning about basic ideas of energy and matter in chemistry, biology and physics, but not yet having applied them in the context of energy transition according to the local science curricula. To get a variety in students’ conceptions we interviewed students from three different classes in three different schools in northern Germany. We interviewed all students of these classes that had the permission of their parents and volunteered to take part in the study.

In the beginning we ran seven individual interviews. To foster the flow of speech and to put students at ease, we then switched to pair interviews. The interviews included a narrative prompt with cards that named and pictured nine different renewable and non-renewable primary energy resources (coal, oil, natural gas, biomass, uranium, wind, sun, water\(^3\), and geothermal heat). The students started by commenting on the cards. After that they were asked to organise them according to their own criteria and explain their classification. If they had not already done so, the students were asked to sort the cards into the categories renewable and non-renewable.

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\(^3\) As we assumed it might be confusing and hard to recognize a difference in the pictures, we decided not to differentiate between tidal energy and hydro energy, although they refer to completely different energy systems.
non-renewable energy resources. The interviews were audiotaped, transcribed and anonymised.

To analyse the scientists’ conceptions, we chose sections of two reports from the German Advisory Council on Global Change (WBGU, 2003: 43-95, 2011: 110-119), as they include a wide and substantial science-based evaluation of the relevant aspects of the energy transition. To gather scientists’ conceptions of renewable energy resources in order to clarify the scientific content the analysis of these written documents is appropriate.

Transcripts and reports were analysed with qualitative content analysis (Mayring, 2002). First, we inductively identified categories that the students used to describe renewable and non-renewable resources. We analysed the transcripts of the interviews until we reached a theoretical saturation. In the next step, we deductively applied the categories we found to the report sections. In some cases, further categories had to be added inductively.

RESULTS AND DISCUSSION

By means of the qualitative content analysis of the students’ interviews and the scientific reports, we identified six categories used to characterise renewable and non-renewable energy resources (Table 1). The category availability was derived from statements describing the availability of renewable and non-renewable energy resources regardless of which kinds of aspects of availability they referred to. The category consequences of use is based on remarks about what impacts the usage of the energy resources has during the transfer and transformation into another energy form. The category producibility refers to whether a renewable or non-renewable energy resource is characterized by the ability of a subject to (re-)create or (re-)build it. Another category is the conservation of energy resources after ‘usage’, which means the energy transfer to another system. Since the category was inductively derived from the student’s statements, it does not specify whether conservation refers to energy or matter. Statements about renewables or non-renewables referring to naturalness as the characteristic feature were pooled in the category naturalness. Under the sixth category costs sequences in the reports that refer to the monetary aspects of the energy resources were summarised.

Comparing the students’ and the scientists’ conceptions we found that they share only two of these categories: availability and consequences of use. Only the students use the categories producibility, conservation and naturalness, whereas the category costs is only found in the analysed scientific reports. In general, students tend to characterise renewable and non-renewable energy resources in a dichotomous way using antagonistic expressions (Table 1). Students tend to use these as a dichotomous instrument to decide whether an energy resource is renewable or not. This often leads to inappropriate results. For example, Jana⁴ justifies wind being non-renewable by using the category ‘naturalness’ saying: ‘There is also wind on an unnatural basis, for example with air conditioning or ventilators. It is wind, but not natural wind.’ This could also explain similar problems with the assignment of different energy resources in former studies (e.g., Bodzin, 2012; DeWaters & Powers, 2011).

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⁴ All names are altered.
Table 1. Categories of conceptions characterising renewable and non-renewable energy resources.

<table>
<thead>
<tr>
<th>Categories</th>
<th>Students’ Specific Subcategories</th>
<th>Scientists’ Specific Subcategories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Availability</td>
<td>limited/unlimited</td>
<td>spatial/temporal/material</td>
</tr>
<tr>
<td></td>
<td>abundant/rare</td>
<td></td>
</tr>
<tr>
<td>Consequences of Use</td>
<td>clean/dirty</td>
<td>human/environment</td>
</tr>
<tr>
<td></td>
<td>toxic/non-toxic</td>
<td></td>
</tr>
<tr>
<td>Producibility</td>
<td>producible/non-producible</td>
<td>X</td>
</tr>
<tr>
<td>Conservation</td>
<td>conserved/vanishing</td>
<td>X</td>
</tr>
<tr>
<td>Naturalness</td>
<td>natural/artificial</td>
<td>X</td>
</tr>
<tr>
<td>Costs</td>
<td>X</td>
<td>production costs/subsequent costs</td>
</tr>
</tbody>
</table>

1X means, that we found no corresponding conceptions in the material.

However, the scientists evaluate every single energy resource under multiple perspectives weighing their advantages and disadvantages. Our results correspond with the findings of Menthe (2006) since the categories he identifies for the students’ conceptions of fossil fuels (they cause pollution, are limited, ‘vanish’ after usage) and renewable energy resources (are natural, are reusable) can all be assigned to one of the overall categories (Table 1) we identified. In our research we showed that students use these categories in different, often dichotomous manifestations to characterise both renewable and non-renewable energy resources. Nevertheless, to be able to participate in the current debate and to evaluate different energy resources it is necessary for the students to gain a more holistic view. To derive more detailed recommendations about how the content could be structured, it is essential to analyse the different categories in more detail.

### Availability of energy resources

Regarding the category of the availability of energy resources, some students think that for renewables it is unlimited whereas for non-renewables it is limited. For example, Olga says: ‘renewable [means] that resources are inexhaustible. [Regarding non-renewable resources] the stock is limited.’ In the view of the scientists both non-renewable and renewable energy resources are limited to various degrees in three dimensions: spatial, material and temporal (WBGU, 2011). In the students’ conceptions, another manifestation of the category availability includes a judgemental component. Karin says: ‘Renewable energies are substances that are much more common on earth, so that other scarce substances don’t become rare.’ According to the WBGU (2011), renewable and non-renewable energy resources are abundant and ‘as yet still available generous volumes of fossil fuels could prove to be an obstacle for the transformation …’ (WBGU 2011: 110).

In the light of the etymological and historical background of the term ‘renewable energy’ (Bithas & Kalimeris, 2016; Harper, 2018), it seems rather natural that the category availability of the energy resources plays a prominent role for both students and scientists. Even more so since common definitions of renewables, due to the temporal correspondence of the occurrence of the expression and the shortage of energy resources, focus on their availability (e.g. Spellman & Bieber, 2011; Twidell & Weir, 2015). It is also interesting to note the differences between the students’ and the scientists’ conceptions in the statements assorted to this category. Whereas the students approach the question of the energy resources’ availability in an...
exclusively material way, scientists also consider aspects of space and time. The narrowed perspective of the students may be caused by their everyday experiences because availability and resources often are connected to material things. Regarding the subcategories of the scientists’ conceptions within the category availability, it is striking that in contrast to the quite dichotomous view of the students the WBGU (2003, 2011) describes each energy resource as limited in a characteristic way, concerning either material or temporal or spatial distribution. This corresponds with common definitions of renewable energy resources (cf. the section theoretical background) that are based on the differences in the availability of renewable vs. non-renewable energy resources. They draw on the same three dimensions to define renewables. In the context of education this could be helpful information that allows the students to reflect on a (partially) insufficient definition of renewable energy (whether it is their own or a scientific definition) and discuss the differences within the dimensions of time, space and matter. For example, this might be enlightening in the case of biomass as an energy resource as it is difficult to include in an overall definition of renewables, because like fossil fuels it is stored energy in a chemical form. From the perspective of time biomass regenerates much faster and at a distinctively higher rate than fossil fuels. Also, there is a spatial difference between fossil fuels and biomass as an energy resource because the latter grows on the surface of the earth whereas coal, oil and natural gas are usually stored underground. Furthermore, the perspective of time, space and matter could help students to reflect upon the limitation of renewable energy resources in a way other than matter, since e.g. sun and wind are also characterised by their fluctuation and the differences in their availability according to geographical reference point.

**Consequences of use**

Concerning the category consequences of use, we found that students held the conceptions that renewable and non-renewable energy resources are clean and dirty or toxic and non-toxic, respectively. Accordingly, Anton states that renewable energy resources would produce ‘no toxic exhaust gases at all’ and Hugo talks about non-renewable energy resources as being ‘more harmful to the environment’, for example, oil polluting the air. In general, the students tend to refer to the conversion process of the energy resource. Only one student, Olga, calculates the consequences using a broader perspective, when she states: ‘In the long run, if you accept this bigger pollution [from building the power plants and running them] … [renewables] are much more useful’. In contrast, the WBGU scientists list consequences for all energy resources, renewable and non-renewable, presenting effects on humans (addressing health and society) and the environment (WBGU 2011). The council calculates different scenarios and takes into account the whole life cycle. For example, the scientists write about bioenergy: ‘Some … pathways can certainly produce higher greenhouse gas emissions than the use of fossil fuels’ (WBGU, 2011: 117). Still as a result of their calculation they come to the conclusion, that ‘the use of renewable energies … is usually associated with considerably lower greenhouse gas emissions than the use of fossil fuels’ (WBGU: 117).

There are different points of references within the students’ and the scientists’ conceptions. The students mostly talk about the transformation process when renewable or non-renewable energy resources are converted into another energy form for use (e.g. electricity), whereas the
scientists refer to the whole life cycle, e.g. calculating impacts of mining, land use, construction and disposal. A possible reason behind these different viewpoints might be that immediate consequences can be more directly observed. This goes along with a greater presence in the media, which report on the negative impacts of emissions rather than the whole life cycle and especially more prominently about accidents (e.g. the accident in the nuclear power plants in Fukushima in 2011).

Nevertheless, their different viewpoint cannot explain why students’ statements show a very unspecific view on the consequences of use, characterising non-renewable energy resources as dirty or toxic without mentioning carbon dioxide. Possibly this could be due to difficulties recognising the connection between the carbon content of the energy resources and greenhouse gas emissions (Cheong et al., 2014).

To understand the massive changes in the earth systems that led to the Anthropocene, students must be able to explain that a massive increase of the use of fossil energy resources always comes with a massive increase of carbon dioxide emissions and is a main cause for the climate crisis. Due to this interrelationship, the energy transition to carbon-free or carbon-low energy resources is a logical consequence. What might be an obstacle to viewing the outcomes is that common definitions of renewable energy resources are based on their availability not on the consequences of their use (Spellman & Bieber, 2011; Twidell & Weir, 2015).

In an education suitable to the age of the Anthropocene it is more important than ever to enable students to evaluate and to argue, enabling them to participate in society in order to shape their future. Hence, it is essential to know about the consequences of use of the different energy resources during the conversion process and to take a broader perspective including different stages of the life cycle. These different perspectives allow students to argue with people who rely on isolated observations (e.g. impacts of the production of photovoltaic systems). Additionally, students should reflect upon the definition of the term ‘renewable energy resource’ under the perspective of the consequences. For example, they could discuss alternative wordings related to outcomes like carbon-low or carbon-free or waste-free (if including nuclear energy resources).

**Producibility of energy resources**

Only the students use the criteria of producibility to distinguish renewables and non-renewables. So, Martha says: ‘Non-renewable energy is something that cannot be produced again, something like oil. … Biomass [is renewable] because when you harvest it or it gets destroyed … you can always grow it again.’

These conceptions could be caused by a literal interpretation of the term renewable. The cognitive linguist Elisabeth Wehling (2016) states that the prefix re- and the suffix -able imply that a (human) subject has to actively do something. This framing could lead to the conception our students expressed that renewable energy resources are producible. These interpretations contradict common definitions of renewable energy that define these energy resources as being ‘naturally replenished’ (Spellman & Bieber, 2011: 8) or refer to a constant flow of energy (Twidell & Weir, 2015).
In science education to foster an understanding that is in line with basic ideas of energy and matter we should reflect together with the students upon the term ‘renewable’, its literal meaning and its limitations.

**Conservation of energy resources after usage**

Other students focus on the observation of what happens to the material in the energy transformation process and explain the difference by the ‘conservation’ or the ‘vanishing’ of this material. Karl explains: ‘Renewable is when the water delivers energy and you can extract energy from the water again and again as long as water exists. If you burn coal and therefore get energy, you cannot burn the coal again, because it is gone. It is non-renewable.’ Karl is one example of some students that consider wind and water to be renewable because these elements are conserved. The students do not recognise that it is not the water itself that is the energy resource but the system in which the water is stored (for example in a dam) and therefore holds potential energy that can be transferred to another system. After this transformation process the water still exists, but holds less potential energy. However, for the water to get back to the dam there first has to be transferred energy (e.g. electrical energy from a pump or energy from solar radiation through the global water cycle) to this system again.

When the students talk about fossil fuels in statements placed in the category vanishing, as Karl, they describe the substance (e.g. coal) as ‘gone’ after the transformation process. Here not only the energy but also the matter is transformed and transferred to another system. These statements show that the students are unable to apply the basic idea of the conservation of matter. As Löfgren and Helldén (2008) propose, this might only be a problem of expression. So, in our case the students may want to simply stress that the reactant of the chemical reaction, the fossil energy resource, is ‘gone’ in its original form and that this process under the given conditions is irreversible. Although this conception is not scientifically inappropriate, in the context of the energy transition and the Anthropocene it is important to emphasise the conservation of matter because carbon dioxide emissions as a by-product of the transformation process are crucial (WBGU 20011, 2003).

Nevertheless, in both subcategories conservation and vanishing, the students focus on the material and do not see the connection to the energy flow: whether it is a renewable energy resource or a fossil fuel, energy is transferred to another system and the sum of this transferred energy is missing in the original system after this process. This observation agrees with the findings of earlier research that shows the problems of students to understand the relationship between energy and the cycling of matter (Jin & Anderson, 2012; Lin & Hu, 2003). A possible explanation could be, that the students understand the term ‘energy resource’ rather in a material way than looking at the systems containing the energy. That students often think of energy as a substance (Wernecke et al., 2017) could support these conceptions.

Due to the ambiguous meaning of the word ‘conservation’ in the English language it could also be assumed that students may confuse the meaning with environmental conservation. It is very unlikely that this is the case in our study since in German there are two different words in these contexts.
Considering the students’ conceptions about the conservation of renewable energy resources, from the perspective of the Anthropocene it would make sense to bring attention to the different systems renewable and non-renewable energy resources represent. This attempt should include both the flow of matter and energy during the process of transfer and transformation into another energy form humans intend to use (e.g. electricity). Special attention should be given to the unwanted by-products of the use of non-renewable energy resources, since the reactants are not only ‘gone’ or ‘used up’ but transformed to greenhouse gas emissions or nuclear waste.

**Naturalness of energy resources**

Frieda is one of the students who uses the conception of naturalness to compare renewable and non-renewable energy resources when she says: ‘Anything natural is renewable and […] anything humans have made, like getting all the oil or the uranium out, is non-renewable.’ In an age when humans shape earth systems the conceptions summarised in the category naturalness are especially interesting. Noteworthy is that there were no statements in the scientific reports that could be placed to this category. However, common definitions of renewable energy resources include aspects of naturalness in their definitions, e.g. speaking of renewables as being ‘naturally replenished’ (Spellman & Bieber, 2011: 8) or a ‘naturally repetitive and persistent flow of energy’ (Twidell & Weir, 2015: 3). Interestingly, Twidell and Weir (2015) dichotomously state for non-renewable energy resources that ‘with these sources, the energy is initially an isolated energy potential, and external action is required to initiate the supply of energy for practical purposes.’ This seems quite similar to the statement of Frieda: ‘… anything humans have made, like getting all the oil or the uranium out, is non-renewable’.

Despite the fact that this category could be used for a positive framing for renewable energy resources, as ‘natural things’ usually give us a better feeling, its value for characterising energy resources in the context of energy transition as renewable is doubt-worthy. The concept of naturalness characterising renewable energy resources could be criticised in that also the origin of non-renewable energy resources is from a natural process and that all energy resources, renewable and non-renewable, need to be made ‘useable’ for transformation into other forms of energy by human interaction. The scientific definitions that draw on naturalness intend to stress the differences in the dynamics of renewable and non-renewable energy sources, contrasting the constant flow of energy with static stores. This brings us back to the category of the availability of energy resources. In an education for a more sustainable Anthropocene it would be important to draw on availability in the sense of the potential of renewable energy resources due to their completely different dynamics, especially considering the immense potential of the direct use of solar radiation.

**Costs of energy resources**

The category costs had to be added inductively to our category system when analysing the scientific reports of the WBGU (2011, 2003). None of the students used cost factors to characterise energy resources whereas this was a prominent issue in sections of the scientific reports, distinguishing between one-off production costs, e.g. for power plants, and subsequent costs (WBGU, 2003, 2011).
We assume that the reason students did not think of categorising or comparing the given energy resources by means of this aspect was due to their young age, possibly related to the fact that they are not responsible for paying bills yet. It would be interesting to see if adults would take this aspect into account.

For an energy transition leading to a more sustainable future, the calculation and argumentation of its costs will be a decisive point. Within this category the scientists calculate aspects of production costs as well as subsequent costs. As with the category ‘consequences of use’, it is necessary to consider the whole life cycle of the different energy resources to be able to judge different scenarios of our future energy supply.

**Limitations**

It remains to be discussed whether our research design influences our findings on the overall differences of students’ and scientists’ conceptions, that is between a dichotomous versus and a more holistic view, respectively. During the interviews at some point we asked the students to sort nine cards with pictures of primary energy resources into the categories renewable and non-renewable. This might have caused more dichotomous statements in the explanations of their categorisation. Despite this, there are hints that the students would still use dichotomies. For example, Anton talks about clean and dirty energy resources even before the terms ‘renewable’ and ‘non-renewable’ are introduced by the interviewer. Nevertheless, these terms represent a dichotomy themselves and the dichotomous view is also implied by the term *energy transition*, as there has to be some kind of different energy supply before and after.

The cards that were provided during the interviews showing words and pictures of the primary energy resources could have supported conceptions of the students that focus on material, since the systems could not easily be derived from those pictures (for example the card *water* only showed water and no dam). However, the conception of energy as a substance is quite common (Wernecke et al., 2017). Also, the narrowed perspective of the students may be caused or reinforced by their everyday experiences, because energy resources are often connected to material things. To further investigate what causes these students’ conceptions a linguistic analysis of the metaphors they used would be helpful to identify the experiences these are based on.

**CONCLUSION AND RECOMMENDATIONS**

In the Anthropocene there has been a shift in the perspective on the energy transition from non-renewable to renewable energy resources. Whereas in the beginning of the Anthropocene the availability of energy resources was the main focus, nowadays the prevalent debate is about the consequences, most prominently the climate crisis, of the use of carbon-based and nuclear energy resources. Nevertheless, both of these perspectives, also found as categories within the students’ conceptions and the scientific reports, are essential to evaluate the energy transition.

To foster a scientifically appropriate understanding and enable students to participate in the ongoing debate, we recommend the following issues to be addressed in science education in the context of the energy transition:
1) Students should be encouraged to reflect upon the term ‘renewable’ and the definition of renewable energy resources and discuss them from the perspectives of a) availability, and b) consequences of use.

2) Science education should draw attention to the systems renewable and non-renewable energy resources represent. Students should reflect upon the role of energy and matter in the processes of transfer and transformation.

3) Students should consider the whole life cycle to balance consequences and costs for the different energy resources.

Concerning the first recommendation our research suggests that there are intrinsic problems in the term ‘renewable’ that seem to be obstacles to a scientifically appropriate understanding. Therefore, the literal meaning should be discussed and compared with the intended meaning.

The availability of the energy resources, renewable or non-renewable, will play a decisive role, especially on a global scale. Hence, it is necessary for science education to address not only the material aspects of the availability of non-renewable energy resources as found in the students’ conceptions, but all of the three dimensions found within the scientists’ conceptions: temporal and spatial distribution as well as matter. This is necessary to be able to evaluate obstacles (like fluctuating availability of solar and wind energy) for a more sustainable energy supply. The discussion about availability should also include the aspects of the potential and different dynamics of renewable and non-renewable energy resources (Twidell & Weir, 2015).

Since the term ‘renewable’ focuses on the availability of energy resources and hides aspects of the consequences of use, the term should also be reflected on from this perspective. When it comes to consequences students tend to see only the effects of the conversion process itself, whereas scientists have a broader perspective that includes all kinds of impacts on humans and the environment during the whole life cycle. Science education should include these two perspectives. Alternative wordings like carbon-free, carbon-low or waste-free should be compared with the term and discussed from these different perspectives.

Concerning the second recommendation, as other studies show (Cheong et al., 2014), also in the context of the energy transition students have difficulties to see the connection between the carbon content of energy resources and the emission of carbon dioxide. Providing opportunities to gain a more detailed view about this connection is very important for science education because without this knowledge, students are unable to understand the relationship between the energy transition and efforts to minimise the impact of climate change. An approach in science education that focuses on the systems the energy resources represent could foster an appropriate understanding that draws on basic ideas of energy and matter. It is essential that the students understand that wind or water is only an energy resource as part of a system. For example, the wind holds kinetic energy caused by compensatory wind flows resulting from solar powered convection currents or water holds potential energy because it is stored in a dam. As a consequence, students would be able to reflect upon the transfer to other systems, e.g. in a power plant. In a next step drawing on the basic ideas of the conservation of energy and the
conservation of matter, students could track and calculate the flow of energy and matter (e.g. carbon) through these systems.

Concerning the third recommendation, the energy transition leading to a more sustainable future is determined by balancing the specific consequences of the use and the costs of a certain mix of energy resources. Our research shows that students tend to focus on the conversion process. To be able to evaluate and take an active part in the debate about our future energy supply it is necessary for students to also take a broader perspective. They should be able to assess and compare the whole life cycles of the various energy resources. Since costs are a very strong argument and play an important role in determining the direction of the energy transition, it is also important to encourage students to include this perspective in their calculations, balancing internal and external costs for humans and the environment.

REFERENCES


Mayring, P. (2002). Qualitative content analysis - research instrument or mode of interpretation. In M. Kiegelmann (Ed.), *The Role of the Researcher in Qualitative Psychology* (pp. 139–148). Tübingen: Verlag Ingeborg Huber.


THE CONCEPT OF RISK: IMPLICATIONS FOR SCIENCE EDUCATION

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As citizens, we make risk decisions on a daily basis, decisions to avoid risks or to take a risk in order to gain benefits. Risk is a concept of high significance for us. Risk also figures in science education, explicitly or implicitly, for instance in teaching of socio-scientific issues. The concept of risk has received academic attention in multiple ways of which we highlight three: 1) Investigations of the use of the term in language. 2) Attempts to capture the risk concept. 3) Attempts to operationalise the risk concept quantitatively for decision-making purposes. We draw three conclusions about the concept of risk that hold implications for science education research and teaching about risk. Firstly, risk is used differently between lay and expert uses, as well as within these groups. Secondly, risk holds both subjective and objective traits. Thirdly, different decision-making contexts may require different ways to operationalise, i.e. assess, risk. We argue that if risk is incorporated in teaching, it may be valuable to make students aware of the different ways to express, frame and assess risks.

Keywords: risk, decision-making, socio-scientific issues

INTRODUCTION

As citizens we make risk decisions on a daily basis, decisions to avoid risks or to take a risk in order to gain benefits. As modernity has seen the introduction of technologies that create risks on a larger scale, not always restricted in time and space, importance of risk as a concept is increasing (Beck, 1992). This viewpoint is also corroborated for instance by the increased use of the term ‘risk’ in newspaper reporting since World War II (Zinn, 2010).

The notion of risk and risk assessment has also drawn the attention of science education researchers, and is dealt with in a variety of ways within science education research. This is particularly true for areas such as Science and Technology in Society (STS) and Socio-scientific issues (SSIs). Teaching through SSIs very often draws upon risk issues, such as nuclear power, emerging technologies or climate change. Indeed, the idea of making science education more socially responsible and contribute to science for citizenship may be traced back at least to the 1930’s (Ratcliffe, 2001), although it began to be more widely argued from the 1970’s (see Howes, 1975). The first large-scale STS-project was launched in the Netherlands in the 1970’s (Eijkelhof, 1986). Already from the beginning, the idea of including controversial issues in which both scientific and social aspects need to be considered was an important part of the STS-movement (see for instance Gaskell, 1982). By the 1980’s, the term ‘socio-scientific issues’ was established (Fleming, 1986) and has, since then, gained increased usage within science education research (Tekin, Aslan, & Yılmaz, 2016) alongside the older term ‘STS’ (see Millar, 2006). There is a growing body of research in which risk is seen as a
component of scientific literacy and, as such, relevant and important to address in science education (see e.g. Christensen, 2009; Hansen & Hammann, 2017).

However, despite half a century of risk research there is no widely accepted definition of the term ‘risk’. The word ‘risk’ is used and interpreted in a multitude of ways. Within the risk management and decision analysis literature, much effort has been targeted at providing definitions of the concept or defending a particular definition or operationalization. Yet, there exists no systematic attempt at relating this multitude of definitions, interpretations and uses to different consequences for teaching. The purpose of this paper is to outline the beginnings of such an analysis and discuss implications for science education research and teaching about risk.

METHOD

Scholarly works from a broad range of academic fields targeting the concept of risk were identified by search phrases ‘risk definition’ and ‘concept(s) of risk’ as well as by snowball sampling from works identified thereby. We identified three main themes in the retrieved literature: focus on usage (mainly from the area of linguistics), focus on capturing the concept (from areas such as philosophy, engineering, sociology, and law) and focus on quantification (mainly from engineering). For each theme a summary review was performed (presented below). The findings from this review were then discussed within a transdisciplinary team of researchers and teachers (riskedu.se) to identify potential implications for teaching. In addition, a selection of science education related works in which teaching about risk issues are touched upon were scrutinised for their descriptions of risks and uses of the word ‘risk’.

RESULTS

In this section we present an examination of the risk concept on the basis of the central academic literature. The examination is guided by the paper’s main purpose, to tease out potentially important those characteristics of the risk concept which may be important to recognise in science education.

The many uses of the word risk

The word ‘risk’, can be used both a noun and a verb. Furthermore, the noun has several different meanings, which are the focus of the present paper. Below we exemplify the polysemy of the noun ‘risk’ with two statements about what risk is from students in our studies (16-17 year olds):

‘I usually think of an act whose consequences are very problematic. For instance, to cheat on a test may be a risk, a consequence may be that you get disqualified and get poor grades.’

‘Risk of getting a disease later in life, such as cancer.’

In the second sentence, we could replace risk with the word probability: Probability of getting a disease later in life, such as cancer. But in the first sentence replacing ‘risk’ with ‘probability’ would drastically change the meaning of the statement. Polysemous words are not unusual, but
this has drawn attention in the risk research field as we often face situations where we want to be precise about what we are talking about. For instance, in regulatory decision-making.

The polysemy of the word in everyday language can be further illustrated with the following three (non-exhaustive) examples found in non-technical texts (Boholm, Möller & Hansson, 2016, based on Hansson, 2004; 2011):

a) Risk = an unwanted event which may or may not occur.
b) Risk = the cause of an unwanted event which may or may not occur.
c) Risk = the probability of an unwanted event which may or may not occur.

However, the word ‘risk’ also has many different technical uses. In fact, the term is used more frequently in specialised technical contexts than in more every-day ones. A linguistic study of the word ‘risk’ in American English showed that the frequency of ‘risk’ in academic texts was nine times higher than in fiction and more than double that of newspaper reporting or spoken language (Hardy & Colombini, 2011). It has also been shown that the word is strongly associated with health and medicine (Hamilton, Adolphs & Nerlich, 2007; Zinn, 2010; Hardy & Colombini, 2011).

Althaus (2005) and Renn (1992) both review the risk concept from a perspective of academic discipline and illustrate how the ontological and epistemological perspectives vary. Nevertheless, there have been efforts towards making transdisciplinary definitions of the risk concept (e.g. Rosa 1998, Aven & Renn, 2009). Aven (2012) presents a classification of risk definitions within different academic fields. He identified nine classes under which one or more individual definition have been published:

1) Risk = Expected value (loss)
2) Risk = Probability of an (undesirable) event
3) Risk = Objective uncertainty
4) Risk = Uncertainty
5) Risk = Potential/possibility of a loss
6) Risk = Probability and scenarios/consequences/severity of consequences
7) Risk = Event or consequence
8) Risk = Consequences/damage/severity of these + Uncertainty
9) Risk = The effect of uncertainty on objectives

These nine classes and adhering examples of risk definitions, with references to relevant literature, are discussed in detail in Aven (2012). For the purpose of the present paper, Aven’s (2012) list serves as an illustration of the variability of risk concept within the academic literature.

Capturing the concept of risk

Hansson (2011) identified two minimal characteristics of the risk concept. First, ‘[r]isks refer to undesirable events’. Second, ‘it is undetermined or at least unknown whether or not that event will occur’. These two characteristics are reflected in the listed definitions of risk presented in the preceding section. The element of undesirability is reflected in usage of terms such as ‘consequence’ and ‘loss’. Even more prominent is the role of uncertainty in different
forms, as indicated by ‘objective uncertainty’, ‘probability’, ‘potential’, and (epistemic) ‘uncertainty’. Thus, when attempting to capture the concept of risk, a general understanding could be that risk in some manner refers to an undesirable event that may or may not happen (Hansson, 2011). Rosa (1998) expressed this as ‘risk is a situation or event where something of human value (including humans themselves) is at stake and where the outcome is uncertain’.

As shown by several previous works (e.g. Renn 1992, Althaus, 2005, Aven, 2012), risk is a multi-faceted phenomenon, originating in both ontological and situational activities. One important aspect that makes the concept of risk so troublesome to capture is the distinction between risk as objective and risk as subjective (Hansson, 2011; Hansen & Hammann, 2017). An objective risk concept means that risk is determined by facts about the physical world, whereas a subjective risk concept defines risk as a social construction independent of physical facts. As pointed out by Rosa (1998) risk concerns ‘something of human value’, i.e. the adversity of the possible outcome is dependent on our value judgements. Nevertheless, as also pointed out by Hansson (2011), risks do also refer to facts about the world. For example, to claim that ionizing radiation may cause tumours in humans is a statement about an outcome in the physical world. Hence, both subjective and objective aspects of risk need to be acknowledged.

Taken together, however, it may be most fruitful to discuss risk as a concept containing both objective and subjective components (Hansson, 2011). From the perspective of science education, this interplay between objective and subjective components is a potentially important factor when incorporating risk in school science education. This is because the dual nature of risk (i.e., having both subjective and objective traits) opens up for discussions on values as integral parts of any decision including risk, but even more how values and knowledge (or established facts) interact in decisions and policy making.

Quantifying risk

Whether risk is used in qualitative or quantitative ways, is another aspect of the polysemy of the risk concept. The everyday uses of the term seem to be mainly qualitative in nature and strictly quantitative meanings are rarely found (Boholm et al., 2016). However, even seemingly qualitative uses of risk may be partly understood also in quantitative terms, as ‘high’, ‘low’ and ‘increased’ are commonly found collocates in a number of corpora (Boholm et al., 2016; Hamilton et al., 2007). Boholm et al (2016) found that somewhat less than a third of the instances of risk in the investigated corpus implied a quantitative notion of risk through such collocates.

Specialist uses of the term as well as formal definitions from scholars in various risk related areas are both qualitative and quantitative (Althaus, 2005; Aven, 2012; SRA 2015). Four of Aven’s (2012a) classes are identified as quantitative risk definitions, namely 1, 2, 3 and 6 whereas definitions 4, 5, 7, 8, and 9 are more or less qualitative in character.

Quantitative definitions are generally a tool for risk management, and serve as operationalisations of risk and a base for decision-making. Definitions in line with e.g. risk a) or 7) (see p.3 in this paper) may not fulfil such purposes, from a risk management perspective it makes little sense to speak of reducing an event. Such a risk definition is not compatible with
the current practice of risk assessment as a basis for decision-making (Aven & Renn, 2009). However, as has been pointed out previously (Aven, 2012; SRA, 2015), definitions attempting to capture the concept of risk do not need to be operationalisations of risk in themselves (which for instance Avens’ class 1, risk = expected value is). The definition of risk needs only to be compatible with quantitative operationalisations. In other words, we can distinguish between the concept of risk and how to measure risk. It may even be reasonable to claim that this distinction needs to be made: For instance, if for a certain case available knowledge does not allow us to derive a probability distribution, it makes little sense to define the risk based on a probability distribution (i.e. objective uncertainty). In other words, the suitability of operationalisations of risk, i.e. risk assessment methods, is context dependent (SRA, 2015). Indeed, this is already implemented in risk management practice. Risk assessment models or methods differ for the assessment and management of monetary risks, risk of contagious diseases, traffic risks, or risks with different means to produce energy. These differences reflect the differences in the size of populations potentially affected, the frequency of potential adverse events, and the nature of consequences.

**IMPLICATIONS FOR TEACHING ABOUT RISK**

Based on findings made within the three themes presented above, 1) Investigations of the use of the term in language. 2) Attempts to capture the risk concept. 3) Attempts to operationalise the risk concept quantitatively for decision-making purposes, a number of potential implications for teaching about risk emerge.

First, as risk is a polysemous term, its use may confer confusion. Different meanings of the word risk are found within and between lay uses of the term, in applied expert uses as well as in academic discourse. Differences seem to be especially large between every day and specialist uses of the term. Hence, we argue that it may be of value to raise the nature of the concept of risk more specifically in the classroom.

One way to approach the multitude of specialised uses of the term risk, of which many are closely connected to risk assessment methods, may be to separate between the concept of risk and the operationalisations of risk as the latter are dependent on the context in which they are to be applied. This distinction between the concept of risk and different operationalisations of risk is relevant both in the context of risk management and when introducing risk and risk descriptions in teaching.

Finally, part of the difficulties seems to lie in the dual nature of risk as both subjective and objective, requiring interplay between knowledge and values. Risk cannot (or should not) be separated from discussions of values. On the contrary, the dual nature of risk (both subjective and objective traits) opens up for discussions on values in science and society and on the role of science in decision- and policy-making. For instance, the issue that Howes (1975) drew upon in the proposal on teaching about radiation risks was that value judgments are unavoidable when we deal with scientific uncertainty and that there are questions and issues that science most likely will never be able to resolve.
In short, we have identified three aspects of the risk concept which may be relevant for science education:

- The polysemy of the term.
- The context dependent operationalisations.
- The interaction between values and knowledge.

These three aspects could be put into play to a different degree depending on the educational aim. For instance, teaching students one or several ways to describe risk, can be one step in teaching towards making students evaluating risk related arguments or performing their own risk assessments. We call this to teach about risk directly. But risk can also come into play indirectly, as a real world example to make science content more relevant to students’ lives, as a topic for students to engage in discussions, or drawing in particular on the uncertainties in risk issues, as a way to illustrate the nature of science and how knowledge is created.

In Table 1 we list some examples of how different aspects of the risk concept may be of relevance to selected educational aims. The different educational aims are not mutually exclusive, rather later aims build upon earlier and one or several of these aims may be part of a particular teaching intervention.

<table>
<thead>
<tr>
<th>Educational aim</th>
<th>Relevant aspects of the risk concept</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Teach about risk (risk explicit)</strong></td>
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</tbody>
</table>
| I Understand risk descriptions (e.g. discuss and learn from examples, compare different aspects in given risk assessments). | Polysemy  
Context dependent operationalisations |
| II Evaluate risk related arguments. | Polysemy  
Context dependent operationalisations  
Interaction of values and knowledge |
| III Perform risk assessment. | Context dependent operationalisations  
Interaction between values and knowledge |
| **Teach through risk (risk implicit)** | |
| IV Learn science content (e.g., radiation or nanotechnology) through real-world examples. | Context dependent operationalisations  
Interaction between values and knowledge. |
| V Engage in deliberations and decision-making | Interaction between values and knowledge |
| VI Learn about nature of science (tentative knowledge, interpretation of data, values, science’s relation to society). | Context dependent operationalisations  
Interaction between values and knowledge |

The first examples concern explicitly incorporating risk in the teaching, exemplifying with risk issues (e.g. UV radiation) rather than primarily teaching about a specific risk issue. Such teaching can range from classroom discussions on risk having student conceptions of risk as a starting point to focus on the risk concept and different ways to describe risk as reviewed herein. One specific aim could be that students should understand risk (I), and to be able to
pinpoint what ‘risk’ stands for in a specific situation. For instance, how we talk about risk regarding sports, traffic or nuclear radiation. In such inquiries, the polysemy and a number of risk descriptions may be explored. A continuation could be to enable students to evaluate risk related arguments (II). For this we have to take the polysemy of risk into account, and explain the coexistence of many possible meanings for a word or phrase. Awareness of different ways to express and describe risk, and the values that come into play under different operationalisations, will help students to deconstruct, as well as formulate their own, arguments on risk-related issues. In aiming to make students (III) perform risk assessments, we may introduce students to one or several context dependent operationalisations and let them apply these.

However, risk may also be used more implicitly in teaching. Risk issues can be used as a means to offer student real-life examples of applications of scientific knowledge (IV). Risk issues that lend themselves to SSI teaching include questions that are scientific in nature but cannot be answered solely by traditional scientific methodology (compare to transscience as coined by Weinberg, 1972). Such questions may be unanswerable either because they inherently involve value issues, or because it’s not possible to design an experiment that will conclusively answer them. Connecting to radiation risks, one such issue would be the determination of an exposure limit for ionizing radiation and how to decide what could be considered an acceptable level. Since our knowledge is incomplete, for instance with regards to the shape of the dose-response curve at low doses, decisions on low-dose radiation risks are influenced by e.g. moral and socio-economic considerations (E.g. Howes, 1975; Eijkelhof, 1986). Another example is nanomaterials, for which there currently are large uncertainties about potential adverse effects on environment or health, which has to be weighed against potential benefits of using nanomaterials in different applications (Enghag & Schenk, 2016). Hence, risk issues may be used, explicitly or implicitly, as a starting point for discussions aiming to encourage student deliberations (V). Furthermore, when focussing on issues connecting to science in the making, risk issues offer opportunities to explore the nature of science as well as its opportunities and limitations with regards to creation of knowledge (VI).

A practical consideration for teachers is how to select which meanings and operationalisations of risk to focus on in their teaching. Obviously, it is reasonable to use the dominant risk definition of the relevant case as a starting point. However, in some contexts more than one way to describe risk may be relevant. For instance, in nuclear safety, we usually encounter an engineering perspective on the safety of operations, such as expected values or combinations of scenarios with their respective probabilities and consequences (see p.3, class 6). However, in issues pertaining to health of workers or the population exposed in case of an accident we will instead encounter risk descriptions from the area of toxicology and epidemiology, i.e. expected values, probabilities and objective uncertainty, as well as probability and consequence (classes 1, 2, 3, 6). Table 2 may also be used as an overview of which risk descriptions have been found relevant in previous science education works.

A simple quantitative definition such as the expected value (class 1) holds many advantages from a decision-making perspective such as being mathematisable and yielding a simple output. Assigning numbers to various scenarios allows for a comparison between risks, which
could be used for instance to prioritisation of resource allocation between different risk management efforts. However, there are many real life examples of when such a reduction does not capture a relevant decision. In real life, there are always other factors in addition to probabilities and utilities that can and should influence appraisals of risk. Nevertheless, discussing risk as probability \(\times\) consequence (i.e. expected loss) also highlights the role of exposure (as a proxy for probability) and intrinsic hazard (potential consequences). If either the exposure or the hazard is zero there is, by definition, also no risk. Hence, this way to operationalise risk could be connected to specific learning outcomes, for instance regarding personal protection from UV radiation (see also WHO, 2003).

Table 2. Overview of risk descriptions found in selected SSI literature.

<table>
<thead>
<tr>
<th>Class of risk descriptors</th>
<th>Defines risk(^a)</th>
<th>Does not define risk(^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>b) Risk = Cause of event or consequence</td>
<td>-</td>
<td>Covitt et al., 2010(^b)</td>
</tr>
<tr>
<td></td>
<td>Gregory, 1991</td>
<td>Ryder 2001</td>
</tr>
<tr>
<td></td>
<td>(Riechard, 1993)</td>
<td>Millar 2006</td>
</tr>
<tr>
<td></td>
<td>(Cross, 1993)</td>
<td>Kolstø, 2006</td>
</tr>
<tr>
<td></td>
<td>Levinson et al., 2011</td>
<td>Covitt et al., 2010(^b)</td>
</tr>
<tr>
<td></td>
<td>Enghag &amp; Schenk, 2016</td>
<td>Lee, 2012</td>
</tr>
<tr>
<td>2. Risk = Probability of an (undesirable) event</td>
<td>Cross, 1993</td>
<td>Howes, 1975</td>
</tr>
<tr>
<td></td>
<td>Zinn &amp; Peyton, 2001</td>
<td>Gaskell, 1982</td>
</tr>
<tr>
<td></td>
<td>Zinn, 2001</td>
<td>France, 2007</td>
</tr>
<tr>
<td>3. Risk = Objective uncertainty [i.e. a measureable uncertainty, such as variability]</td>
<td>-</td>
<td>Fleming, 1986</td>
</tr>
<tr>
<td>4. Risk = Uncertainty [e.g. epistemic uncertainty]</td>
<td>-</td>
<td>Tytler at al., 2001</td>
</tr>
<tr>
<td>5. Risk = Potential/possibility of a loss</td>
<td>-</td>
<td>Kolstø, 2006</td>
</tr>
<tr>
<td></td>
<td>Ejkelhof, 1986</td>
<td>Millar 2006</td>
</tr>
<tr>
<td></td>
<td>Riechard, 1993</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Cross, 1993)</td>
<td></td>
</tr>
<tr>
<td>7. Risk = Event or consequence</td>
<td>Enghag &amp; Schenk, 2016</td>
<td>Covitt et al., 2010(^a)</td>
</tr>
<tr>
<td>8. Risk = Consequences/damage/severity of these + Uncertainty</td>
<td>-</td>
<td>Lee, 2012</td>
</tr>
<tr>
<td>9. Risk = The effect of uncertainty on objectives</td>
<td>-</td>
<td></td>
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</tbody>
</table>

\(^a\)One reference may fall under more than one risk description class, due to multiple different uses and/or multiple possible interpretations. Parentheses indicates that the class of risk description is found in the text but is not the same as that given as a definition in the same text.

\(^b\)Covitt et al., 2010 indicate that risk is defined to students of the described teaching efforts, however, risk is not defined for the readers of the paper.
A complement to the expected value is to use a simple matrix where categories of probability are plotted against categories of severity as exemplified in Figure 1. This semi-quantitative representation does not reduce the issue to a simple number, highlighting the contributions from probability and consequence respectively. Similar to the expected value, a risk matrix can also be a useful construct in education targeting how to reduce one’s risk. Furthermore, contrasting the expected value and this matrix (or other ways to operationalise risk) can be used as a starting point for more in-depth discussions concerning these operationalisations’ suitability as decision-making tools.

![Risk Matrix](image)

**Figure 1 An example of a risk matrix.**

**SUMMARY AND CONCLUSIONS**

Christensen (2009) pointed out that ‘where scientific knowledge is connected with risk, this is not the reliable or ‘certain’ knowledge of traditional science classrooms, but science surrounded by uncertainties, and this constitutes new territory for science educators’. Thus, incorporating risk in science education poses many challenges to educators. Christensen (2009) in particular highlights the uncertainty brought by complexity, the uncertainty pertaining to incomplete and/or conflicting knowledge (science-in-the-making) and that science and knowledge must be seen in a social context in risk decisions. We wish also to highlight the polysemous nature of the noun risk as a challenge to educators.

Boholm et al. (2016) point out that the polysemous nature of the noun risk, and the fact that the everyday use differs from that in technical contexts may give rise to misunderstandings that could for instance hamper risk communication or risk management efforts. Different risk definitions have also been pointed out as one potential cause behind the often-found disparities between laypersons’ and experts’ risk perception (Sjöberg, 1999a; 1999b; Slovic, 2016). These observations could be used both as an argument towards adapting specialist uses of the term towards the everyday understanding as well as an argument towards teaching about different ways to conceptualise risk in pre-university education.
The classroom may be the setting of the first time students encounter the meeting of the everyday uses of risk and the specialist uses of the same term. At this point it could be valuable to provide students with an understanding of the different definitions of risk. We do not propose to define one single meaning of ‘risk’ and excluding all other, or even to promote one definition of risk as superior to others. We argue that awareness of the risk polysemy is a topic relevant to bring up in the classroom. Furthermore, the polysemy of risk can be used as a starting point for encouraging students to discuss decision-making in risk issues from various perspectives.

In conclusion, if risk is to be incorporated in teaching, e.g. as part of an SSI, it is valuable to make students aware of the different ways to express risk. We propose that risk as a concept is discussed in relation to a selection of both qualitative and quantitative definitions as well as in relation to specific risk issues. Furthermore, risk cannot (or should not) be separated from discussions of values. If we include risk in our teaching, we need to make room for thoughts and possibly discussions on value aspects. The aim is to raise awareness of the many ways risks can be framed and assessed, and to highlight the role of both scientific knowledge and values in risk decisions.

ACKNOWLEDGEMENT

Financial support was received from Marcus and Amalia Wallenberg foundation.

REFERENCES


THE ROLE OF MYTH IN STUDENTS DISCUSSING « PEST »- AGRICULTURE RELATIONS

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Socio-scientific issues and socially acute questions enable moral judgement through rational, emotional, intuitive and imaginative thinkings. Our research focuses more specifically on the place of the myth in student discussions about controversial issues. We have analyzed the mythemes expressed through online exchanges between students from England, France and New Zealand about three 'pest'-animal issues, the 'pests' in question being the Badger (England), Wolf (France) and Possum (New Zealand). We observe the expression of recurrent mythemes by issue, one demonizing the animal and encouraging its destruction or control, one protecting its proper nature, one ambivalent proposing a dialogue between the two first ones. These expressions relate to the living contexts of the students. Wolves and Possums stimulate more myths than Badgers. The potential of myths to enable critical thinking is discussed.

Keywords: myth, socio-scientific issues, socially acute questions, debate

PROBLEMATIC

Socio-Scientific Issues (SSI) and Socially Acute Questions (SAQ) respectively conceptualised by Zeidler and Sadler (2008) and Legardez and Simonneaux (2006) are designed to enable reasoning based on rational, emotional, intuitive and imaginative thinking to navigate through issues and to frame moral judgement. Research which analysed student argumentation of about SSI or SAQ focused more specifically on the links between the ethical, affective and cognitive dimensions (Fowler, Zeidler & Sadler, 2009; Sadler & Zeidler, 2002; Zeidler & Keefer, 2003; Zeidler, Sadler, Simmons & Howes, 2005; Simonneaux & Simonneaux, 2015). We propose to analyse the place of the imaginary in argumentation.

The relationship between ‘mythos’ and ‘logos’ is an old issue. Dialogue between rational thinking and mythological thinking is an integral part of this discourse (Lévi-Strauss, 1958). For the structural anthropologist Claude Lévi-Strauss (1962), the savage mind is distinguished from the civilised mind. The savage mind, sometimes referred to as 'primitive', or preferentially 'mythic', is represented as elementary or enduring. Mythic thinking, however, is present in western or civilised societies, just as much as pre-modern societies, without considering one superior to the other. Myths are conceived as the expression or outcome of processes of sacralisation which ensure unity of social groups through sharing ways of thinking or acting. Myths are not easy to discern because they are often concealed in modern societies (Cullatti, 2011). Relations between mythical thought and scientific/rational thought is re-examined in Western societies, notably through the approach of the 'imaginary' (Durand, 1963). Usually considered as a fairytale, the myth is a story where expressed beliefs and fundamental antagonistic tensions are staged, as for instance those between the necessity to protect nature and to control it. According to Durand (ibid.), the myth is a dynamic system of schemes, archetypes and symbols, creating a story. Schemes are the movement of the body, a fundamental way of expression in the world which lead to 'archetypes', primordial images. For
instance the scheme of the ascent links archetypes of the mountain peak to the head. The symbols are ambivalent, culturally instantiated. Wolf can symbolise the nourishing mother, the wilderness or the demon according to the civilisation. Consequently, according to Durand (ibid.), there is no opposition between the imaginary and our sensory perceptions of the world, imaginary and its expression through myths, dialogue with the relation that we elaborate with the world. ‘There is no disconnection between the rationality and the imaginary, the rationalism being no longer, among others, a particular polarizing structure of the field of the image’ (ibid, p.38).

The two anthropologists agree that the myth has a permanent structure instantiated in language, discourse and that it is based on constitutive unities, the mythemes which are the minimal significant semantic unity of a myth, its principle of identification and the instrument of its interpretation. The mythemes enable the myth to exist in observable forms in the discourse. It means also that a mytheme will appear in different mythical stories, as for instance the mytheme of the incestuous love which is present in the myths of Oedipe, Lot, Electre. Creating the concepts of “mythocritic” and “mythanalysis”, Durand (1996) suggests that ‘the myth would be the matrix model of any narrative, structured by fundamental schemes and archetypes of the psyche of Sapiens Sapiens”. A mythanalysis enables, in a first step, to enlighten the recurrence of the mythemes which constitute the synchronicity of a myth by the repetition of permanencies and invariants. The repetitions enable to make manifest the structure of the myth. In a second step, the mythanalysis focuses on the diachronicity of the myth, or, in other words, how the myth is translated, interpreted according to its context at different stages in the history of cultures.

This second step seems difficult to observe if we analyse discourses of persons at a specific time and in a specific context. Nevertheless, the analysis of discourses of persons belonging to different cultures, to different ecological, social, cultural, economical contexts about the same issue may enable us potentially to observe differences or similarities of translation of myths.

This research is a first essay to observe the place of the myth in argumentations about SAQ/SSI. Our aim is not to define the structure of myths deployed by students but to identify if there are observable mythemes in students’ thinking in cross-national discussions of controversies around ‘pest'-agriculture relations and how they interact in the process of exchanges.

**METHOD**

Six discussions forums in the form of blogs were held between students from U.K., New Zealand and France. These were analyzed for mythic tracks incorporating both situations (e.g. ‘pest-ecology relations as actors, e.g. individual animals-wolf, possum, badger). There were three different ‘pest-animal’ scenarios: (a) The relationship between the growth of possum numbers in New Zealand as an ‘invasive’ species and their effect on extant habitats. (b) The perceived threat of wolves to sheep farming in rural France. (c) The perceived threat of badgers in the United Kingdom transmitting Mycobacterium bovis to cattle.

Students were introduced to the ‘pest'-agriculture scenarios through a short summary sheet which aimed to set out the controversies although these were necessarily non-exhaustive. A summary sheet of the pest-agriculture controversy is included in the appendix. Students were
then asked to discuss the controversy and map out the issues collaboratively using eco-network maps (Abbott, 2005). In these maps actors (usually identified through nouns) are linked through ‘tasks’ (identified through verbs). To give two examples, a supermarket (actor) sells dairy products (tasks) to customers (actor). Badgers (actors) transmit M.bovis to cows (actors). M.bovis (tubercular bacteria) themselves are actors, e.g. they infect cows. This allows students to summarise their ideas but also to have a representation where they can shift actor-task relationships through negotiations. An example of a map is shown in figure 1. Having discussed the controversy, also drawing on any extra information available, e.g. through web-searches, students start the asynchronous discussion forum by introducing themselves. Three discussion forums were held (NZ-France, NZ-UK, France-UK).

These forums were read independently by three researchers from different countries (France and U.K.), and a mythanalysis of discourses was generate according to the following criteria (Durand, 1992): (1) the myth is narratively conditioned; (2) the mythemes can be identified and are generally limited in number; (3) The mytheme has a syntactic and semantic homogeneity; (4) the choice of mythemes makes it possible to highlight an encyclopedic myth; (5) the position or action verbs are the main criterion of the mytheme.

We have considered the following tracks in the talks of the students for each forum: the qualification of the human through the adjectives, the metaphors and the action and position verbs associated with the human in the issue; the qualification of the “pest”-animal and of the nature through the adjectives, the metaphors and the action and position verbs associated with them. For instance, in the sentence, “wolfs are not criminals”, they deserve to be free”, “criminal” is a metaphor, “deserve to be” a position verb, and “free” an adjective which qualifies the wolf.

We have gathered the utterances which express the same mytheme. We have then demonstrated how diachronically during the forum the different mythemes are expressed and the number and the origin of utterances supporting each mytheme.

RESULTS

Analysis of the discussion about the Possum between French and New-Zealander students

The theme for the discussion about possums is based on a contemporary issue in the NZ where the brush tail possum, introduced from Australia in the 1870s rapidly spread throughout the country, transmitting the tubercular bacterium, Mycobacterium bovis, to cattle, attack New Zealand’s native bush by eating the foliage and animals, particularly the endemic birds. There are controversies about the use of the poison 1080 licensed for aerial dispersal to control possum population. First, it is considered by a part of the NZ population as a cruel method. Secondly, there is a perception that 1080 indiscriminately is dangerous for birds, livestock, deer, dogs and people and poisons the environment. Hunters see their potential trophies dead and dying in the bush.

In the discussion about the Possum issue between French and New Zealand students, we observe three mythemes: The first one is supported by verbs, adjectives and metaphors about the possum. The possum is considered as a nuisance, an environmental pest, for the country,
and even for human well being and survival. It has an inferior biological status to domestic animals. Nature's interest lies in its native character. Humans have to exterminate Possum. This mytheme is illustrated by the following utterances (in bold, the verbs, adjectives and metaphors considered as tracks):

Ascension (NZ): « We *value our animals* (...) *more* than Possum. **Possum don't only affect our animals but they also affect the way we live** »,

Tuukalikali (NZ): « **Possums are just pests to society** »,

Ascension (NZ): « *if we keep these possums alive and around our environment, then we are basically risking our lives* / “they also affect our farmers and our companies and factories being shut down” »,

Martha (F): « **The possum harmed the environment too much, it would obviously all kill them** »,

Paule (NZ): « **Possums should be killed** because they are *ruining the environment* (...) [possums] can also *affect humans* / *spread diseases* to humans/they are the *dangerous* animals that can kill and *this leads to human extinction* / *ruin environment/the native birds will extinc* »,

Killpossum (NZ): « **possums are ugly, they deserve to die** ». 

The second mytheme is supported by verbs, adjectives and metaphors about the Possum considering this animal as a free living being equivalent to human, and about Nature having its own laws. Humans are considered dangerous and have to respect Nature’s Laws, as illustrated by the following extracts:

Carine (F): « *[Humans] must let the nature do its job* (...) *It's a living being like you and I. They must eat and eat like us/It's a little animal who wants to live like everybody!la pire espèce au monde c'est les humains*5 »,

Mona (F): « *I don't want them to die, it's nature* »,

Clara (F): « *It is normal for them the kill others animals is feed. It's nature* »,

Emilia (NZ): « **Possums are just as important as humans** »,

Samuel (F): « **Possums do deserve the free will to live/should have the right to live and be free** »,

Carla (F): « **all animals should be able to live in their ecosystem** »,

Madfire (F): « **humans destroy everything, and possums probably want us to die** »

In the third mytheme, the possum is considered as a living being that should be allowed to live, but whose numbers should be controlled according to the diseases they spread, as illustrated in the following extracts:

Carla (F): « **we shouldn't kill the possums because all animals should be able to live in**

5 In french in the text : personal translation : « the worst specie in the world, it's the Human »
**their ecosystem** but I think that we **should control** them (...) one way we can control them is with biocontrol that makes the possums unable to reproduce »,

Emilia (NZ): « we kill them just because there infected, we can **stop it from spreading by giving them treatment or medicine »,

Samuel (F): « Reproduction pill is a good idea for possums were **not harming them physically but only disabling their reproduction system** as doing so there will be less population of possums ».

The mythemes are expressed during the discussion are recurrent (Figure 1).

![Figure 1. Expression of the mythemes during the discussion French/ New-Zealander about the Possum issue](image)

The mythemes 1 and 2 are recurrent during the discussion. Mytheme 1 is expressed 9 times by French students, once by a New Zealander student. Mytheme 2 is expressed 5 times by French students, 20 times by New Zealand students. Mytheme 3 is expressed once by a French student, once by a New-Zealander.

Mytheme 1 is expressed mainly by French students, mytheme 2 mainly by New Zealander students. Mytheme 3 is expressed only three times.

**Analysis of the discussion about the Wolf between French and New-Zealander students**

The theme for the discussion about wolves is based on a contemporary issue in France related to the increasing of the number of wolves, considered as a protected species according to the international Berne convention since 1993. The wolf eats wild game but also attacks flocks of sheep. There are a number of aspects to this controversy. First, the tension between on one side farmers and hunters and on the other the conservationists prioritising badger protection; secondly, the uncertainty surrounding the efficiency of sheep farming practices based on protection dogs or electric fences but also the efficiency of wolf shooting ; thirdly, the uncertainty about the economical impact of the wolf presence, affecting sheep farming and at the same time promoting a form of ecotourism; fourthly, the uncertainty about the ecological interest of the wolf presence, considered as increasing or decreasing the biodiversity.

In the discussion about the Wolf issue between French and New Zealand students, three mythemes were observed: mytheme 1 is supported by verbs, adjectives and metaphors about a wolf destroying the balance of the nature and being dangerous for the human. Humans must control the wolf, it is their responsibility. This mytheme is illustrated by the following extracts:
Strand 8
Nepatina (NZ): « Wolves are just like guns (...) they can kill people »,
Joshua (NZ): « putting them in captivity or controlling their population/ killing some of them/ in enclosed area / making them unable to escape »,
Nepatina (NZ): « putting up barriers that prevents them from entering where people reside, also knowing restrictions with signs informing the reader that you are entering areas where wild animals are...»,
Tupoi (NZ): « taking away the wolves ».

In mytheme 2, interest in the wolf lies in its wild character, which is founded on principles of freedom and struggle. The Human has to respect the wolf and has to respect its territory. This mytheme is illustrated by the following extracts:

Inest (F): « /Wolves/ they deserve to be free »
Madfire (F): « They should be free animals and eat what they want »,
Gaelle (F): « isn’t a good idea because it limits there natural instinct »,
Amandy (F): « putting wolves in captivity is very cruel, it’s like a prison »,
Amandy (F): « they must eat like us »,
Claralala (F): « I am against the death of the wolf because they are animals that deserve to live »,
Lesina (F): « without wolves, ecosystems can go haywire, the ecosystem will be unbalanced again ».

In mytheme 3, the wolf is considered at the same time in danger and dangerous. The human has the responsibility to control it and save it:

Tupu (NZ): « they’re an endangered animal and we need to protect them because they could become extinct due to the decrease in their population during the last few centuries. But (...) if they were to kill the wolves then I believe that they might as well kill the sheep too, I mean they’re both apart of life. taking away the wolves just because the sheep are important to providing for the economy is unfair if you think about it. the best thing to do is put the wolves in safe captivity, having both animals alive and in safe conditions ».

The mythemes which are expressed during the discussion are recurrent (Figure 2).

Figure 2. Expression of the mythemes during the discussion French/ New-Zealander about the wolf issue
legend: Sign in white: French talk; Sign in dark: New-Zealander talk; (X): number of talks without expression of specific mythemes
The mythemes 1, 2 and 3 are redundant during the discussion. Mytheme 1 is expressed 12 times by French students, once by a New Zealand student. Mytheme 2 is expressed 4 times by New Zealand students. Mytheme 3 is expressed 8 times by New Zealand students.

Analysis of the discussion about the badger between French and English students

The theme for the discussion about badgers is based on a contemporary issue in the UK where there is a controversy about badgers transmitting the tubercular bacterium, *Mycobacterium bovis*, to cattle. There are a number of aspects to this controversy. First there is uncertainty surrounding both the scientific evidence for the transmission and the effectiveness of methods for dealing with the problem; secondly, the tension between farmers and conservationists prioritising badger protection; thirdly, a more general controversy about the influence of agro-industry in the UK.

In the discussion about the Badger issue between French and English students, two mythemes are observed: mytheme 1 is supported by verbs, adjectives and metaphors about badgers considered as a nuisance for humans and nature; nature is seen as a combination of useful and useless living beings. Humans dominate nature, and must control what is useful and useless. This mytheme is illustrated by the following extracts:

A (UK): « *humans are much higher in the animal kingdom* »,
Elpadrino (F): « *we have to kill badgers because it will disrupt the ecosystem* »,
JUL (F): « *I think the badgers are not important for the english people, they are useless* »,
S (UK): « *no other positive impact on humans apart from being a nuisance* ».

Mytheme 2 is supported by verbs, adjectives and metaphors about the nature and life as being a balance, and about humans who respecting nature, and acting justly. This mytheme is illustrated by the following extracts:

G (UK): « *Culling of badger is inhumane* »,
Zoule (FR): « *They are useful to the biomass, if they were useless, nature would have gotten rid of them* ».

The mythemes expressed during the discussion are redundant (Figure 3).

Figure 3. Expression of the mythemes during the discussion French/English about the Badger issue

The mythemes 1 and 2 are redundant during the discussion. The mytheme 1 is expressed 4 times by French students, 4 by English ones. The mytheme 2 is expressed 3 times by French students, 5 times by English ones.
DISCUSSION

The place taken by the mythemes in the discussion of students positions human actors as *homo mythicus* (Méheust, 1990). The contemporary human creates and lives myths and associate myths with lived experiences, with contextualised issues. It cannot be considered as having an anecdotal interest insofar as it is integrated or even it bases a reasoning, an argumentation. In other words, the *logos*, as the dialectical exercise of reason, does not purge the *mythos*, but both of them co-exist, with interpenetrations and singular dialogues that it deserves to be deepened, and which shows a sensible reason (Maffesoli, 1996) for the work as illustrating in the following sentence combining an imaginary of freedom and a reasoning to avoid the poison 1080 and the suffering of possums: “*possums do deserve a free live, however (...) reproduction pill is a good idea for possums were not harming them physically but only disabling their reproduction system (...) 1080 isn't good for animals, in general every animal should have the right to live and be free***”. Thus, with Durand (1963), we rehabilitate the imaginary as a place for reciprocal exchanges between instinctive, imperative and objective reasons emanating between perceptions of Nature and the social environment. We reflect on interactions between myth and rationality not through a radical duality of the human mind (the irrational mythic and the rational logos) but rather through the forms of dialogue that they co-generate.

Each discussion conveys not more than 2 to 3 mythemes. A first mytheme demonizes or depreciates the animal, considering it as dangerous for Nature and/or humans. Humans are considered more important than non-human animals. The animal is described through alterity in relation to the human. It can be reified or considered as a stranger. Nature in such case is associated with a territorial identity: animals are or native of the region, or alien and in such case depreciated. The “pest”-animal must be killed or captured. In accordance with Campion-Vincent (1990), the animal, considered as a disaster and associated with uncertainties generates discourses which could be assimilated to a call to the crusade and to the death sentence of the species.

A second mytheme “essentialises” the living (as defined by Panissal, in publication) the living, considers the animal as having a place in Nature, as been on the same level as humans, or on a higher level, and can be supported by thinking based on values as respect of freedom or justice. In other words, the animals are considered through their similarities to humans. This mytheme is associated with symbols of Nature, considered as a fragile balance. This mytheme has its own natural laws to be respected.

When a third mytheme is expressed, it appears as an attempt to elaborate a dialogue between the two first ones. The animal is considered as a living being to respect, and at the same time its danger necessitates a control of the species.

Some animals, as the Possum or the Wolf are greater triggers than the Badger. The first two are often qualified as enemies or companions, which is typical of the ambivalence of a symbol (Durand, 1963). As a companion, the animal has commonalities with the human. As an enemy, it is considered as Other. Nevertheless we can also observe some attempts of dialogue between the two polarities in a third mytheme, to realize the coincidencia oppositorum, taking in consideration the respect of the animal and the damage it can cause.
The Badger appears to stimulate the imaginary less, the myths being more related to Nature in general than to the animal itself. Or the ethological behaviors of the wolf and the possum would stimulate the creation of myths more so than the Badger, the biological instinct being considered as mythical representations (Caillois, 1972), for the humans, or, the nature of the contexts of the controversy might have an effect, considering that the badger has a central role as a mythic character in English literature.

The expression of the myth is associated with the life context of the participant. New-Zealand students express an imaginary related to the destruction of the Possum considered as a pest while the French argue for the freedom of the animal as part of Nature. Whereas the new-zealander want to control the wolf, to separate his territory from that of the man, the second summons symbols of freedom. The New-Zealand students have an imaginary based on a hierarchy between humans and animals while the French place them at the same level. We do not observe a clear difference between the French and the English students discussing the Badger. We cannot assume that the national identity is the only key-factor explaining these differences. The place where students live can also shape their imagination. In particular the situation of the French school in an urban environment can explain their positioning in favor of the wolf. The imaginary thus makes it possible to build a meaning to the world, and it is social in the sense that gives Castoriadis (2017) insofar as it creates a space of representations in which all its members participate.

We do not think it wise to expurgate myths from talk in the name of a strict rationality. Myths allow us to interpret our forms of action and thought by which humans understand themselves in this world (Ricoeur, 1960) as considered by Natanson (2001). But beyond a hermeneutic of the myth, the creation of debate between groups of students from different countries, different social contexts, has enabled confrontation of different imaginaries, different myths. It avoids a polarisation of the imaginary which would threaten the psyche of a person or a group (Durand, op.cit.). Myths are recurrent and we suggest they encourage student argumentation and problematisation of the relationships between scientific, ethical, experiential reasoning and development of critical thinking.

REFERENCES


DIDACTICAL DILEMMAS WHILE TEACHING
CONTROVERSIAL SOCIO-SCIENTIFIC ISSUES – AN
INTERNATIONAL COMPARISON

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This study followed groups of teachers within an Erasmus+-partnership, in which the teachers conducted an intended reflexive and interdisciplinary teaching about complex and controversial issues, including socio-scientific issues. Five schools, with students aged 12-16 years, in five different countries (Croatia, Poland, Italy, Sweden and Turkey) were involved. The overall research design was inspired by research models where researchers and practitioners cooperate and share responsibility. Iterative systematic investigations have been done, when teachers with support of a teaching model created interdisciplinary arenas in their respective context. Through focus groups and participant observation, the study aims to explore potential tensions that emerge during the enactment of the interdisciplinary teaching. Preliminary results show a variety of emerging tensions that might cause didactical dilemmas. The tensions are anchored both at macro level, concerning different types of curriculum goals and related to politics and religion, as well as those at the classroom level and at levels in between.

Keywords: socio-scientific issues, interdisciplinary teaching, environmental education, education for sustainability, teacher professional development

DIDACTICAL DILEMMAS IN INTERDICIPLINARY TEACHING

In this study, we have followed groups of teachers who conducted an intended reflexive and interdisciplinary teaching about complex and controversial issues in line with Sjöström’s and Eilk’s (2018) Vision III for an eco-reflexive science education (Sjöström, Eilks & Zuin, 2016). Such teaching is Bildung-oriented and holistic, and ethical and political aspects of science are foregrounded (Sjöström et al., 2017). An important objective is to give all students the opportunity to develop as independent political subjects, by giving them chances to both challenge the existing views in society, examine their own stance on societal issues, as well as to enable them to take their own position (Hasslöf & Malmberg, 2015).

This study has followed groups of teachers from five schools, with students aged 12-16 years, in five different countries (Croatia, Poland, Italy, Sweden and Turkey). The schools participated in an Erasmus+-partnership with the objective to test and implement an interdisciplinary teaching about complex and controversial issues, including socio-scientific issues. The sociodilemmas (complex SSIs) the schools worked with in the study contained content from several different school subjects. This kind of teaching ought to have an important role in both natural and social sciences classrooms, as well as in technology and sustainability education (Crick, 1998; Zeidler & Keefer, 2003; Englund, Öhman, & Östman, 2008; Keirl, 2012).

This study is thus inspired by research from different fields of educational research with the ambition to induce interdisciplinary teaching about controversial issues on a structural and
socio-political level at the involved schools. The development of students’ abilities for critical thinking and decision making were highlighted as well as oral discussions between students. The teaching was furthermore also supposed to create room for the students to form their own opinions about the issues. In this study, the teaching in line with theses intentions were labelled “reflexive teaching”.

The study aims to explore potential tensions that emerge during the enactment of the interdisciplinary teaching when the schools implemented the kind of teaching mentioned above. Through focus groups and participant observation in all participating countries, we ask firstly, which tensions are discernible across the different classrooms? Secondly, we make a reduction of the data and focus the Swedish teachers in the light of the international pattern. We ask “which tensions are most salient for the Swedish teachers”? These two questions are theoretically elevated and clustered in the discussion to “which didactical dilemmas may emerge during interdisciplinary teaching”. In this paper, we will primarily focus on the first question.

THEORETICAL FRAMEWORK

The international setting of this study opens opportunities for cross-cultural comparisons and analyses that could generate knowledge about teaching, teaching content, learning and socialization. Almqvist (2014) describes that teachers constantly must make judgment about which educational content to include and which methods should be used. These decisions are generally based on previous experiences. Almqvist states that it is vital for teachers to occasionally visualize and problematize what has been taken for granted in the teaching. This is the basis of “comparative didactics”, which is about making the taken for granted visible and critically reflected on, and thus acquires knowledge for teaching and learning.

Comparative didactics can be about comparing teaching within the same subjects or between different subjects as well as studying similarities and differences in teaching in different socio-cultural contexts. This can lead to more precise descriptions of the teaching and thus generate new knowledge (Almqvist, 2015). Analysis is often done in two steps, where a first step is about describing teachers’ actions in a teaching practice (Almqvist, 2008; 2014). In a second step, this description is compared with alternative descriptions followed by a critical discussion about the relation between the taken for granted didactical choices and alternative didactical choices.

This study originally presupposed an activity theory perspective on the collective and complex activity systems of the schools to examine how participants’ actions and operations are influenced and affected by both internal and external factors (Leontiev, 1978; Engeström, 1987). Different didactical contradictions and dilemmas that occur in the complexity of everyday teaching may be viewed as obstacles for successful teaching and learning, but by identifying such dilemmas and then discussing them among the teachers, this may instead be a starting point for a permanent transformation and a spark for school and professional development (Sannino & Nocon, 2008).

To gain a deeper understanding of teachers’ challenges and dilemmas, the study assumed a complementary theoretical perspective by considering this form of teaching as a “dilemmatic
space” (Fransson & Grannäs, 2013) in which the dilemmas are ever-present. The dilemmas are the result of social constructions, but the dilemmatic space is constantly in a dynamic process, where everyday positions and negotiations both redefine the dilemmas and the actors. Fransson and Grannäs described that teachers in their daily work often end up in dilemma situations. The teacher must deal with formal laws and regulations as well as more informal work routines. Furthermore, the teacher must balance different purposes of teaching towards each other, focusing on the three different functions that the education should meet: qualification, socialization and subjectification (Biesta, 2009). All this should be done at the same time and the teacher must deal with a variety of social relationships and contexts with different norms, values and expectations. This is also done in a complex and changing activity where decisions need to be taken quickly in the dynamic interactions of the classroom.

Dilemmas are sometimes regarded as individual and disconnected situations, but Fransson and Grannäs (2013) argue that dilemmas constantly are present in our lives because of the social constructions created by everyday positions and negotiations. Fransson and Grannäs use the theoretical perspective dilemmatic space (Honig, 1994) to describe this in an educational setting. Honig describes a dilemmatic space as a complex, moving and mutable system with different actors and different positions. Honig states that we should consider dilemmas as if they are always present in our life where one position oneself, and are being positioned, in various dilemmas. These positions then create peoples’ identity and action space.

**RESEARCH METHODS**

The study followed five European lower secondary schools working together over a two-year period within an EU-funded Erasmus+-partnership. With the help of a teaching model, they designed their own teaching set up based on their own school context. To support the teachers, the model did not just include student tasks; it also included a theoretical framework on how the teachers could implement an inquiry-based approach of this intended reflexive and interdisciplinary teaching (Rydberg, 2015). This framework was based on methodological models from Bybee et al. (2006) and Presley et al. (2013). Inspiration and ideas concerning teaching about controversial and socio-scientific issues were also provided from e.g. Ekborg, Ideland and Malmberg (2009), Zeidler and Kahn (2014) and Eilks (2015).

Teachers and students worked on different controversial issues containing both scientific, technical and social science content, as well as socio-political and ethical aspects. The student tasks were inspired by the Storyline method (Bell, 2008) in which the students were placed in a scenario where they landed on an imaginary, and newly colonized, planet named PromethEUs. On this imaginary planet, students should together create a new society, which meant that the issues were mainly at a structural level. A companion meaning (Roberts & Östman, 1998) of the teaching was that students would gain insight into the fact that political decisions on complex issues like these – with both scientific, social, economic, political and ethical aspects – is not about "right or wrong". Rather, it's about weighing the advantages against the disadvantages and in this process, try to make reasonable and acceptable decisions. The issues were deliberately chosen to be complex and controversial. They are sociodilemmas where no definite answer exists; instead all possible solutions have both positive and negative
consequences. The design of the student task strove to develop students' critical thinking abilities, which obviously are prerequisite abilities in order to be able to independently make decisions and express ethical and political standpoints. Students would also be given opportunities to take their own position in the issues and do it in a European context. The students would base their position on knowledge of human rights and fundamental democratic values, on their personal experience as well as on acquired factual knowledge regarding the issue.

The work at the schools was done in three cycles, where each of these ended with a transnational meeting with both teachers and students. In conjunction with these, data collection was done, primarily using focus group interviews. Furthermore, during a third cycle, when the schools were working on issues related to the use of robotics and biotechnology in the future, participant observations were carried out. This study applied a flexible research design and it was during the process of the research that the research questions emerged.

First, the didactical dilemmas which participants at the five schools experienced in the work with the intended reflexive teaching were studied. Focus group interviews were transcribed and the different tensions the teachers experienced where put in themes. After analyzing the data from the first cycle results was brought back to the focus group discussions in the following cycle. With this data, the preliminary themes and categories of tensions were refined. Four themes and eighteen tensions that could create didactical dilemmas emerged from the thematic analysis after the third and last cycle. The teachers’ descriptions created basis for a comparative didactic analysis where what is “taken for granted” in the teaching was made visible when both researchers and teachers studied the similarities and differences of the teaching in the various cultural contexts.

**PRELIMINARY RESULTS**

The study is still ongoing, but in the data from the international focus groups different didactical dilemmas have been identified, analyzed and grouped. The purpose of the study was at a first stage to investigate and identify the tensions teachers experienced when working with the intended reflexive teaching. In a second stage, the study aims to further explore teacher dilemmas that arise from these tensions, focusing on the dilemmas that were considered most relevant from a Swedish context. This paper will primarily focus on the first stage of the study while results from the second stage will be presented in forthcoming publications.

In the dilemmatic spaces of the intended reflexive teaching the teachers described different tensions. These tensions can cause concrete didactical dilemmas for the teachers as they plan, conduct and evaluate the teaching in the study. However, this study doesn’t intend to describe all the tensions that may exist in this form of teaching. Instead a selection was made based on the empirical evidence.

In the data from the study 18 tensions were revealed which may cause didactical dilemmas for the teacher (see further below). It should be stressed that tensions and dilemmas in a dilemmatic space never are separated from the context. Depending on one's positioning in a didactical dilemma this will affect positions in other dilemmas. Furthermore, a didactical dilemma that
from one perspective can be interpreted as a single dilemma, could in fact consists of several related dilemmas.

Below are the eighteen tensions listed. It is not easy to describe them clearly in just a single sentence and the naming should be seen more as an orientation of the tension and the character of the intrinsic didactical dilemma. A tension that causes a didactical dilemma in daily classroom teaching usually has links with other levels of education. To understand the different tensions better, and the didactical dilemmas, the eighteen were divided into the following four themes:

**Theme 1: Tensions linked to curriculum, national tests and assessment**
1. What primarily governs the planning of teaching – the social, democratic and character development goals or the overall educational goals.
2. The impact of national tests on the teaching - big or small.
3. Assessment of students during the theme day - collect evidence for future grading or not.
4. Room for teachers to choose methods and content on their own - large or limited.
5. Room to discuss controversial topics that not relate to the curriculum's core content - large or limited.

**Theme 2: Tensions linked to prevailing religious values and political views in society**
6. The influence of prevailing religious values in society on the teacher's choice of methods and content - significant or slight.
7. The influence of current political views in society on the teacher's choice of methods and content - significant or slight.

**Theme 3: Tensions linked to teachers' interdisciplinary cooperation**
8. Socio-economic challenges in relation to teachers' joint planning of new teaching methods - tangible or insignificant.
9. Potential staff meeting opportunities at school for teachers to co-plan their teaching - large or small.
10. Coordinated training of students' basic skills for a reflexive teaching between the school subjects - comprehensive or non-existent.
11. Opportunities to temporary change the regular school schedule in order to work thematically and interdisciplinary - large or limited.

**Theme 4: Tensions linked to the implementation of the teaching in the classroom**
12. The amount of time the teacher uses for self-studies of the subject matter from beyond the field of his or her domain-specific expertise - large or small.
13. The dominant work form for the discussions in the reflexive teaching – whole class or group discussions.
14. The prioritized method for pupils to retrieve relevant information regarding the current issue - through teacher mediation or through the students looking for it themselves.
15. Grouping of students for group discussions in reflexive teaching – ability grouping or homogeneous groups.
16. Adaptations for “silent” students in oral discussions in a reflexive teaching - adaptation for these or no adaptation.
17. Weather the teacher should express different viewpoint in the discussions - strong objectivity or weak objectivity.
18. Weather the teachers should express their own opinions and beliefs regarding the issue - strong neutrality or weak neutrality.
Not all the eighteen tensions will be covered below. Instead, a selection of the tensions will be discussed. These will be exemplified by didactical dilemmas that the different groups of teachers experienced that were caused by the tension.

**Tensions linked to curriculum, national tests and assessment**

The five first tensions had an emphasis on a macro level in terms of contradictions, primary between working toward the educational goals in the curriculum, or putting more emphasis on social, democratic and character development goals. This is also linked to tensions and didactical dilemmas concerning assessment, national tests and teacher autonomy. Ways that the national curricula should be interpreted, and the significance of national tests for the everyday teaching is also regulated at the school level, depending on the emphasis the school leadership puts on them. Curricula and other national control systems are in turn influenced by internationally formulated education policies and international knowledge surveys.

For example, the Polish teachers in the study felt steered towards teaching that focuses on the educational goals, mainly on facts. The teachers described that they have syllabi with a comprehensive core content and national examinations that mostly test factual knowledge. Since they perceived that the individual teacher is accountable for poor student results, this creates limited space for teaching in line with reflexive teaching outside this project. They also expressed that it wasn’t really feasible for them to address content that isn’t explicit in the subject’s syllabus.

All teacher groups experienced didactical dilemmas related to the national steering documents and assessment systems when they used the reflexive teaching methods. They all agreed that this kind of teaching offered knowledge that would be very valuable for the students in their future lives. Still, subject content, knowledge or abilities in this weren’t always something that traditionally is stressed in either their curriculum or national tests, at least not the ways the teachers in the study interpret these.

The Swedish teachers expressed that they used to have more teacher autonomy, but during the last years they felt that their lesson planning was more and more affected by the national syllabuses and the national tests. A major difference between the Swedish teachers and the others regarding this matter was that while the teaching in the other schools had a more fact-based focus, the focus in the Swedish school was on developing students’ abilities.

The Italian teachers described that they as teachers have a freedom to choose both teaching methods and content (even if the latter was contradicted by the school’s principal). They meant that both their curriculum and their national examinations promoted teaching that not just are fact-based, but traditions and teachers’ perceived autonomy slow down the rate of change. This teacher autonomy had as consequence that the teachers feel free to continue using more traditional and fact oriented teaching methods.

**Tensions linked to prevailing religious values and political views in society**

Teachers also experienced didactical dilemmas that can be related to tensions due to the prevailing political forces in the country or to religious values in society. The teachers at the Italian school described that some staff members held strong religious values and these also
existed in the local community. When a controversial issue included an aspect that was contradicting the Catholic values, this created tensions for some of the participating teachers. As for issues about abortion and homosexuality some single teachers choose not to discuss these in their classroom. However, the other participating teachers at the Italian school did not experience any influence from religion that would stop them from discussing subjects like these in their classroom.

The teachers at the Turkish school in the study described that both the prevailing political viewpoints in the country and the religious values of society create didactical dilemmas for the teachers. If any issue had aspects that are in contradiction to strong beliefs in society, the teachers often avoided to discuss these aspects. The teachers stated that if they addressed aspects of a controversial issue not included in the syllabus, it may cause problems for them as teachers. This could lead to parents reacting and proceeding with the matter to the school authorities. As for the Polish teachers, they didn’t experience any didactical dilemmas due to influence of prevailing religious values, however they felt that the current dominating political views in their country affected them when they discussed some issues.

**Tensions linked to teachers' interdisciplinary cooperation**

The teachers described also didactical dilemmas on intermediate levels, which among other things had to do with the teachers working interdisciplinary and how to organize this. These dilemmas were caused by more practical tensions concerning parts of the school’s organization, for example regulation about working hours and scheduling. These aspects aren’t easy for an individual school to influence and change on their own. However, these can create great resistance in a transformation process at the school since this require joint actions. As for the prerequisite for cooperation and co-planning the Swedish school stood out. Here the teachers had a couple of staff meetings each week, they had work places at the school as well as public childcare for teachers with younger children. This allowed the teachers to plan and evaluate lessons at school and they had good conditions for joint development activities.

The teachers at other schools in the study didn’t have the same possibilities. At the Turkish school, they had two shifts which meant that there wasn’t any actual space for the teachers at school when the shift was over. The Turkish teachers described that it was a challenge to work with school development since teachers were forced to work with this to a large extent individually since the teachers' lesson planning wasn’t done at school. Furthermore, the relatively young Turkish teachers who participated expressed that the lack of childcare meant that they had to prepare lessons at home at the same time as they were taking care of their children. They described that they and their spouse synchronized their working hours and combined work at home with caretaking of the children, while their spouse went to work.

In the same way as in Turkish schools, many Croatian schools have teaching shifts and thus short school days for students, with just short breaks. This means that there are basically no opportunities for the teacher to plan or meet colleagues during the school day. The time for planning was in the afternoon, since the school building was locked after lunch time and the teachers had to do the planning at home. The Croatian teachers described that a large part of the teachers at the school felt forced, for economic reasons, to have another job aside and the
short school day made this possible. This obviously affects the potential time that teachers put on preparing lessons and developing the teaching. It was described that this dilemma lead to the teachers sometimes regarded the job as a teacher's as "the second job". They of course understood that this meant that they put less time on planning and developing the teaching than they ought to.

**Tensions linked to the implementation of the teaching in the classroom**

Dilemmas also arose in the classroom teaching. For example, whether the fact-finding primarily should be done by letting the students work individually using computers, or if the teacher would present relevant facts and information about the issues through more traditional methods. Other didactical dilemmas originated from tensions regarding whether the teacher should choose a whole class or group work approaches, as well as tensions related to the teacher's objectivity and neutrality.

The Swedish teachers had a taken for granted position that it should be students themselves who find the information needed in order to take a stand in an issue. In the study, the Swedish students mainly discussed in small groups and during these discussions most of the time there were no teacher acting as discussion leader. Instead it was the students that handled the discussions themselves. Occasionally the Swedish teacher participated in the group's dissociation.

This differed from the teaching the other teacher groups conducted. Here, the teacher took a more active role and was primarily responsible for finding and highlighting the various aspects of the controversial issue. At these schools, the teacher mostly organized whole-class discussions about the issues, even if also group discussion was used. During the student-centered teaching at the Swedish school the main focus was on having the students develop their critical thinking abilities in practice. During the more teacher-centered teaching at the other schools it was the content of the issues that was put in the foreground. The teachers encountered a didactical dilemma regarding to what degree the student should be active in the information finding and discussions. A related dilemma for the teacher was how to balance learning of subject content and the development of general critical thinking abilities. The common conclusion of the teachers was that the Swedish students generally had better argumentation skills but often rather shallow knowledge about the content of the controversial issues.

During the discussions about the different controversial issues the Swedish teachers remained neutral and didn’t reveal their own opinions. However, the teachers at the other involved schools didn’t stay neutral in the same way as the Swedish teachers. Instead these teachers rather saw it as important to share their own opinions, at the same time as they pointed out that their opinion should be treated as one opinion among others. During the discussions with the students, the Swedish teachers often took the opposite view to the students. This opinion wasn’t necessarily their personal opinion; instead it was a professional standpoint in order to challenge the students’ reasoning and argumentation abilities. This approach was rarely used at the other schools during the study. Either the teachers stated his or hers view and stood by this or the
teacher had a more objective and balanced role and presented a wide range of alternative views for the students.

Some of the didactical dilemma teachers described was regarded to be more relevant to focus from a Swedish point of view. In these dilemmas, the Swedish positioning were sometimes other than the positions of the rest of the teachers’ groups in the study. The positions of the Swedish teachers in some dilemmas were strongly related to tensions about the curriculum's different goals, the influence of the national tests on the teaching and tensions around assessment. Some selected didactical dilemmas from a Swedish point of view will be examined deeper. This will be done using data from the in-depth focus group interview with the Swedish teachers, but also using empirical data from the Erasmus+-partnership. This aims to describe the essence of these didactical dilemmas, both in terms of underlying causes, as well as possible consequences, according to various positions in the dilemmatic space of this form of teaching.

**PRELIMINARY DISCUSSION**

When it comes to carrying out an interdisciplinary and intended reflexive teaching with discussions about complex and controversial issues the teacher needs to move beyond the traditional teacher role. Engeström (2008) describes that the deep social structures of an activity system are found in three different parts. It is first the rules, regulations and traditions, secondly the community that have an interest in the teaching and finally the division of labor in the classroom and at the school. These parts give the educational system an inertia that creates tensions when the teaching practice is changed; as it was in this study.

In an altered form of teaching with a partly new motive, the teacher need to be aware that previously taken for granted and operationalized actions might not be valid anymore (Almqvist, 2014). The teachers have to renegotiate their positions in the various didactical dilemmas they constantly experience in their everyday teaching. This study aimed to highlight the dilemmatic space of this form of teaching and showed didactical dilemmas that arise.

The results from this study shows that this kind of teaching is complex and the teacher needs to take many different aspects in considerations. Biesta (2015) points out that the teacher's different forms of judgement are extremely important for good teaching. He says that the teacher first needs to identify what the purposes might be for the forthcoming lesson sequence, then identify possible conflicts between the purposes and finally prioritize between the purposes.

This study shows that to handle the didactical dilemmas in the dilemmatic space of an intended reflexive teaching, it is crucial for the teachers to relate to the main purposes of education as well as other purposes in school activities. Teachers need to analyse how the different purposes are related to the goal-oriented actions that they perform daily in the teaching practice (Biesta, 2015). This way, one can discover that different purposes may sometimes conflict each other and that the different performed actions in the classroom teaching, even if they are done with good intentions, may counteract each other.

This could be illustrated by the position that the Swedish teachers took regarding to what degree the teaching would be student-centered. When the students themselves were responsible for
finding and evaluating information this created opportunity for the students to develop their critical thinking abilities in practice. This in turn was because these students had a lot of training about how to search for and evaluate information, how to reason and how to discuss. However, with this position there is a risk that the students only will obtain shallow knowledge about the content of the controversial issues since it is hard for students at this age to find relevant information on their own. If the teacher takes more responsibility for providing relevant information about different aspects of the issues, the chances for the students to get the full picture of the sociodilemma is greater. However, if the teacher takes too much responsibility the student may miss opportunities to develop his or her abilities to search for information about society from the media, the Internet and other sources.

What position the teacher should take in this specific didactical dilemma depends on the main purpose. If it is to develop critical thinking abilities in order to take well-informed standpoints in the future, then it’s wise to let the students practice the abilities and it’s ok that the student misses some content related aspects. Is the main purpose with the issue instead that the students should get knowledge and insight about different aspects of the controversial issue the teacher needs to make sure that the content of the issue is foregrounded. If the main purpose is providing an opportunity for the student to take an own stance in a current sociodilemma, then both critical thinking abilities as well as knowledge about the content of the issue is important, as well as knowledge about other aspects concerning the issue. Then the teacher needs to balance the different purposes.

As a teacher, you position yourself in the didactical dilemmas according to prior experience, current rules and norms and the surrounding social context. This is creating the dilemmatic space where different norms, values, action, decisions and roles all stand in relation to each other (Fransson, 2012). As for some of the didactical dilemmas, the teacher has actual leeway to make judgement about different didactical choice. However, the teachers’ possibility to take positions in a didactical dilemma could sometimes be limited by education policy and by the surrounding community.

Even if teaching about these issues is regarded as valuable for the students in their future lives, the subject content of the issues, as well as the abilities that are developed, are not always what is valued in grading and testing students. If a teacher feels that this type of teaching may risk students achieving a poorer result in a national test or equivalent, it becomes a didactical dilemma for the teacher. Even if the teacher agrees that a reflexive teaching about controversial issues is good for the students, he or she still needs to consider if it is worth the risk of lower scores at a traditional test. This especially if the teacher is held accountable for the results of the tests.

The results from this international study shows that prevailing religious values and dominating political views in the society could affect the teachers when working with controversial issues. Some teachers expressed that they avoided certain aspects to prevent conflicts with parents and local authorities. This highlight that some of these issues not only are challenging to deal with for the students in the classroom, but also could be challenging for the teacher in real life.

This study also points out that it requires time and discussions between teachers to transform teaching practices, especially if it is interdisciplinary teaching with controversial issues. In the
frame of this EU-funded Erasmus+ projects the teachers had this, and all involved teacher teams succeeded with their reflexive teaching. Still, the teachers expressed that outside this project there is a lack of prerequisites for joint and long-term transformation processes of their practice. This is for example due to organizational factors as lack of joint teacher training and socio-economic factors that make it hard for the teachers to find time and places to co-plan and develop the teaching together with colleagues.

CONCLUDING REMARKS

A purpose of this study was also to contribute to pre- and in-service teacher training and the results will form a basis for a discussion tool. This tool aims to provide support for teachers to develop their shared teaching knowledge. It could contribute to the development of teachers’ action competence and expand their repertoire of strategies for dealing with the didactical dilemmas that could occur in this form of teaching. The discussion tool aims to raise awareness about both possibilities and potential negative consequences with different positions in different didactical dilemmas. It will also support teachers to question what is taken for granted in their own practice. This discussion tool will be described in detail in forthcoming publications.

REFERENCES

THE INFLUENCE OF ENGAGE MATERIALS ON STUDENTS’ LEARNING ABOUT SOCIOSCIENTIFIC ISSUES

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Today’s society needs citizens who are familiar with the scientific way of thinking, and can use it in everyday life. Therefore, science education aims to engage students in socioscientific issues (SSI). In this study, two chemistry teachers used ENGAGE lesson material with 53 students to teach SSI. The study aims to investigate how successful the Engage materials are in engaging students in SSI, that is, connecting these with chemistry knowledge, personal life and society. De Groot’s Learner Report was used to gather the data, and these data were analyzed by qualitative content analysis, using Atlas.ti software. The findings indicate that the ENGAGE materials fostered students’ learning related to SSI. Especially connecting chemistry concepts, society, and personal life through SSI. This study also revealed opportunities and challenges for teaching SSI in science lessons.

Keywords: socioscientific issues (SSI), curriculum materials, students’ learning

INTRODUCTION

Problem statement and theoretical framework

Science education has a crucial role in preparing future citizens to engage with personal and public science-based issues. Currently, science education does not only aim to educate future scientists but also whole student population who are scientifically literate. That means, they can make informed decisions regarding ill-structured, complex, dilemmatic social problems which deal with scientific issues, based on understanding of concepts, principles and the processes of science (DeBoer, 2000; European Commission, 2015). Recent research in science education addresses scientific literacy, Responsible Research and Innovation (RRI), inquiry-based learning (Osborne & Dillon, 2008) and improving student cognitive abilities, i.e. scientific skills such as examining consequences, interrogating media, estimating risks, justifying opinions, and thinking ethically (Bayram-Jacobs, 2016). Today’s society needs citizens who are familiar with the scientific way of thinking, and can use it in their everyday lives. One powerful way to do this is incorporating socioscientific issues (SSI) in science education and to engage students in SSI (Driver, Newton, & Osborne, 2000; Millar & Osborne, 1998).

Socioscientific issues

Socioscientific issues (SSI) are defined as controversial, ill-structured problems which usually do not have a single solution. Through some innovations in science and technology, society is faced with dilemmas, which are related to political, economic, social and ethical aspects. Citizens need scientific reasoning to be able to make informed decisions about scientific or technologic innovations. Besides, SSI includes ethics and moral reasoning about the social problems which base on science (Zeidler, Sadler, Simmons & Howes, 2005). Dealing with SSI
means more than just using scientific and social knowledge. It requires applying scientific knowledge in a social context, and in everyday life to solve a controversial SSI problem (Sadler, Barab & Scott, 2007).

Many countries incorporated SSI into their science curricula to promote scientific literacy. By discussing SSI in science lessons, it is aimed to improve students’ inquiry skills and to make connections with society. SSI based instruction is accepted as an efficient way to support students’ science learning. There is evidence that SSI based instruction (e.g. genetic modification, climate change, hydraulic fracturing, etc.) motivates students for science learning, improves their inquiry skills and offers a context to combine science knowledge with social life (Ekborg, Ideland & Malmberg, 2009; Sadler, Barab & Scott, 2007). These real-life issues are not only meaningful but also engaging for students. By discussing SSI, making their own arguments, searching for evidences and weighing up the claims students gain required knowledge and skills to be responsive citizens. Consequently, they can participate in public debates, and can make informed decisions, which make them active and responsive citizens of the society (Fowler, Zeidler & Sadler, 2009; Lewis & Leach, 2006; Ratcliffe & Grace, 2003, Simonneaux & Simonneaux, 2009).

However, it is known that teachers have difficulties to embed SSI in science lessons, to focus on skills development, and to help their students in their learning process in SSI (Evagorou, 2011; Sadler, Barab & Scott, 2007). Limited teaching time, exam driven school goals and structure, and limited curriculum materials are just a few examples to mention. Researchers and teacher trainers have been trying to support teachers through different means such as professional development courses, workshops, curriculum materials, etc. Although there were some curriculum materials produced to foster SSI-based instruction, these materials are mostly sequential materials. Therefore, their enactment requires long lesson series. On the other hand, it is known that many teachers are not open for new practices because they require long time (Serdyukov, 2017). Therefore, in the ENGAGE project we designed SSI curriculum materials by considering teacher difficulties and time constrains.

The ENGAGE Project and ENGAGE SSI Materials

The ENGAGE project was granted by European Commission under the ‘science in society’ call. The Engage project aims equipping the next generation to participate in socioscientific issues (Bayram-Jacobs, 2015). To reach this aim, the project has several strategies including designing curriculum materials that focus on SSI for science teachers. Teachers can download these SSI curriculum materials, which are open educational resources, from the project’s website (www.engagingscience.eu) as a complete package including presentation (powerpoint), teacher guide and student sheets.

The materials were designed in a stepwise way in three categories. That means, there are three types of materials: topicals (for 1 lesson), sequences (for 2-3 lessons), and projects (for >3 lessons). In this way, we allow teachers to choose the material according to their need and time. For example, science teachers who do not have any experience in using SSI, can choose to use the topicals. In this way, they have time to learn about this new teaching practice, improve their knowledge and skills for teaching with SSI and reflect on their actions in practice.
In the materials, the 5E learning cycle (Bybee, 1997; Trowbridge, Bybee & Powell, 2000) was used as a pedagogical approach to introduce SSI to students. The material framework includes SSI goals, practices, strategies (Shwartz. & Sherborne, 2016) and the following US next generation science standards (NGSS, 2013): Content big ideas, RRI big ideas, Nature of science big ideas, and Scientific practices.

The SSI materials include controversial issues, ethical values, forming opinions, making choices, and so on (Ratcliffe & Gravies, 2003). For example, the material ‘Death to Diesel’ introduces the dilemma of ‘driving cheap versus environment-friendly’, and one of the activities involved role-playing, for example persuading car buyers to boycott diesel cars. In this way, it is expected from students to connect SSI with chemistry knowledge, personal life and society (like we presented it in Figure 1).

![Chemistry concept](image)

**Figure 1. Student learning areas through overarching SSI theme**

There are studies where teachers evaluated ENGAGE materials (Bayram-Jacobs & Henze, 2016; Okada & Bayram-Jacobs, 2016) that showed that the students liked the materials. Although there is evidence that SSI-based instruction motivates students for science learning, for the ENGAGE materials this has not been studied, yet. Therefore, it is necessary to investigate the influence of the ENGAGE materials on students’ learning related to SSI.

Given that curriculum materials should be "both effective and efficient" by helping teachers to deal with implementation problems (Davis and Krajcik, 2005), the materials that were used in this study were designed to facilitate the first step of 'classroom experimentation'. This is also based on the argument that using curriculum materials has an impact on specific teaching practices (Schneider & Krajcik, 2002). Although the materials are ready-to-use, teachers may adapt them according to level, interest and needs of their students.

**AIM**

This study aims to investigate how successful the ENGAGE materials are in engaging students in SSI, that is, connecting these with chemistry knowledge, personal life and society.

This general aim gives rise to the following specific research questions:

1. To what extent did students learn about SSI?
2. How far do students connect the SSI to chemistry concepts?
3. How far do students connect the SSI to their personal lives and society?
METHOD

Participants

The participants of this study are 53 students from two secondary schools in the Netherlands, in the age of 14 to 17 years old. In two classes, the Chemistry teachers chose to use ‘Death to diesel’ ENGAGE material, among the other chemistry materials. The teachers stated that they chose this material because the science content of the material was relevant to the curriculum. This material is a topical, means that it was designed for a single lesson.

Data collection

In order to measure students’ engagement in SSI, standardized tests cannot provide valuable data. Since we want to know if students connect science knowledge to their personal and everyday life, it is needed to ask more personal questions. De Groot (1974) developed a method that includes fundamental learning experiences of students defined as “the experiences that are subjectively remembered and reported by a student to develop important insights where s/he has learned something.” Moreover, previous research (Bayram-Jacobs & Henze, 2016; Kniep & Janssen, 2014; Schrijvers, Janssen, Fialho & Rijlaarsdam, 2016; Van der Meij, Broerse & Kupper, 2017) showed that this instrument is useful to study this type of student learning. The classification matrix of the instrument is represented in Table 1 (De Groot, 1974).

Table 1. Classification system of De Groot (1974)

<table>
<thead>
<tr>
<th>Rules</th>
<th>Exceptions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>World</strong></td>
<td></td>
</tr>
<tr>
<td>A. Knowledge and insights</td>
<td>B. Insights in the existence of something (new facts, surprises)</td>
</tr>
</tbody>
</table>

Therefore, in this study to investigate the influence of the ENGAGE materials on students’ learning related to SSI, the “Learner Report” (De Groot, 1974) was used as a self-reporting instrument. The Learner Report focuses on a student’s learning in two dimensions: first, about the outside world and about himself/herself, respectively. Second, distinguishing between universal facts (rules) and exceptions. This gives rise to four categories, in which students formulate so-called learning sentences of the form “I have learned that..”, see Table 1. The students filled the learner report out after the lesson where the ENGAGE material was used. On average, it took 20 minutes to complete the Learner Reports.

Data Analysis

For analysing the data, qualitative content analysis was performed by using Atlas.ti software. The learning statements were the units of analysis. First, we looked for sentences containing chemistry concepts related to the topic of the lesson. Then, we identified sentences mentioning a SSI about diesel cars, and classified sentences as referring to ‘society’, and ‘personal life’. Within these categories, we classified the content of the statements (e.g., distinguishing between societal aspects) using an inductive coding procedure. Testing and adapting the codes continued until the researchers reached consensus.
FINDINGS

Totally, 305 learning sentences were analyzed, and 16 codes were created and 167 sentences were coded. We coded 70 times ‘chemistry concept’, 87 times ‘society’, and 41 times ‘personal life’.

After the lesson with ‘Death to Diesel’ ENGAGE material, 51 of 53 students reported learning related to SSI, giving rise to 141 learning sentences containing SSI. In all of the 141 cases, the sentences contained connections to ‘diesel’ related chemical concepts such as combustion, mixture, nitrogen monoxide, nitrogen dioxide, etc.

Related to connecting SSI with chemistry concepts, society and personal life the results were presented below in Table 2. From the society related learning sentences, three groups appeared: ‘human health’, ‘environment’ and ‘human behaviour’. Personal life related learning sentences were grouped into two: ‘personal life-active’, and ‘personal life-passive’. Personal life-active refers to learning sentences where student has an active role as someone who influences the course of affairs.

Table 2. Classification of SSI sentences

<table>
<thead>
<tr>
<th>Society</th>
<th>f</th>
<th>Personal life</th>
<th>f</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human health</td>
<td>49</td>
<td>Personal life-active</td>
<td>38</td>
</tr>
<tr>
<td>Environment</td>
<td>32</td>
<td>Personal life-passive</td>
<td>4</td>
</tr>
<tr>
<td>Human behaviour</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total sentences</strong></td>
<td><strong>87</strong></td>
<td><strong>Total sentences</strong></td>
<td><strong>41</strong></td>
</tr>
</tbody>
</table>

Some examples of students’ sentences related to connecting chemistry concepts with society:

for ‘human health’:

“I have learned that using diesel can make your life 2 years shorter and you can get blood clots that can cause heart problems and lung complaints.” (Student 22, class2)

for ‘environment’

“I have learned that diesel is worse for your health and for the environment than gasoline.” (Student 7, class1)

for human ‘behavior’:

“I think that the best way to solve it is economically, since every normal person knows that diesel is ultra bad, but because it is so much cheaper, people use it anyway.” (Student 3, class2)

An example for a learning sentence of ‘Personal life-active’:

“(I have learned) that I pay attention to where I am going to live later i.e emissions in the air that can cause to decrease your life expectancy.” (Student 19, class2)

Consequently, with the ENGAGE SSI material most of the students learned chemistry concepts, applied these into society and their personal lives. The students’ learning sentences referred more on society than personal lives. Besides, among society related sentences,
expressions about ‘human health’ were noticeable. Additionally, it also came out that the students improved some skills while applying the chemistry concepts into their personal lives and society. For example, they improved the skills; ‘interrogate media’ (f=6) and making informed decisions (f=1). For example:

“I now know that advertisements are more like bad soaps, it would be much more fun to watch.” (Student 30, class 2)

“I now know that cars are not always as economical as the manufacturers claim.” (Student 24, class 2)

“I have learned how I can judge an advertisement” (Student 16, class 1)

“(I have learned that) I should check carefully the CO₂ emission of the cars before buying one.” (Student 16, class 2).

**CONCLUSIONS AND DISCUSSION**

The findings of this study showed that through specially designed *ENGAGE* material, students learned about the dilemma of ‘driving cheap versus environment friendly’. While studying this dilemma, they connected chemistry concepts to their personal life and society. We found more society related learning sentences than chemistry concepts. This may be because the material includes more connections to society and personal life and less chemistry content. The teachers used this type of material for the first time and taught a SSI lesson for the first time. As we know from the teachers that they did not adapt the material but used it in the original format, this may have lead them to focus more on society and personal life since this is the innovative aspect and the focus of the material. Moreover, it might also show that the students are more enthusiastic to talk and write about society and their personal life than chemistry concepts.

In society related learning sentences, there was more emphasis in ‘human health’. Many students stated sentences about the damage that emission from diesel car generates. Apparently, the case in the material ‘Death to Diesel’ which is the news from the Daily Post where a mother talks about her sick son, influenced the students and motivated them to think about the damages that diesel may cause.

This study also introduced the opportunities and challenges for teaching SSI in science lessons. As the teachers mentioned to us, the students liked this different type of science lesson. They enjoyed discussing, group works, thinking about themselves, their environment and society. From our talk with the teachers we learned that the lesson was very engaging even for the less active students. Therefore, there is an opportunity to engage students more in science lessons with these type of SSI materials. On the other hand, it is difficult for teachers to make their own materials, especially when they have less experience and time. Not only this study but also our previous studies (Bayram-Jacobs & Henze, 2016; Okada & Bayram-Jacobs, 2016) showed the need of teachers for this type of materials. To scaffold their students SSI learning, teachers need complete curriculum materials.

Furthermore, we suggest that teaching with the *ENGAGE* materials fosters students’ learning related to SSI. However, there are other factors such as ‘teacher’ and ‘context’, which were not in the scope of this study, should be considered, too. Since all the *ENGAGE* materials have the
same structure and were designed with the same principles, there are benefits of using other ENGAGE materials.

Finally, in this study we repeat the question we raised in our previous study (Okada & Bayram-Jacobs, 2016) “How to ensure the sustainability of these resources and opportunities for teachers?” and this study raises a new question “How to make it easy for teachers to design their own materials?”

ACKNOWLEDGEMENT

In this research, the materials, which are developed by the “ENGAGE” project, were used. The project has received funding from the European Community’s Seventh Framework Programme FP7/2007-2013 under grant agreement No [612269].

REFERENCES


INVESTIGATING THE RELATIONSHIP BETWEEN CONTENT KNOWLEDGE AND THE CONSTRUCTION OF ETHICAL ARGUMENTS ON SOCIO-SCIENTIFIC ISSUES

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This study investigated the relationship between university students’ content knowledge and the construction of ethical arguments on socio-scientific issues (SSIs). Particularly, we investigated whether university students’ content knowledge about value-laden, controversial SSIs, predict the number and the quality of ethical arguments that they construct. We focus particularly on this possible relationship because we hypothesized that the content knowledge could promote the ability of students to recognize when a situation, such as SSI, contains a moral aspect and be aware of how possible resolutions of the situation have the potential to affect others in a negative manner and construct relevant ethical arguments. 240 university students were asked to construct different types of supportive arguments – social, ethical, economic, scientific and others, – as well as counterarguments and rebuttals after they had read a scenario on a value-laden SSI. Participants’ content knowledge was assessed separately. Results show that university students' content knowledge predict students’ number and quality of ethical arguments that they construct on value-laden SSIs, but differences in the predictability of the content knowledge about SSIs were found. That indicates context dependence. Additional research is needed that can robustly describe the relationship between content knowledge and ethical arguments on value-laden SSIs. We discuss the significance and the educational implications of these findings.

Keywords: content knowledge, ethical arguments, socio-scientific issues.

INTRODUCTION

A long standing goal of science education reform is to promote scientific literacy for all. For many contemporary science educators, scientific literacy must entail the ability to negotiate and make decisions regarding complex, social issues with theoretical and/or conceptual links to science. These issues have been termed ‘socio-scientific issues’ (SSIs). They are usually controversial in nature but have the added element of requiring a degree of moral reasoning or the evaluation of ethical concerns in the process of arriving at decisions regarding possible resolution of those issues (Sadler & Zeidler, 2004). They are associated with morality, and moral considerations are central to their negotiation and resolution (Aikenhead, 2006; Driver, Newton & Osborne, 2000; Kolsø, 2001a; 2001b; Roberts, 2007; Zeidler & Keefer, 2003; Zeidler & Nichols, 2009; Zeidler, Sadler, et.al., 2005). Some authors have suggested that moral considerations necessarily contribute to argumentation in the context of SSIs, and several studies have revealed decision-makers’ tendencies to actually construe SSIs as moral problems (Sadler & Donnelly, 2006; Sadler & Zeidler, 2004). Additionally, Sadler and Zeidler (2004) argue that an individual in order to make informed decisions regarding SSIs, s/he needs to have considered the moral ramifications of those decisions. Conclusions drawn in ignorance of the moral and ethical dimensions of SSIs fetter the efficacy of those conclusions.
Given the significant role played by socio-scientific issues in science education, it is important to understand how learners perceive, negotiate, and resolve these issues. For example, Science educators have become interested in examining several factors, such as epistemic beliefs – which refer to individuals’ beliefs about the nature of knowledge and the process of knowing –, content knowledge, values, desires and expectations, as potential contributors to the negotiation of SSIs (Sadler & Donnelly 2006).

We extend this line of research related to SSIs and content knowledge by investigating the possible relationship between scientific content knowledge and the construction of ethical arguments on value-laden socio-scientific issues. We focus particularly on this possible relationship because we hypothesized that the content knowledge can promote the ability of students to recognize when a situation, such as SSI, contains a moral aspect and be aware of how possible resolutions of the situation have the potential to affect others in a negative manner and construct relevant ethical arguments (Fowler et al., 2009). Additionally, to our knowledge, this issue has not yet been investigated. By doing this, we hoped to understand better the role of content knowledge for the negotiation of value-laden SSIs, and explore ways to prepare future citizens to deal with such SSI-dilemmas.

Particularly, we set out to answer the following research questions: (1) Is there a relationship between university students’ content knowledge and the number of ethical arguments that they construct on a value-laden socio-scientific issue? (2) Is there a relationship between university students’ content knowledge and the quality of ethical arguments that they construct on a value-laden socio-scientific issue?

Content knowledge and ethical arguments on socio-scientific issues

According to Novak & Gowin (1984), a well-structured knowledge can sustain higher levels of reasoning than poorly structured knowledge. Additionally, Toulmin (1972) states that argumentation is involved with reasoning and critical thinking and is the mechanism for creating and using knowledge. On the other hand, discussions of SSIs in the science education literature are accompanied by the assumption that individuals’ content knowledge contributes significantly to their reasoning and argumentation in the context of SSIs (Sadler & Fowler, 2006; Sadler & Zeidler, 2005). However, there is some disagreement among the researchers regarding the kind of the relation between content knowledge and argumentation on SSIs.

Generally, discussions of content knowledge and SSIs in the science education literature are frequently accompanied by the assumption that an individual’s content knowledge contributes significantly to his/her reasoning and argumentation in the context of SSIs. On the other hand, there are evidence showing that conceptual understanding of an issue does not determine the quality of thinking skills used for this issue (Kuhn, 1991). For example, some researchers found relations between university students’ content knowledge and the number and quality of arguments for the negotiation and resolution of SSIs (Baytelman, Iordanou, & Constantinou, 2016). In contrast, Means and Voss (1996) argued that content knowledge did account for a greater number of responses, but these quantitative differences did not necessary lead to higher quality of informal reasoning and argumentation.
Furthermore, the possible relationship between content knowledge and the construction of ethical arguments on value-laden SSIs has not yet been investigated, according to our knowledge. The number and the quality of ethical arguments, constructed during negotiation of value-laden SSIs, could be employed as indicator for moral sensitivity, according to the Four Component Model, developed by Rest and his colleagues (Rest et al., 1986). In particular, according to Fowler, Zeidler and Sadler (2009), the Four Component Model, provides a useful framework for exploring morality. Rest and his colleagues at the Centre for the Study of Ethical Development developed an extensive research programme related to moral development. Their design and validation of the Defining Issues Test (DIT) (Rest et al., 1974) revolutionized the study of moral reasoning. Based on findings that suggested that moral reasoning underdetermined moral behavior, Rest developed the Four Component Model. This model proposes four psychological processes that contribute to moral behavior.

The four components which define Rest’s model are described below (Fowler, Zeidler & Sadler, 2009):

1. Moral sensitivity: Moral sensitivity is the ability to recognize when a situation contains a moral aspect. When confronted with a situation, such as SSI, a person with moral sensitivity is aware of how possible resolutions of the situation have the potential to affect others in a negative manner. Thus, a person with moral sensitivity is attuned to the feelings and reactions of others. He or she is cognizant of alternate courses of action and is able to anticipate consequences of each. He or she is able to examine aspects of a situation and the importance of each to that particular situation.

2. Moral reason: Moral reason is the analysis that is used to determine which course of action is morally desirable in a given situation and the ability to defend that position through the use of critical thinking skills. It requires the identification of courses of action and the ability to provide justification for them.

3. Moral commitment: Recognition of a moral situation and analysis through moral reasoning do not guarantee that a moral course of action will occur. Knowing the right thing to do and actually doing it is not the same thing. Thus, priority to moral concerns is the third component of moral development. This first requires that a person recognize that personal concerns are not always compatible with the moral course of action followed by a willingness to choose what he or she has deemed the most moral course of action.

4. Moral courage: Closely linked to priority to moral commitment is moral courage, the fourth component. A person may recognize a moral situation, reason a moral course of action and be willing to follow the moral course of action, but at times, a person may encounter pressure from others not to do so. Though willing to follow a moral course of action (i.e. having moral commitment), a person also needs moral courage in order to do follow through.

According to the Four Component Model, moral sensitivity, that means the ability to recognize moral aspects of SSIs, is necessary but not sufficient condition for moral reasoning and moral behavior. However, we focus on this possible relationship because we hypothesized that the content knowledge could promote the ability of students to recognize when a situation, such as
SSI, contains a moral aspect and be aware of how possible resolutions of the situation have the potential to affect others in a negative manner and construct relevant ethical arguments.

In the present study, content knowledge is defined as prior domain-specific conceptual content knowledge and includes the knowledge of concepts, principles, facts and theories of a subject, but also an understanding of how concepts and principles of a subject are organized (Shulman, 1986; Kleckmann et al., 2012). The more connections that exist among facts, ideas, and procedures, the better the understanding (Hiebert & Carpenter, 1992; Hiebert & Lefevre, 1986). Additionally, according to Novak (1998) concept maps can provide evidence for a meaningful distinction of meaningful and rote learning or deep and surface understanding. Ethical arguments are all ethical-oriented socio-scientific arguments based on deontology and human and animals rights. Deontological principles such as beneficence and justice impose duties, on moral agents, that can guide their decision-making and behaviors (Sadler & Zeidler, 2004).

**METHOD**

**Participants**

Participants were 240 undergraduate university students at a public University in South Europe. Students were between the second and the fourth year of their study. All participants were elementary or early childhood education majors and were enrolled in a required science education course, within this experiment was administered. The participants were Caucasian native speakers and shared a homogeneous middle class social background. All the participants had at least 12 years of schooling before starting their university studies. With very few exceptions, all the participants had completed their secondary education in public schools.

**Data Collection**

Three different SSI-dilemmas were developed and used in the present study (a) safety and usage or not usage of vaccines, (b) consumption of bottled vs. tap water, (c) usage of underground vs. overhead high voltage lines. Our rationale for the choice of these SSI-dilemmas is the following: (a) The three different SSIs are value-laden and have different scientific, political, ethical, social and economic aspects, (b) The last decade, SSIs such as safety and usage of vaccines, high voltage lines and consumption of bottled vs. tap water have attracted increasing attention in the country of this study, therefore students might be more motivated to engage in thinking about these topics; (c) The participants of this study had already learned about vaccines, drinking water and high voltage lines in their science classes at the secondary school and they had content knowledge regarding these issues.

The content knowledge was assessed in two different levels. The first level was assessed by open-ended questions which assessed separated basic scientific concepts related to each SSI. The second level was assessed by a concept map with appropriate relationships between the relevant scientific concepts related to each SSI. In particular, to assess students’ content knowledge, students were asked to answer five open-ended questions and to construct a concept map for each SSI. For the development and validation of questionnaires, we followed four steps (a) Review of literature for the development of preliminary item pool; (b) Interviews with experts for the validation and optimization of items; (c) Pilot studies for the internal
consistency and item analysis; (d) Preliminary data analyses. The open-ended questions were scored 0-2, on the basis of their correctness and completeness, by the first author and an independent judge. For the creation of each concept map, the students were asked to use a list of ten concepts, which were provided to them, relevant to each SSI of this study, describing the appropriate relationships between the relevant concepts. We decided to use a list of ten basic concepts for each SSI, because in this way all participants had available some relevant background knowledge that they could use them if they wished. For each student’s concept map, we counted the number of appropriate concepts and the number and quality of appropriate relationships between concepts (propositions). Propositions were scored using a four-point scale (0-3).

Students’ ethical arguments were assessed using a written instrument (Baytelman & Constantinou, 2014; Baytelman, 2015). In particular, for each SSI-dilemma, students were asked to take a position and justify it by formulating supportive arguments, counterarguments and rebuttals, using different types of arguments, such as social, ethical, economic, scientific, according to their opinion. For each participant, we computed the total number and quality of valid ethical supportive arguments, ethical counterarguments and ethical rebuttals constructed. Ethical arguments are all ethical-oriented arguments based on deontology and human rights. In particular, in this study, students had to list their different types of arguments and not to write one coherent text weighing and synthesizing strategies (argument–counterargument integration, see Nussbaum et al., 2008), because we are interested in the construction of different types of arguments and not argumentation per se. The quality of ethical arguments was determined based on the scoring scheme of Sadler & Fowler (2006), using a four-point scale (0-3).

**Procedure**

Each participant participated in 2 sessions. In the first session, the content knowledge measures were administered. The first session lasted 40 min. In the second session, the SSI-scenarios, and the questionnaire for the investigation of ethical arguments on SSIs were administrated. Students were given unlimited time to carry out the second session’ tasks. The first author did the data collection.

**RESULTS**

To answer the two research questions of this study “Is there a relationship between university students’ content knowledge and the number of ethical arguments that they construct on a value-laden socio-scientific issue?” and “Is there a relationship between university students’ content knowledge and the quality of ethical arguments that they construct on a value-laden socio-scientific issue?”, multiple regression analyses were carried with the number and the quality of ethical arguments, counterarguments and rebuttals for each SSI constructed as dependent variables. Predictors of each of these equations were the results of the five open-ended questions and the concept map of the content knowledge measures.

The results of the multiple regression analyses for variables predicting scores on number and quality of ethical arguments on each SSI are shown in Tables 1 and 2. The six content
knowledge predictors together (five open-ended questions and one concept map) explained a significant amount 49.4% of the total number of ethical arguments regarding SSI1, (F(6,234)=12.02, p<.01, R²=.494), and 26% of the quality of ethical arguments on SSI1, (F(6,234)=4.32, p<.01, R²=.259). The six content knowledge predictors together (five open-ended questions and one concept map) explained a significant amount 20% of the total number of ethical arguments regarding SSI2, (F(6,234)=3.07, p<.01, R²=.20) and 25% of the quality of ethical arguments on SSI2, (F(6,234)=4.13, p<.01, R²=.251). No predictability about SSI3 was found.

Table 1. Results of multiple regression analysis for students’ content knowledge about SSIs variables predicting students’ number of ethical arguments on SSIs.

<table>
<thead>
<tr>
<th>Predictors</th>
<th>B</th>
<th>β</th>
<th>Sig.</th>
<th>B</th>
<th>β</th>
<th>Sig.</th>
<th>B</th>
<th>β</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question 1</td>
<td>.118</td>
<td>.033</td>
<td>.708</td>
<td>-.148</td>
<td>-.075</td>
<td>.523</td>
<td>-.334</td>
<td>-.124</td>
<td>.399</td>
</tr>
<tr>
<td>Question 3</td>
<td>-.451</td>
<td>-.129</td>
<td>.157</td>
<td>-.730</td>
<td>-.270</td>
<td>.029</td>
<td>.477</td>
<td>.154</td>
<td>.211</td>
</tr>
<tr>
<td>Question 4</td>
<td>.514</td>
<td>.165</td>
<td>.106</td>
<td>.373</td>
<td>.154</td>
<td>.197</td>
<td>.256</td>
<td>.084</td>
<td>.546</td>
</tr>
<tr>
<td>Question 5</td>
<td>-.669</td>
<td>-.186</td>
<td>.057</td>
<td>.794</td>
<td>.356</td>
<td>.002</td>
<td>-.227</td>
<td>-.067</td>
<td>.613</td>
</tr>
<tr>
<td>Concept-map</td>
<td>.131</td>
<td>.528</td>
<td>.000</td>
<td>.002</td>
<td>.008</td>
<td>.001</td>
<td>.054</td>
<td>.211</td>
<td>.069</td>
</tr>
</tbody>
</table>

**p≤.01, *p≤.05

Table 2. Results of multiple regression analysis for students’ content knowledge about SSIs variables predicting students’ quality of ethical arguments on SSIs.

<table>
<thead>
<tr>
<th>Predictors</th>
<th>B</th>
<th>β</th>
<th>Sig.</th>
<th>B</th>
<th>β</th>
<th>Sig.</th>
<th>B</th>
<th>β</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question 1</td>
<td>.244</td>
<td>.029</td>
<td>.788</td>
<td>-.144</td>
<td>-.063</td>
<td>.766</td>
<td>-.648</td>
<td>-.098</td>
<td>.499</td>
</tr>
<tr>
<td>Question 2</td>
<td>-.002</td>
<td>.000</td>
<td>.998</td>
<td>.589</td>
<td>.185</td>
<td>.492</td>
<td>.859</td>
<td>.131</td>
<td>.313</td>
</tr>
<tr>
<td>Question 3</td>
<td>.801</td>
<td>.105</td>
<td>.344</td>
<td>-.248</td>
<td>-.826</td>
<td>.000</td>
<td>.672</td>
<td>.090</td>
<td>.453</td>
</tr>
<tr>
<td>Question 4</td>
<td>3.001</td>
<td>.418</td>
<td>.001</td>
<td>1.130</td>
<td>.416</td>
<td>.092</td>
<td>1.477</td>
<td>.270</td>
<td>.122</td>
</tr>
<tr>
<td>Question 5</td>
<td>-.430</td>
<td>-.300</td>
<td>.020</td>
<td>1.247</td>
<td>.469</td>
<td>.030</td>
<td>-1.939</td>
<td>-.236</td>
<td>.069</td>
</tr>
<tr>
<td>Concept-map</td>
<td>.081</td>
<td>.151</td>
<td>.008</td>
<td>.029</td>
<td>.048</td>
<td>.447</td>
<td>.147</td>
<td>.251</td>
<td>.059</td>
</tr>
</tbody>
</table>

**p≤.01, *p≤.05

The dominant forms of ethical arguments that university students in the present study employed were ethical arguments based on principles such as principles of justice, meaningful participation, sanctity of human life, health and human rights.
CONCLUSION

The findings of this study suggest that relationships between content knowledge about SSIs of university students and the construction of ethical arguments regarding value-laden SSI-dilemmas vary with context. So, science content knowledge is a necessary but not sufficient condition for construction of ethical arguments on SSIs (indicators for moral sensitivity) as well as for negotiation of SSIs. Fowler and Amiri (2004) also concluded that science content knowledge alone did not increase moral sensitivity. That means that more factors play a role.

However, our findings show that the content knowledge could promote the ability of students to recognize when a situation, such as SSI, contains a moral aspect and be aware of how possible resolutions of the situation have the potential to affect others in a negative manner and construct relevant ethical arguments. Additionally, our findings show that this is dependent on the scenario given to students. According to the Four Component Model, developed by Rest (Rest et al., 1986), this ability is an indicator for moral sensitivity, which is the first of the four components which contribute to moral decisions and behavior. Possible relationships between science content knowledge and moral sensitivity and context dependence were also found by Sadler (2004).

According to others authors, in addition to science content knowledge, a series of other factors emerge as important dimensions of socio-scientific decision-making. These factors include emotions, personal experiences, family biases, the impact of popular culture (Fowler, Zeidler & Sadler, 2009; Sadler & Zeidler, 2004; 2005; Sadler, 2004) and epistemic beliefs (Baytelman, 2015; Baytelman, Iordanou, & Constantinou, 2016). The interaction between content knowledge and all above factors remains an open area for future research on SSIs. Furthermore, for the relationship between content knowledge and ethical arguments on SSIs, additional research is needed that can robustly describe this relationship.

REFERENCES


BIODIVERSITY EDUCATION: THE IMPORTANCE OF KNOWLEDGE ON CONCEPTS

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Brazil is a country with mega biodiversity and higher levels of destruction of forests. The preservation of biodiversity depends on education. The objective of this study is to discuss the importance of knowledge of three hierarchical levels about biodiversity. I analyzed four studies (from my coordination) about biodiversity education. I identified the hierarchical levels present on objectives, results and conclusion in these studies. I concluded that the species’ level and ecosystem’s level are more frequently. The biodiversity is a complex concept and very important to understand the preservation. The students need to understand the hierarchical levels to improve awareness about preservation, conservation and recuperation of biodiversity.

Keywords: biodiversity education, preservation, hierarchical levels of biodiversity

INTRODUCTION

Brazil is a mega biodiversity country. This biodiversity is part of our culture and is objective of many researches. Brazil has the largest number of species of plants, amphibian and primates. It is the second country with the highest number of species of mammal and reptiles. About 20% of the planet’s total biodiversity is in Brazil (Brasil, 2016).

Nevertheless, there is a paradoxical situation: “while on one side biodiversity science in Brazil is clearly improving in quality and quantity, on the other side environmental degradation is reaching alarmingly high rates throughout the country” (Scarano, 2007, p. 440).

The education, and more specifically the scientific education, is a way to change this reality. However, the biodiversity is a complex concept to science and it is very difficult to teach this concept at school.

The increase of discussions on environmental issues at school creates an environmental awareness that contributes to reinforce the idea that it is necessary to teach to preserve the environment and at the same time to teach to understand scientific knowledge and its relations with society (Motokane et al., 2010). Issues involving biodiversity are the most important, and the students have many doubts about preservation (Motokane et al., 2010).

Science education is important for the general formation of a citizen capable of discussing and making decisions on environmental issues. The list of scientific papers published in Brazil and in the world is immense. Among these authors, Manzanal & Jiménez (1995) focus on the teaching of ecology concepts as a means of educating to preserve. In addition, since the 1970s, Brazilian educational documents have pointed to the need to include environmental issues in school curricula.

When we think about the teaching of science and biology and concepts pertinent to ecology, questions arise such as: What concepts are fundamental to teach? How should the organization of the curriculum be so that we can promote the education of people capable of exercising their citizenship? What are the most appropriate teaching materials?
Motokane (2000) and Grace & Ratcliffe (2002) have found similar results in investigating the concepts that biology and science teachers focus on when teaching ecology. The main are: ecosystem, food web, food chain, population and habitats. When teachers teach these concepts, they think that this concepts supported students to discuss biological conservation. According to Grace & Ratcliffe (2002), concepts derived from genetics, which are fundamental to the understanding of conservation problems, genetic concepts are not taught by teachers. The belief that learning basic concepts can lead to the construction of more complex concepts or even more elaborate analyzes of everyday problems is very frequent among teachers.

The learning of contents belong to different areas of the natural sciences is important because the student can understand complex phenomena present in their daily life. Biodiversity is a subject that raises a number of issues, such: What is the value of biodiversity? What happens when a population disappears? How to measure biodiversity? The wide range of meanings given to the term, coupled with the great controversy caused by conservation policies, make biodiversity a profitable topic for teaching science and biology.

According to Grace & Ratcliffe (2002), biodiversity conservation is precondition for sustainable development, and their understanding is essential for the sustainable exploitation of natural resources. The authors claim that learning something about biodiversity is learning about political and economic aspects linked with preservation and conservation.

Weelie & Wals (2002) present three perspectives on education for biodiversity. According to the authors, biodiversity provides an educational perspective that assists the understanding of nature and of itself. From this perspective, the basic idea is to promote situations that seek to make people realize the meaning of biodiversity for their lives. The key words from this perspective are pleasure, curiosity, appreciation, contemplation and care.

The second perspective presented by the authors is that of ecological literacy, which seeks to understand the intricate relationships that exist between different species and ecosystems and discuss the position of man within these ecosystems.

In the third perspective presented by Weelie & Wals (2002) it is the politics of nature. This perspective seeks to increase the equitable distribution of natural resources and promote an understanding of international policy, what treatments are given to resources, and what impacts their exploitation can bring to the environment and to the economy. The key ideas are: sustainable development, respect for pluralism, exploitation, responsibility, democratic decisions.

Weelie & Wals (2002) proposed the term ill-defined to biodiversity. “An ill-defined concept cannot be captured by single or universally applicable definitions, can be interpreted in many ways and is hard to define operational even in a specific application domain” (WEELIE & WALS, 2002, p1143). For them, biodiversity is an ill-defined because is not possible describing or interpreting the concept in a way that fits all contexts.

According to some authors (Lévêque, 1999; Almeida & El-Hani, 2006; Scarano, 2007), in biological science, the concept of biodiversity depends on the methodology of researches and the choice of organization level.
The word "BioDiversity" (BioDiversity) was created by Walter G. Rosen and Edward O. Wilson during the organization of the National Forum on BioDiversity, (September 21-24, 1986) in Washington and hosted by the National Academy of Scientists and the Smithsonian Institution. The summaries of the forum, signed by researchers from different areas, were published in 1988 in the book "BioDiversity".

The Biodiversity became popular in World Conference on Biological Diversity, in Rio de Janeiro (1992), called ECO-92. After this event, Biodiversity acquired many meanings and the school became a place to discuss the preservation, conservation e recuperation of biodiversity. During the event, was written the document called “Convention on Biological Diversity” (CBD), also known as the "Convention on Biodiversity". In Article 2, entitled "Use of Terms", it defines:

“Biological Diversity means the variability of living organisms of all origins, including, but not limited to, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they form part; including diversity within species, between species and ecosystems.” (Brazil, 2002.)

Wilson (1997) published, in the introductory chapter of the book "Biodiversity II: understanding and protecting our biological resources", the definition of biodiversity:

“...any variation at all levels of organization, from genes within a single local population or species, to species that make up part of a local community, and finally to the very communities that make up the living part of the multifactorial ecosystems of the world. The key to biodiversity analysis is the precise definition of what level of organization one is interested in...” (Wilson, 1997. p 2)

As has been described in Lévêque (1999), the concept of biodiversity has three different levels (species diversity, genetic diversity and ecosystem diversity), but these levels are linked and they are not independent:

“Biodiversity is not a simple catalog of genes, species or environments. It have been understood as a dynamic and interactive set between different hierarchical levels. According to current theories of evolution, it is because of the existence of genetic diversity in the species that the living beings can adapt to changes of environment. Reciprocally, the genetic diversity evolves because of mutations during the time and in response to changes in the environment. The same occur with plants and animals, which constitute ecosystems and which respond to fluctuations of the environment (...). This dynamic explains that species evolve and the environments change”. (Lévêque, 1999, p. 18-19)

In this study, the question is: what is the importance of knowledge the hierarchical levels of biodiversity? The objective of this study is to discuss the importance of knowledge of three hierarchical levels about biodiversity to improve awareness about preservation, conservation and recuperation of biodiversity. This study is a synthesis of other studies from my research group.
**METHOD**

In our research group, we elaborate inquiry didactic sequences (Motokane, 2015) that explore the different hierarchical levels of biodiversity. We try to development activities to promote scientific literacy using argumentation. In this study, I analyzed four researches (from my coordination). The researches study the learning and teaching of biodiversity in biology classes.

I choose four studies made by my research group about discourse in science education. All studies were done in public schools. The students were different ages (12 to 16 years old). The schools are from two cities (Ribeirão Preto and Dumont), both in São Paulo State. I identified the hierarchical levels (species, genetic and ecosystem diversity) present on objectives, results and conclusion in these studies. The data of the studies are from interviews, written texts and observation of biology classes or outdoors activities. The studies are from Grandi & Motokane (2014); Grandi et. al. (2014), Moraes (2016) and Castro & Motokane (2017).

**FINDINGS**

Now, I present the results obtained from the analysis of the studies.

1) Castro, R.G., & Motokane, M. T. (2017a). After application of inquiry didactic sequence (IDS), the students produced written texts with three levels. When we analyzed the students’ speeches, we obtained the following results: 93% talk about the species level, 69% talk about the genetic level and 48% talk about the ecosystem level. There is a high classification in texts with species diversity and genetic diversity. These finds are possible because the activities in inquiry didactic sequence promoted the genetic discourse. Genetic level is not so easy to do, because involve many genetic concepts. These concepts are more abstract, but with this inquiry didactic sequence, the students could to talk about them.

2) Moraes, T.A. (2016). The students use different levels (Table 1) when the activities allow the production of texts in different textual genders (Moraes, 2016). The textual genders are texts with socio communicative characteristics as contents, functions properties, style and composition (Marcuschi, 2007). That is important to emphasize that some textual genders do not present levels of biodiversity. This fact is because of “scientific reports” present only descriptions about the experiment. The students do not use this type of textual gender to develop their ideas about biodiversity.

Table 1. Percentage of text that present one or more hierarchical levels of biodiversity by different textual genders. (Moraes, 2016)

<table>
<thead>
<tr>
<th></th>
<th>STANDPOINT ARTICLE</th>
<th>SCIENTIFIC REPORT</th>
<th>SCHOOL EXERCISE</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 LEVELS BD</td>
<td>8%</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2 LEVELS BD</td>
<td>25%</td>
<td>71%</td>
<td>40%</td>
</tr>
<tr>
<td>1 LEVEL BD</td>
<td>17%</td>
<td>29%</td>
<td>20%</td>
</tr>
<tr>
<td>WITHOUT BD</td>
<td>33%</td>
<td>0</td>
<td>20%</td>
</tr>
<tr>
<td>WRONG CONCEPT</td>
<td>17%</td>
<td>0</td>
<td>20%</td>
</tr>
</tbody>
</table>
3) Grandi, L. A. et. al. (2014). In this study, we analyzed the conceptions from teachers about biodiversity. We analyzed the discourse during outdoors activities in a forest. The teachers express ideas about species and ecosystem level, but do not mention genetic diversity. Species and ecosystem levels were common because the activity was about the plants composition of the forest.

4) Grandi, L. A. & Motokane, M. T. (2014). A study about the discourse in science classes, the students written about only species diversity. The authors analyzed 21 written texts. In this case, the texts are produced after outdoor activities. They written about the activities and they described what they did. When they mentioned something about biodiversity, the specie level is mentioned, but others levels no. This study is complementary of the last one.

In Table 2, I present the main results concerning the different hierarchical levels present in different studies. It is important emphasize that there are different quantities in each study. In Table 3, I present what levels are present in each study analyzed.

**Table 2. Quantity of levels in each study analysed**

<table>
<thead>
<tr>
<th>STUDY</th>
<th>QUANTITY OF HIERARCHICAL LEVELS</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>PRESENT 3 LEVELS. HOWEVER IN DIFFERENT PROPORTIONS: SPECIES &gt; GENETIC &gt; ECOSYSTEM</td>
</tr>
<tr>
<td>02</td>
<td>PRESENT 3 LEVELS ONE TYPE OF TEXTUAL GENDER.</td>
</tr>
<tr>
<td>03</td>
<td>PRESENT 2 LEVELS: SPECIES AND ECOSYSTEM</td>
</tr>
<tr>
<td>04</td>
<td>PRESENT 1 LEVEL: SPECIES</td>
</tr>
</tbody>
</table>

**Table 3. Hierarchical levels present in each study analysed. (P – PRESENT ; A – ABSENT)**

<table>
<thead>
<tr>
<th>STUDY</th>
<th>SPECIES</th>
<th>GENETIC</th>
<th>ECOSYSTEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>P</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>02</td>
<td>P</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>03</td>
<td>P</td>
<td>A</td>
<td>P</td>
</tr>
<tr>
<td>04</td>
<td>P</td>
<td>A</td>
<td>A</td>
</tr>
</tbody>
</table>

**DISCUSSION AND CONCLUSIONS**

The concept of biodiversity is very complex in biological science. The teachers have teach this important concept in biology and science classes. This is fundamental because the comprehension of this concept supports why the preservation, conservation and recuperation of biodiversity is important.

At basic education, the species diversity is the most common hierarchical level. Most activities have the objective to observe or to compare different individuals. The variability of external or internal characteristics are the focus of activities. The main skill for these activities is descriptions. The students are stimulated to do descriptions, but they are not stimulated to do
argumentative texts or to write about evolutionary aspects. Although the activities promote the argumentation, in classes or outdoor activities, this opportunities are not explored.

The ecosystem diversity level is the second common level. The activities present in this inquiry didactic sequences show images or description about ecosystems, biomes and landscapes. The activities can be descriptions about abiotic factors or comparisons between places. However, this level is presented without relations with other levels.

These levels (species diversity and ecosystem diversity) are more factual or concrete and these characteristics contribute to learn the levels. However, others skills like an argumentative text are not produced.

The genetic diversity is less frequently in biology or science classes. Although the didactic materials allow the comprehension about the three levels. This hierarchical level is more abstract and it uses concepts and contents from genetic, biochemistry and molecular biology. In Brazilian studies about difficult to understand genetics concepts, the authors (Dentillo, 2009; Pereira, Campos & Bonetti, 2010; Rosa & Silva, 2010; Klatau, Pedreira & Oliveira, 2014) indicated the lack of contextualization with the student’s quotidian, a lot of contents, the misunderstanding of terms and concepts about genetics and the lack of relation between contents of genetics and cell division.

The three levels are possible when the didactic material allow the production of different textual genders.

I concluded that the knowledge about hierarchical level of biodiversity is important to students. It is a very important when students recognize that biodiversity is a complex concept and the relation between hierarchical levels. This recognition are fundamental to students understand the importance of preservation, conservation and recuperation of Brazilian biodiversity.

ACKNOWLEDGEMENT

This study was funded by Pró-Reitoria de Pós-Graduação from University of São Paulo, FAPESP (Fundação de Amparo à Pesquisa do Estado de São Paulo). I thank Programa de Pós Graduação em Biologia Comparada da FFCLRP/USP and Programa Interunidades de Pós Graduação em Ensino de Ciências. Finally, I thank students and teachers from “Escola Municipal de Ensino Fundamental Arlinda Rosa Negri” to work together. The students of this school are the reason for this research!

REFERENCES


ASESSMENT OF SCIENTIFIC LITERACY THROUGH SOCIOSCIENTIFIC ISSUES WITH SECONDARY SCHOOL SCIENCE STUDENTS: A PILOT STUDY

Ruth Chadwick, Eilish McLoughlin and Odilla E. Finlayson
CASTeL, Dublin City University, Dublin, Ireland

Inquiry in the context of socioscientific issues (SSI) is said to develop the skills and knowledge of scientific literacy. SSI are contemporary and relevant scientific topics with moral or economic implications (Sadler 2009). In the Scottish Curriculum for Excellence students carry out inquiry in the context of SSI, the National 5 Assignment, as part of their senior phase science education (SQA 2016). This research is a pilot study that explores the student and teacher experience of the National 5 Assignment. Six biology teachers participated in the case study and provided documentation relating to 150 of their students. The methods of data collection and analysis were qualitative and included teacher questionnaires, teacher interviews and secondary document analysis relating to the teacher and the student experience. The findings indicate that the student experience is described in similar terms between the students and teachers. The focus was mainly on the skills and knowledge developed and assessed, and the process of inquiry, with less focus on the Assignment as an assessment. The teachers also discussed their teaching approach to the Assignment in terms of balancing facilitating and direct teaching. The findings from this study will be used to inform the methodological design of a wider study. This wider study will include teachers and students of biology, chemistry and physics and will compare their experience of the Assignment in the different subjects.

Keywords: socioscientific issues, scientific literacy, science education

INTRODUCTION

In the Scottish Curriculum for Excellence (CfE) students carry out an in inquiry in the context of socioscientific issues (SSI) as part of their senior phase science education (SQA 2016). SSI are social issues with conceptual and procedural connections to science that can be used as the contexts for learning (Sadler 2009). SSI centre around a range of scientific, social or moral viewpoints, which may conflict with the students’ own views. This makes them personally relevant to the students (Levinson 2006, Zeidler et. al. 2009). Scientific literacy can be described in terms of the skills and knowledge of science and student engagement in inquiry exploring SSI contexts is said to these skills and knowledge (OECD 2013, Sadler 2009, Zeidler & Nichols 2009).

CfE is a curriculum for learners aged 3-18 which aims to develop “scientifically literate citizens with a lifelong interest in the sciences” (Education Scotland 2010 p253) and describes scientific literacy as:

- Developing informed social, moral and ethical views of scientific, economic and environmental issues
- Developing self-awareness through reflecting on the impact, significance and cultural importance of science and its applications to society
• Being able to **read and understand** essential points from sources of information including **media reports**

• **Discussing** and **debating** scientific ideas and issues

• **Reflecting critically** on information included or omitted from sources/reports including consideration of limitations of data (Education Scotland 2010)

Assessment in CfE aims to support learning, help plan next steps, inform learners and their parents, summarise achievements, monitor the education system and inform future developments (The Scottish Government 2011). Assessment in CfE is not limited to traditional, written exams. For example, the National 5 Assignment is a novel form of assessment, in which students carry out an inquiry in the context of SSI. The National 5 Assignment aims to assess a range of skills and knowledge (Table 1). Students apply their knowledge of biology, chemistry or physics to new situations and interpret information. They select, process and present information and data in a variety of forms, communicate their findings and draw valid conclusions with explanations supported by evidence (SQA 2016 p2).

Table 1: Assessment criteria for the National 5 Assignment in science

<table>
<thead>
<tr>
<th>Assessment criteria</th>
<th>Mark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Devise an appropriate aim for the investigation</td>
<td>1</td>
</tr>
<tr>
<td>Describe an application of biology and its effect on the environment/society</td>
<td>2</td>
</tr>
<tr>
<td>Select relevant sources</td>
<td>2</td>
</tr>
<tr>
<td>Select relevant information from sources</td>
<td>2</td>
</tr>
<tr>
<td>Process and present data/information</td>
<td>6</td>
</tr>
<tr>
<td>Draw a valid conclusion</td>
<td>1</td>
</tr>
<tr>
<td>Apply knowledge and understanding of biology</td>
<td>3</td>
</tr>
<tr>
<td>Structure of the report</td>
<td>3</td>
</tr>
</tbody>
</table>

(SQA 2016 pp8-19)

The number of marks available for each skill or knowledge assessed gives an indication of its emphasis or importance in the assessment. Of the 20 marks available, 14 are for demonstrating skills and six are for knowledge and understanding, although the SQA does not make it clear which of the above assessment criteria are skills and which are knowledge (SQA 2016).

In terms of demonstration of skills, students must first propose an aim or question for investigation (1 mark) and then carry out research, which includes selecting relevant sources (2 marks) and selecting relevant information from sources (2 marks). Students may also gather data through experimental investigation (no marks allocated). Once the students have gathered the data and information, high emphasis is placed on processing and presenting the data, with six marks awarded for demonstration of this skill. This skill is divided into two separate but
related aspects: presenting and processing. Presenting data/information is described by SQA (2016 p13) as presenting in appropriate formats such as summary, graph, table, chart or diagrams. Processing data/information is described by the SQA (2016 p13) as performing calculations, plotting graphs from tables, populating tables from other sources, summarising referenced text. Three marks are awarded for structuring the report appropriately. This includes using heading and sub-headings, referencing in the appropriate format and writing a clear and concise report (SQA 2016).

Students are required to use their knowledge of science to describe an application of science and its effect on society or the environment (2 marks) and draw a valid conclusion (1 mark). The SQA (2016) also describes how students are expected to apply knowledge and understanding of science to explain the underlying biology (3 marks). This means using terms and ideas at a depth appropriate to the student’s level of cognitive development and excludes any explanations or descriptions that are copied verbatim. The application and its effect on society or the environment describe the SSI context within which the student inquiry is situated. An application is a deliberate human act, used to effect change in the world or environment and students are required to explain a clear relationship between the application and its effect on the environment or society (SQA 2016). The SQA give exemplar topics such as “the decline of the honey bees” which allows students to explore the positive and negative implications of the use of pesticides (SQA 2014). Another SSI context that is given as an exemplar by the SQA is “genetically modified crops” which again discusses multiple points of view and gives “pros” and “cons” in terms of implications for society (SQA 2014 pp45-50 course unit support notes biology). The physics exemplar topic given by the SQA, car safety contains a range of material relating to various advances in car safety and the associated benefits to society (SQA 2013).

In terms of recommended teaching approach to the Assignment, the SQA describes specified conditions for facilitating and supervising the inquiry. The student work is then externally marked by the SQA (SQA 2016). The teaching approach is described by the SQA as consisting of two stages: a research stage and a communication stage. There is also evidence in the SQA guidelines of an initial instructional stage prior to commencement of the assessment itself. The SQA states that the requirements of the assignment should be made clear to candidates at the outset and describe the importance of sharing SQA instructions and marking guidance with candidates (SQA 2016). The Assignment is recommended to take no more than eight hours, which is around two to three weeks of lessons (SQA 2016).

The SQA describes the research stage as students gathering information/data from a variety of sources including internet, books, newspapers, journals under the “supervision and control” of their teacher (SQA 2016). At this stage the students may work in groups or individually (SQA 2016). The SQA describes the role of the teacher during the research stage and uses the term ‘reasonable assistance’ to clarify to teachers how to balance support with giving too much assistance. During the research stage teachers may direct candidates to SQA materials, clarify instructions and requirements, and advise candidates on the choice of the topic or issue (SQA 2016). Teachers may also provide students with resource packs for their research. If students are to carry out an experiment during the research stage, a guided approach should be adopted with the instructions on the method provided (SQA 2016).
During the next stage, the communications stage, students produce a report of their findings under a “high degree of supervision” (SQA 2016 p6). This means that students should be in direct site of their teacher or invigilator and may not discuss their work (SQA 2016). This may be done over a number of lessons but no time limits or recommendations are stated by the SQA for this stage. Students have access to the notes and other material they collected during the research stage, for example: graphs, numerical or experimental data; data and information from the internet; published articles or extracts; notes taken from a visit or talk; notes taken from a written or audio-visual source (SQA 2016 p4-5).

RESEARCH QUESTIONS AND METHODOLOGY

This research presents a case study of the National 5 biology Assignment in one Scottish school and aims to investigate: *What are the student and teacher experiences of carrying out the CfE National 5 Assignment?*

Six biology teachers participated in the study and provided secondary documentation relating to 150 students, aged 15-16. The participating school is a large, mixed gender, non-denominational school, which has been rated “excellent” in all aspects by HMIE.

The following methods of data collection were used:

1. Observation of lessons;
2. Teacher post-lesson questionnaire and individual interviews with 6 participating teachers;
3. Document analysis relating to the teacher experience (e.g. lesson plans, teacher notes, quality assurance documentation).
4. Document analysis relating to the student experience (Student post-lesson evaluations with 150 students)

The teacher questionnaire consisted of open-ended questions designed to gather information regarding the teacher experience (Figure 1).

Thematic analysis of the teacher questionnaire and student lesson evaluations was carried out using the software Nvivo. The method used was based on Braun & Clarke (2006) and consisted of 6 steps:

1. Familiarisation with the data
2. Generate initial codes
3. Search for themes
4. Review themes
5. Define and name themes
6. Produce the report
An inductive, bottom-up approach was used. A consistent approach was reached by producing a detailed codebook that could be referred to throughout the coding process, ensuring that each reference to certain topics or key words were consistently coded into the same working theme. Extracts could be coded into as many themes as were appropriate. If codes appeared more frequently, i.e. had a higher number of coded references they were deemed as more important.

**FINDINGS**

Thematic analysis of the teacher questionnaires and student lesson evaluations identified a number of themes relating to the student and teacher experience of carrying out the National 5 Assignment. Tables 2 and 3 show the overall themes/ sub-themes and relevant quotes showing how students and teachers discussed their experience in relation to that theme.

The student experience, as identified from the student lesson evaluations, 5 main themes were identified: personal experience; ways of working and learning; recall and apply scientific knowledge; working with sources, information and data; and Assignment as an assessment.

The students focused mainly on the skills and knowledge developed and assessed in the Assignment and the process of carrying out the inquiry. They discussed their personal experience of the Assignment, including their feelings towards the assessment. They were slightly more negative than positive. Students also discussed the ways they worked and learnt, mainly focussing on planning and carrying out research. There was less focus on carrying out experimental investigations. Students discussed carrying out research including identifying and selecting sources of information and selecting information from the chosen sources. Presentation of data and evidence gathered through research was a relatively large focus of the students. The students discussed recall and application of scientific knowledge and around half the time they linked this to the implications for society and the environment, the SSI context.

The students focused little on the Assignment as an assessment.
The teacher experience consisted of three distinct themes: student experience (as viewed by the teacher), teaching approach and Assignment as an assessment (Table 3).

Table 2. Student experience of the National 5 Assignment

<table>
<thead>
<tr>
<th>Themes</th>
<th>Sub themes</th>
<th>Number of references</th>
<th>Quotes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal experience</td>
<td>Positive</td>
<td>15</td>
<td>&quot;To be confident in yourself&quot;, &quot;I really liked them and it was easy to follow through&quot;</td>
</tr>
<tr>
<td></td>
<td>Negative</td>
<td>22</td>
<td>&quot;I didn't like that no guidelines were given and didn't understand the content&quot;, &quot;it was over complicated, kinda in a big rush to do it all&quot;</td>
</tr>
<tr>
<td>Ways of learning &amp; working</td>
<td>Independent</td>
<td>4</td>
<td>&quot;Conduct an independent research task&quot;</td>
</tr>
<tr>
<td></td>
<td>Planning</td>
<td>12</td>
<td>&quot;A good, pre-planned assessment&quot;, &quot;I would plan what I was going to write&quot;</td>
</tr>
<tr>
<td></td>
<td>Research</td>
<td>21</td>
<td>&quot;Develop research skills and write-up skills&quot;</td>
</tr>
<tr>
<td></td>
<td>Experiment</td>
<td>5</td>
<td>&quot;Carry out an experiment and plan a write up&quot;</td>
</tr>
<tr>
<td></td>
<td>Resources</td>
<td>5</td>
<td>&quot;The guide booklet was a great help able to take information from the guide booklet and put it in our assignment&quot;</td>
</tr>
<tr>
<td>Recall and apply scientific knowledge</td>
<td>Content knowledge</td>
<td>17</td>
<td>&quot;To recall and apply appropriate scientific knowledge&quot;</td>
</tr>
<tr>
<td></td>
<td>Terminology</td>
<td>3</td>
<td>&quot;Meaning of terms such as &quot;processed&quot; data&quot;, &quot;phenotypes, genotypes, plants, neurones&quot;</td>
</tr>
<tr>
<td></td>
<td>Impact on society &amp; the environment</td>
<td>14</td>
<td>&quot;To learn how science can affect our environment and society in many different ways&quot;</td>
</tr>
<tr>
<td>Working with sources, information &amp; data</td>
<td>Identifying and selecting sources</td>
<td>6</td>
<td>&quot;How to find reliable sources&quot;, &quot;source evaluation&quot;</td>
</tr>
<tr>
<td></td>
<td>Identifying and selecting information</td>
<td>15</td>
<td>&quot;Gathering information about enzymes&quot;</td>
</tr>
<tr>
<td></td>
<td>Selecting, analysing and presenting data</td>
<td>15</td>
<td>&quot;To practice processing data, to analyse data&quot;, &quot;To interpret results&quot;</td>
</tr>
<tr>
<td></td>
<td>Presenting information</td>
<td>52</td>
<td>&quot;Present info in a report that explains any conclusions you have reached and how you reached them&quot;</td>
</tr>
<tr>
<td>Assignment as an assessment</td>
<td></td>
<td>8</td>
<td>&quot;To get a good mark&quot;, &quot;Experience an SQA assessment and a chance to achieving an A in our end of year biology exam&quot;</td>
</tr>
</tbody>
</table>
### Table 3. Teacher experience of the National 5 Assignment showing themes, sub-themes and relevant quotes from teachers

| Themes                              | Sub-themes                      | Number of references | Quotes from teachers                                                                                                                                                                                                 |
|-------------------------------------|---------------------------------|----------------------|--------------------------------------------------------------------------------------------------------------------------------********************************************************************************|
| **Student experience**              | Students’ personal experience   | Positive            | 11                                                                                 "Students were very focused” "Pupils had to be self motivated and confident to complete the task.”                                               |
|                                    |                                 | Negative             | 7                                                                                   "Overall the complexity of the flow/structure of the report was very challenging for pupils at this level. Some sections /words could not be accessed, especially for the less able pupils" |
| **Ways of learning and working**    | Independent                     |                      | 8                                                                                   "Independent research: selecting information and constructing this information in their own words”                                               |
|                                    | Planning                        |                      | 5                                                                                   "Working individually on planning and writing up the assignment.”                                                                   |
|                                    | Research                        |                      | 12                                                                                  "Research skills - appropriate use of text from a variety of sources, finding reliable data and information.”                             |
|                                    | Experimental                    |                      | 4                                                                                   "Students were able to plan and carry out an experiment.”                                                                           |
| **Recall and apply scientific knowledge** | Terminology                |                      | 11                                                                                  “I would spend slightly more time on each section to ensure understanding of terminology.”                                           |
|                                    | Impact on society & the environment |                    | 3                                                                                   “the application of theory they have learnt in class in the real world and the impact on society”                                         |
| **Working with sources, information and data** | Identifying and selecting sources |                      | 4                                                                                   “They learned how to choose references that were relevant and reliable”                                                            |
|                                    | Identifying and selecting information |                    | 6                                                                                   “Pupils developed their research skills and became quite adept at identifying appropriate information that they required for the assignment.”                                      |
|                                    | Selecting, analysing and presenting data |                    | 7                                                                                   "Finding suitable, relevant and reliable data”,                                                                                       |
|                                    | Presenting information          |                      | 16                                                                                  "Developing skills in processing data from one format to another”                                                                         |
| **Teacher experience/ approach**    | Teacher actions/ pedagogy       | Facilitating         | 5                                                                                   “Pupils were directed to read the success criteria for the report and marks allocation for the different sections.”                          |
|                                    | Direct teaching                 |                      | 7                                                                                   “Lessons 1 - 3: In depth explanation of what is required for the assignment.”                                                          |
|                                    | Time management                 |                      | 5                                                                                   “Allow more time for planning stage.” “Perhaps allow more time for student feedback”                                                      |
| **Assignment as an assessment**     | Resources                       |                      | 15                                                                                  “Using logbooks”                                                                                                                     |
|                                    |                                 |                      | 6                                                                                   “Pupils completed their assignment under exam conditions.”                                                                               |
The teachers talked mainly about the student experience and discussed it in very similar terms to the students themselves; the same sub-themes were identified between students and teachers. When talking about their own experience, teachers discussed their pedagogical approach to the Assignment, in which they discussed using a mixture of facilitating and direct teaching and how time pressures and time management had an effect on their ability to carry out the Assignment. Teachers talked little about the National 5 Assignment as an assessment.

Figure 4 shows how the student and teacher experience overlap and diverge.

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**Figure 4. Student and teacher experience of the National 5 Biology Assignment**

Students and teachers talked about the students’ experience in very similar terms. Regarding the students’ personal experience, the students were more negative than their teachers. Students commented on the negative emotions, e.g. “I didn’t like...” while their teachers focused on the positives, e.g. “students were self-motivated...confident”. In terms of the process of the inquiry, the students and teachers focused on highly on carrying out research and little on experimental investigations. The students focused on planning their inquiry while their teachers did not place importance on this. When describing working with sources, information and data, both the students and teachers focused highly on presenting evidence, including data and other information. They focused less so on the research process of selecting sources of data and evidence and choosing information from sources. In relation to the knowledge developed and assessed there was clear differences in how the students and their teacher discussed this. While students focused on recall and application of scientific knowledge, both with and out with the SSI context, the teachers mainly focused on the terminology of the assessment including scientific terms and Assignment specific terms. Around half the time the students discussed their knowledge in relation to the SSI context but the teachers focused little on this. The students placed more importance on the SSI context than their teachers. This may indicate that the context was personally relevant to them.
The students and teachers focused mainly on the Assignment as an assessment of skills and knowledge and little on the Assignment as an assessment. This may indicate that they placed more importance on the process of the inquiry rather than the end result or grade.

CONCLUSIONS AND IMPLICATIONS

Scientific literacy is described in terms of skills and knowledge of science and there is evidence from the student experience as described in this study, which mainly focuses on these skills and knowledge, that scientific literacy is developed through the National 5 Assignment (OECD 2013). The student experience also focuses on the process of carrying out the inquiry, the method by which the skills and knowledge of scientific literacy are developed. There was a high level of agreement between the students and teachers when talking about the student experience of the National 5 Assignment. While this could indicate that the teacher understands the student experience, it is more likely that the teacher dictated the student experience with their teaching approach. The teachers talked about their approach to teaching the Assignment in terms of a balance of facilitating and direct teaching.

This research is a pilot study contributing information to a wider case study. The findings from this pilot study will be used to inform the methodological design of a wider study. This wider study will include teachers and students of biology, chemistry and physics and will compare their experience of the Assignment in the different subjects.

ACKNOWLEDGEMENT

Many thanks to the cooperating teachers for their time and help with organisation of the project in school.

REFERENCES

A COOPERATIVE LEARNING STRATEGY USING A
SOCIALLY ACUTE QUESTION APPROACH: CHANGES IN
STUDENTS’ ATTITUDES

Michel Vidal
Montpellier SupAgro, Montpellier, France

The pedagogical strategies based on a Socially Acute Questions (SAQ) approach are well-documented as fostering learners’ agency. However, if the emotional proximity of the SAQ is great, the learning can be weak (Simonneaux & Simonneaux, 2009). We hypothesise that the integration of a cooperative learning strategy using a very-acute SAQ enables socio-critical reasoning (Sadler, Barab & Scott, 2006). We interviewed four students from an agricultural vocational school before and after their participation in a cooperative learning strategy using the wolf’s re-appearance in the French Alps. We analysed students’ attitudes by exploring the knowledge, rationale and axiological modalisations in their discourses. This learning strategy enabled ‘cooling down’ of the SAQ and students felt their ideas were listened to and recognised. However, following the teaching of the strategy, it was found that the students only implemented some socio-critical reasoning because of confirmation bias as no expressed scepticism about the knowledge presented during the strategy was identified.

Keywords: cooperative learning, socially acute question, attitude

INTRODUCTION

Social conflicts managed by a critical pedagogy of discussion can enable self-affirmation, social integration and a recognition of the other (Lenoir, 2012). More particularly, a socially acute questions (SAQ) approach in education can foster learners’ agency, empowerment, and the modification of their behavior, especially through debates. The educational challenge of the SAQ approach is to enable students to develop an informed opinion about these issues, to be able to make choices about prevention, action, use and to be able to engage in debate them. However, when the emotional proximity of the SAQ is great, the teachers take the risk of introducing an issue where opinions are heated, making discussions difficult to control and so the learning can be weak (Simonneaux & Simonneaux, 2009). In such a context, we hypothesise that the pedagogical adaptation of a socially-very-acute question to include a cooperative learning strategy could foster an attitude enabling socio-scientific reasoning (Sadler, Barab & Scott, 2006) to occur. Socio-scientific reasoning is based on the recognition of the inherent complexity of the issue, an examination of the issue from multiple perspectives, the appreciation of on-going inquiries into the issue, the expression of skepticism about knowledge related to the issue, recognising potential bias, the consideration of the knowledge provided by different producers, and the exploration of governance modalities to manage the issue (Sadler, Barab & Scott, op.cit.; Morin & al., 2014). We consider attitude as based on four dimensions: a cognitive one through knowledge and beliefs related to the object; a conative one through the projections on the future; an affective dimension (Hovland & Rosenberg, 1960) to which we add an axiological one.

The pedagogical approach used in this research is based on an adaptation of the Cooperative Learning in Multicultural groups strategy (CLIM) (Cohen & Lotan, 1997) in the context of an
SAQ. CLIM principles include intellectually challenging and open-ended tasks around a central concept; problem solving strategies; assigning specific roles to each students; and providing opportunities for equal participation for all pupils. It has been adapted to deal about the wolf's re-appearance in the Alps with 16-17 years old students from two classes in an agricultural vocational school, one related to livestock production, the other to agri-environmental issues. As an SAQ, the wolf issue arouses debate about the production of scientific reference knowledge, has high stakes and is highly publicised. While teachers and students are familiar with this SAQ, teachers feel poorly prepared to address it (Legarède & Simonneaux, 2006). This issue is particularly acute in the territory of the Alps and, according to the director and the teachers of the school, is a huge source of conflict between the students in the two classes.

METHOD

The pedagogical strategy was applied by one teacher over half a day and following these six steps: (1) Students in the two classes with conflicting opinions were put in groups of four people. In each group, the students had to take on the roles of «facilitator» leading the group, «time manager», «hardware manager » and «presenter» of the final results; (2) Each student individually completed a photo-montage expressing their own opinion about the issue. Then the participants discussed points of agreement and disagreement within their group without any debate in a framework of respect and non-judgment; (3) Four files were shared between the students in each group. Each file described one of the four controversial nodes of the issue (does the wolf increase or decrease biodiversity? Does the wolf have a favorable or unfavorable economic impact on the territory? Are wolf protection and regulatory techniques effective or not? Does the wolf attack people or not?) presenting two opposite researchers’ points of view. Each student had to read their file, identify the most important points with the students having the same file, and finally to present them within the group; (4) Each group received the same information describing the issue of the wolf in Scandinavian countries with the task of proposing possible solutions. Presenting the issue of the wolf in another context can enable the learner to remove the automatism of perception established by habit, thus allowing a distancing inspired by the principle of “estrangement” (Ginzburg, 2013) and to encourage reflexivity and a possible change of representations; (5) Each group made a presentation about their conclusions to their peers; and (6) Finally, all the students debated the issue of the wolf’s re-appearance in the Alps following 3 steps: firstly, each student could express their position with the other students listening. Secondly, after highlighting the points of convergence and divergence, the teacher, facilitator of the debate, facilitated discussion about the points of divergence. The students had the opportunity to express their viewpoints without judgment from their peers. Finally, the teacher asked the students to imagine ways of resolving the wolf issue in terms of each of the differing viewpoints.

Four students, two from Class 1 (N. and S.), and two from Class 2 (J. and F.) were chosen to be interviewed individually for one hour the day before and then again on the day after the CLIM strategy was used. The first semi-structured interview aimed to discover each student’s attitude towards the SAQ, the events and information which formed the basis and justification for their attitude, interactions with their peers about the SAQ, their interest in and involvement
Strand 8

with the pedagogical strategy, the support and the difficulties they met, their strategy used to communicate with their peers, and their own assessment about the efficacy of CLIM approach. During the second interview, the student could suggest any modifications they would have liked to have carried out on their photo-montage according to the information they experienced during the pedagogical strategy. The interviews were recorded and transcribed. Data were then analyzed to explore the dimensions of students’ attitudes before and after the CLIM approach as follows.

The cognitive dimension of the students’ attitudes was analyzed through an interpretation of two cartographies of controversy, based on the Actor-Network Theory (Akrich, Callon, & Latour, 2006) that visually expresses the actants and their interactions (France, Birdsall & Simonneaux, 2017) to unravel the diversity of participants taking part. We have inventoried in the students’ discourse the human and non-human actants mentioned in the issue, and their interactions through the action verbs they used to connect the actants. We have compared the discourses in the two cartographies.

The conative dimension of their attitude has been analysed through Mermet’s (1992) ratione that consists of four criteria. The first criterion « richness » characterizes the elements of a eco-socio-system which are important to preserve or to implement for the person. The second criterion « security » relates to the threats which can affect the richness. The third criterion of « adaptability » qualifies the conditions, actions, and concessions to be considered by the person. The fourth criterion « coherence » qualifies contradictions in the discourse. To highlight the criteria, we have made a semantic analysis of the arguments in the discourse according to the theory of Semantic Blocks (Carel, 1994). This theory onsiders that every utterance is argumentation, which it makes it possible to describe argumentative content conveyed by statements through normative or transgressive sequences, the former instantiating a link of cause and effect, the latter establishing an opposition. An example of Normative linking was this statement, "I protect sheep breeding against wolf because it’s an important tradition of this territory” will result in: sheep breeding as an important territorial tradition THUS protecting the sheep against the wolf. The word, THUS marks the causal link. "I protect sheep breeding with dogs YET wolf's attacks don't decrease" will result in transgressive sequencing: protecting sheep breeding with dogs YET NEG decrease the wolf's attack. In this example the word YET marks the link of opposition and NEG is the negative effect of the protection. In these two examples, we can conclude that sheep breeding as a territorial tradition, is an example of the criterion of « richness », the attack of the wolf as a threat falls under the criterion « security », and the protection of the sheep using dogs under the criterion « adaptability ». In this way, the rationale of each student has been compared in the two discourses.

The affective and axiological dimensions in students’ discourses have been analyzed through the following axiological modalisations (Galatanu, 2003): moral-ethical judgments with the two polarities good-bad; aesthetic judgments with the two polarities beautiful-ugly; pragmatic judgments with the two polarities useful-useless; intellectual judgments with the two polarities interesting-uninteresting; and affective judgements with the two polarities happy-sad. The
Strand 8

Axiological modalisations have been inventoried and counted. The percentages of the presence of each axiological modalization have also been compared in the two discourses.

RESULTS

The data obtained from the four interviewed students is now presented successively.

Comparison of N.’s attitude of N. in the pre- and post-discourses

The interpreted maps of controversies (Figure 1) of N. remained the same over the two discourses.

Figure 1. Interpreted map of controversy according to N’s discourses (in bold the change observed in the second discourse)

11 actants and 13 action and position verbs were mentioned by N. For him, the wolf was reintroduced by ecologists but this controversial opinion has been proven to be false. N. believes that the wolf attacks sheep and breeders, but also game. These attacks, appraised by federal guards, cost the French state, but the breeders don’t want any compensation. Protection dogs prevent the attacks and can also defend against tourists. The Anatolian shepherd is a better protection dog, as it respects the tourists.

As shown in Table 1, N. is scared of the wolves being released from parks because he wishes to protect pastoralism and hunting. N. thinks it is not to enough to have the wolves shot down. Furthermore, he believes that breeders are going bankrupt as they receive insufficient compensation.

Finally, there is a reduction of other game animals, and also a picture of sadist. During the first interview, he proposed regulating the number of wolves, having the right to shoot them, and to continue to use protection dogs.

During the second interview, the « adaptability » criterion changed. He wanted to gain a better understanding of the pro-wolves position, to find a solution that suits everyone, but also, illogically, to convince them to reduce the number of wolves.

The axiological modalisations in the two discourses are presented in Table 2.
Table 1. N’s rationale according to Mermet’s criteria

<table>
<thead>
<tr>
<th>Interview</th>
<th>Richness</th>
<th>Security</th>
<th>Adaptability</th>
<th>Coherence</th>
</tr>
</thead>
</table>
| pre       | - pastoralism  
            - sheep as a loved animal  
            - sheep as a financial resource  
            - hunting | - release wolves from parks  
            - do not have enough wolves shot down  
            - breeders going bankrupt  
            - have a reduction of game  
            - to have insufficient and poorly distributed compensation  
            - to be not understood and considered as a sadist | - at first to regulate the number of wolf  
            - to use protection dogs  
            - to have the right to shoot the wolf | - to consider the regulation of the wolf as a first step with the wish to go beyond |
| post      | No change | No change | - to find a solution that suits everyone  
            - to understand the pro-wolves people  
            - to convince the pro-wolves people to reduce the number of wolves  
            - to put wolves in parks | - to wish to understand better the pro-wolves people and find a common solution and at the same time to convince them to reduce the number of wolves using reason |

Table 2. Polarity of the axiological modalisations in N’s discourses (%)

<table>
<thead>
<tr>
<th>Modalisation discourse</th>
<th>Moral-ethical</th>
<th>Intellectual</th>
<th>Pragmatic</th>
<th>Affective</th>
<th>Aesthetic</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre (%)</td>
<td>33</td>
<td>4</td>
<td>0</td>
<td>15</td>
<td>7</td>
<td>87</td>
</tr>
<tr>
<td>Post (%)</td>
<td>7</td>
<td>8</td>
<td>0</td>
<td>12</td>
<td>20</td>
<td>27</td>
</tr>
</tbody>
</table>

While the first interview was dominated by 38% of « negative » affective modalisations, with 33% of moral-ethical ones expressing what is bad, and 15% of pragmatic ones expressing the usefulness, the second interview is dominated by 30% of positive affective modalisations, 18% of negative ones, and 22% of pragmatic expressing the utility. We can also observe 12% of intellectual modalisations expressing interest. While 87% of modalisations are in the negative polarity in the first discourse, 73% are positive in the second one.

The pedagogical strategy appears to have reduced the negative affectivity related to the issue, to have implemented a focus on the pragmatic and to have enabled a wish for the negotiation of a common solution for the different actors.

Comparison of S.’s attitude in the pre- and post-discourses

The interpreted maps of controversies (Figure 2) of S. changed over the two discourses. S. mentions in the first interview an anti-wolf system, without giving any details, which can stop and kill the wolf and save domestic animals. While farmers fight against the wolf, townsfolk, considered as pro-wolves protect it. S. adds in the second interview the actor wildlife, which can be affected by the wolves. He mentions six actants, and uses seven position and action verbs.

As shown in Table 3, in the first interview, breeding is a richness but also the wolf considered as a part of the biodiversity.
The quick development (re-introduction of the wolf and its protected status is a threat difficult to solve because of the number of actors involved in the issue and the extremists. S. suggests that all the actors negotiate a common solution, but inconsistently, he considers citizens as Nazis. During the second interview, biodiversity is regarded as a richness which can be affected by the wolf. S. believes that the wolf a lot of money, and economically endangers the breeders. He suggests setting up technical monitoring to track wolf numbers so that shooting quotas can be adjusted accordingly.

The axiological modalisations in the two discourses are presented in Table 4.
Table 4. Polarity of the axiological modalisations in S’s discourses (%)

<table>
<thead>
<tr>
<th>Modalisation discourse</th>
<th>Moral-ethical</th>
<th>Intellectual</th>
<th>Pragmatic</th>
<th>Affective</th>
<th>Aesthetic</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre (%)</td>
<td>13</td>
<td>26</td>
<td>8</td>
<td>13</td>
<td>15</td>
<td>87</td>
</tr>
<tr>
<td>Post (%)</td>
<td>5</td>
<td>6</td>
<td>0</td>
<td>11</td>
<td>2</td>
<td>28</td>
</tr>
</tbody>
</table>

In the first interview, S.’s discourse was dominated by 26% of moral-ethical modalisations expressing what is good and 13% expressing what is bad, 15% of pragmatic expressing what is useless, and 13% of intellectual modalisations expressing what is interesting. In the second discourse, S.’s discourse was dominated by the following modalisations: pragmatic expressing what is useful (30%), positive affective (26%), and negative affective (21%). While in the first discourse, 87% of modalisations are in the negative polarity, 72% are in positive in the second one.

S. partially changed his attitude over the two discourses. He still considered it necessary to protect the breeding and the wolf. Nevertheless, in the first discourse, he considered the wolf as a part of the biodiversity and in the second as also affecting the biodiversity. The pedagogical strategy used appears to have been able to help him more affectively express his attitudes. His attitudes that were a “negative one” seemed to be linked to an awareness of the threat to the breeding, as he said, «I was shocked by the damage that the wolf can do on farms».

Comparison of J.’s attitude in the pre- and post-discourses

The interpreted maps of controversies (Figure 3) of J. are changed in the two discourses.

As shown in Figure 3 and in more detail in Table 5, the wolf, the lamb but also a secure campaign are the components of J.’s “richness”. According to her, hunters kill too many game animals. She explains that the wolf attacks hens, horses and sheep, which makes the breeders angry, and they then kill wolves. Nevertheless, the wolf can attack humans. She suggests that farmers regulate the population of wolves. However, she inconsistently considers that the wolf scares humans, and can attack them.

During the second interview, J. adds that wolf can regulate game and protect crops. She also considers that killing wolves increases the population of wolves. This information comes directly from research outlined in one of the files presented during CLIM strategy where the...
wolf was presented as a useful species, regulating biodiversity. The wolf attacks livestock because there aren’t enough uninhabited areas where to live. J. proposes a reduction in hunting and creating enclosures for the wolf.

The axiological modalisations in the two discourses are presented in Table 6.

**Table 5. J’s rationale according to Mermet's criteria**

<table>
<thead>
<tr>
<th>Interview</th>
<th>Richness</th>
<th>Security</th>
<th>Adaptability</th>
<th>Coherence</th>
</tr>
</thead>
<tbody>
<tr>
<td>pre</td>
<td>- wolf, as a species to protect - lamb as a cute animal - secure campaigns</td>
<td>- Too many wolf in France which can attack human, kids - Hunters kill too many game, a necessary food for the wolf - wolves kill lambs because of a lack of game</td>
<td>- to regulate the number of wolves by the farmers</td>
<td>Wolves are afraid of the human in contradiction with wolves can kill human</td>
</tr>
<tr>
<td>post</td>
<td>Wolf, as a useful species to regulate the biodiversity</td>
<td>- wolf attacks in farms because of the difficulty to find uninhabited areas</td>
<td>- to reduce hunting and having more game - to create enclosures for the wolf</td>
<td></td>
</tr>
</tbody>
</table>

**Table 6. Polarity of the axiological modalisations in J.’s discourses (%)**

<table>
<thead>
<tr>
<th>Modalisation discourse</th>
<th>Moral-ethical</th>
<th>Intellectual</th>
<th>Pragmatic</th>
<th>Affective</th>
<th>Aesthetic</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre (%)</td>
<td>-22</td>
<td>-11</td>
<td>00</td>
<td>-22</td>
<td>-17</td>
<td>56</td>
</tr>
<tr>
<td>Post (%)</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>-11</td>
<td>-17</td>
<td>28</td>
</tr>
</tbody>
</table>

The axiological modalisations in her two discourses changed. The first discourse was dominated by the following modalisations: moral-ethical expressing what is bad (32%), negative affective (26%) and positive affective (22%). The second discourse was dominated by moral-ethical modalisations expressing what is good and bad (respectively 22 and 22%), pragmatic expressing what is useful (22 %). While in the first discourse, 63% of modalisations are in the negative polarity, in the second one 72% are in the positive one.

If J. considered in the first interview that the wolf can be a danger for the human, she nevertheless maintained a protective attitude towards the wolf and added argumentation in that sense in the second interview. The pedagogical strategy appears to have reduced a negative affectivity, to have implemented a focus on pragmatic useful account.

**Comparison of F.’s attitude in the pre- and post-discourses**

According to F. (see Figure 4), breeders who manage sheep and cows are affected by the wolf's attack. They are not compensated for all the damage and fights against politicians and economists, who are also affected by the issue of the wolf. Researchers control the wolf population. Nevertheless, the wolf regulates flora. In the second interview, F. adds that it also regulates wildlife and allowing less damaged crops. For F., it is an interesting argument because his father is crop farmer. But he also changes his mind, stating that wolf can affect biodiversity.

As shown in Table 7, the wolf helps to preserve biodiversity of flora as F.’s “richness”.

1162
Table 7. F’s rationale according to Mermet’s criteria

<table>
<thead>
<tr>
<th>Interview</th>
<th>Richness</th>
<th>Security</th>
<th>Adaptability</th>
<th>Coherence</th>
</tr>
</thead>
<tbody>
<tr>
<td>pre</td>
<td>Wolf, as preserving biodiversity flora breeding as an economic pillar</td>
<td>- to consider the wolf as a fierce beast to be exterminated - to bring down sheep drove and to close the farms - to have schizophrenic politics of protection of and fight against the wolf - to have purely financial reasoning to analyze the issue - poor compensation for breeders</td>
<td>- to preserve the species - to keep the wolf in its natural state - to control the wolf</td>
<td></td>
</tr>
<tr>
<td>post</td>
<td>- Wolf, as useful to protect cultivation area - Biodiversity - Breeding</td>
<td>- Biodiversity can be reduced because of the wolf - poaching of wolves - cost of the measures to solve the issue</td>
<td>- a number of collars to regulate the number of wolves by hunters and to be adapted by area - monitoring and control of collar management</td>
<td>As crop farmer’s son, he has a specific focus on crop protection</td>
</tr>
</tbody>
</table>

In the second interview this idea is extended as the wolf regulates wildlife, but also breeding as an economic pillar. He fears the prejudices about wolf, but also the impact of the wolf’s attacks on breeding practices, and of the financial situation of breeders. He blames a schizophrenic state policy protecting and fighting against the wolf. He suggests preserving and controlling the wolf. In the post-interview, he fears wolf poaching but also the degradation of biodiversity. He suggests a pragmatic approach to regulate the number of wolves through having a defined number of collars each year.

The axiological modalisations in the two discourses are presented in Table 8.

F.’s first discourse is dominated by the following modalisations: moral-ethical expressing what is bad (29%) and intellectual expressing what is interesting (24%). His second discourse is dominated by the pragmatic expressing what is useful (42%), and moral-ethical expressing what is bad (30%).
Table 8. Polarity of the axiological modalisations in F.’s discourses (%)

<table>
<thead>
<tr>
<th>Modalisation discourse</th>
<th>Moral-ethical</th>
<th>Intellectual</th>
<th>Pragmatic</th>
<th>Affective</th>
<th>Aesthetic</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre (%)</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>46</td>
</tr>
<tr>
<td>Post (%)</td>
<td>30</td>
<td>13</td>
<td>0</td>
<td>12</td>
<td>42</td>
<td>67</td>
</tr>
</tbody>
</table>

The pedagogical strategy appears to have made F.’s arguments more complex, as he considered the wolf both positively and negatively affecting biodiversity and farming. It also seemed to result in a focus on a pragmatic useful account.

**DISCUSSION**

The use of the CLIM strategy appears to have created changes in attitudes that we now consider in the light of the development of socio-scientific reasoning.

We observe that the pedagogical strategy increased the positive potential of the axiological modalisations of the issue even if the students did not change their opinion about the wolf and about the other actants. We hypothesise that the movement between the two axiological polarities enriches socio-scientific reasoning, allowing students to reflect on the issue between the questions what is good, what is bad, what is interesting and uninteresting, what is useful and useless to do, what makes me annoyed or happy.

More particularly, CLIM strategy seemed to cool down the socially acute question for N. and J.. N. said, “I was afraid about nervousness in the class, but everybody spoke calmly” and it provided the possibility of self-affirmation for J. who said, “we had the possibility to say that you like the wolf”. There was also the feeling of being recognized by others as J. said, “I'm glad to have been heard”. The strategy gave him the opportunity to express his opinion in a non-judgmental frame and seems to have had a cathartic effect and freed up an elaboration capacity (De Mijolla & De Mijolla, 1996). For example, this is illustrated by N., who demonstrated curiosity about the opinion of others, and about the wolf itself. He expressed that the issue is subject to on-going inquiry about wolf behaviour, and agreed to consider knowledge from other actors (as the ecologists) to find a common solution even if he stays ambivalent about convincing others with differing attitudes. Listening to others with empathy promotes openness to the other and the world (Rogers, 2005).

To listen to others can also stimulate an emotional sharing, an affective empathy (Decety, 2010), which can warm up the SAQ, which was illustrated by S.’s surprise and anger when learning about the damage created by the wolf in his colleagues’ breeding. In this way, to enable a time of confrontation is to also enable a time to make more cohesive groups of opinions. Our results can't show clearly if such emotion can affect the socio-scientific reasoning or on the contrary, stimulate interest in the SAQ, to arouse concern about the issue (Pettit, 2004), or both of them. We can hypothesise that it anchors the link with one actant (in that case the breeders) but risks the creation of disinterest or emotional distance in the perspectives of other actants, and at the same time increases concern for the issue.

The four students’ understanding of the complexity of the issue was enriched differently after the implementation of the CLIM strategy. N. didn't appear to develop any knowledge as he
said, “I knew already well the situation”. While he mentioned the largest number of actants and interactions, compared with the three other students, he also rejected the information which contradicted his beliefs. This backfire effect (Nyhan & Reifler) maintains the persistence of the misconception. More particularly, the belief that wolf is reintroduced persists in N.’s attitude, despite evidence showing it is wrong. However the CLIM strategy should take discrediting beliefs into consideration. We suggest that introducing information not only about the current controversies, but also about relevant past controversies even if they have arrived at a clear and socially accepted answer, could assist in this case.

S. developed new knowledge during the pedagogical strategy which seemed to confirm his initial attitude about the danger of the wolf, not only for humans but also for biodiversity. J., having an attitude in favor of the protection of the wolf, added knowledge confirming the utility of the wolf for game regulation and the protection of crops. However, the file introduced during the CLIM approach about biodiversity mentioned a controversy about this issue. Two students processed this information but did not reject their beliefs. This confirmation bias usually appears when considering affective questions (Wason, 1960). If it can be considered as an obstacle to implementing a more relativistic attitude about the issue, it could also allow a student to enrich their argumentation. To implement a more relativistic attitude, we suggest discussing this bias that privileges information that confirms ideas and beliefs prior to implementing the strategy.

These four students appear to have implemented reasoning about pragmatic considerations according to what could be useful to resolve the issue. The CLIM strategy would need to incorporate an affective and moral-ethical position about wolf issue to assist further with problem solving. More particularly one of the student (N) changed his opinion about the way of governance to solve the problem. From a more regulatory approach, he implemented a more participative one.

The main findings of implementing the CLIM strategy were that it cooled down the SAQ; enriched argumentation when considering students’ initial opinions; implemented a focus to solve the issue and it supported socio-scientific reasoning. However, there did not seem to be any development of a more skeptical attitude about knowledge/research presented. When using the CLIM strategy in future, we might have to consider this strategy as a first step. We could also take into account the students’ wish to have more information about the wolf and about the rationale of actors as a lever.

Further research could be carried out to understand which steps of the CLIM approach enabled these changes and how.

REFERENCES
Marine literacy is critical for teachers to allow children to consider the marine as a source of employment in a wide range of industries which otherwise they remain unaware of. Marine literacy is something that comes about through interpersonal exchange of experience, which in the past relied on grand-/parent-to-child transmission. However, nowadays, marine literacy must now be ‘taught' or learned in 'new ways'. It is hypothesised that children lack basic content knowledge as well as an integrated higher level understanding of humanity's relationship with the marine. In order to provide a baseline of student teachers' marine literacy, as future educators of future citizens, and to test the efficacy of the Ocean Literacy Questionnaire OLQ, developed by the Marine Institute, a sample of n=35, mean age= 19.8yrs, student teachers at Dublin City University completed the OLQ prior and following an intervention on marine literacy. The OLQ is a six-section multipart-question questionnaire which elicits perceptions of how ocean literacy fits into the primary school curriculum, perceived importance of content areas, and perceived barriers to implementing marine education in primary school. The resulting data was analysed using standard statistical methods for non-parametric data which established a positive differential across the implementation of the intervention. The intervention involved a pilot marine module 'Environmental Systems: The Marine Environment' being delivered by Dublin City University and the Marine Institute’s Explorers Education Programme™. It is expected that as a result, the intervention will be broadened to include further marine literacy training of student teachers.

Keywords: Marine deficit disorder, marine literacy, initial teacher education

**INTRODUCTION**

In Ireland, Marine literacy, as a subset of scientific literacy, is critical for teachers to allow children to consider the marine as a source of employment in a wide range of industries; as the fundamental driver of our climate; of the source of food and materials; of transportation which otherwise they remain unaware of, and which have taken on renewed focus in light of the current BREXIT negotiations as of 2018. Therefore we consider marine literacy to go beyond 'knowledge': it is something that comes about through interpersonal exchange of experience, which in the past relied on person-to-person transmission. As this transmission has been interrupted, marine literacy must now be 'taught' or learned in new ways. To that end we hypothesise that young people lack basic content knowledge as well as an integrated higher level understanding of humanity's relationship with the marine and that this propagates into adulthood. It is further hypothesised that young people from specific backgrounds hold a skewed understanding of the marine environment at best, or are 'marine blind' at worst.

and Kevrekidis (2017) examined student teachers’ content knowledge of ocean sciences issues and attitudes toward the state of ‘ocean stewardship’. Boubonari, Markos, and Kevrekidis (2013) examined student teachers’ knowledge, attitudes, and environmental behaviour toward marine pollution. A variety of methods have been used to explore marine education in children, notably, Lu and Liu (2015) explored integrating augmented reality, AR, technology to enhance children’s learning in marine education. It would be the authors of this work’s view that AR could be a useful tool but not replace the physical interaction with the marine environment. This work reports on a pilot study to probe the ocean literacy of pre-service / student teachers in the Republic of Ireland. The Explorers Education Programme™ (Marine_Institute, n.d.) is a successful primary school intervention, however following the review of 2015, it was decided to intervene at the source of teacher education.

METHODOLOGY

The Ocean Literacy Questionnaire, OLQ, developed by the Marine Institute, a sample of n=35, mean age= 19.8yrs, student teachers at Dublin City University completed the OLQ prior and following an intervention on marine literacy. The OLQ is a six-section multipart-question questionnaire which elicits perceptions of how ocean literacy fits into the primary school curriculum, perceived importance of content areas, and perceived barriers to implementing marine education in primary school.

The raw data from the OLQ was analysed in its constituent sections for both the pre- and post-test administrations. Multidimensional scaling also known as coordinate grid analysis was carried out on the data once it had been prepared by creating matrices of the scores provided by the student teachers reflecting their perceptions of certain attributes. The matrices consisted of both the pre- and post-test data combined thus all data points were involved in the algorithm. The MDS was carried out in the R environment (R_Core_Team, 2013) using the MASS package (Venables & Ripley, 2002) using the following algorithm:

Code for R:

```
# first row contains variable names, comma is separator
# assign the variable id to row names
# note the / instead of \ on mswindows systems
FILENAME <- read.table("c:/FILE PATHWAY", header=TRUE, sep="", row.names="id")

# Classical MDS
# N rows (objects) x p columns (variables)
# each row identified by a unique row name
d <- dist(FILENAME) # euclidean distances between the rows
fit <- cmdscale(d,eig=TRUE, k=2) # k is the number of dim
fit #view results

# plot solution
x <- fit$points[,1]
y <- fit$points[,2]
```
RESULTS

Section 1 of the OLQ prompted the student teachers for their perceptions of whether ocean literacy was relevant to which subjects of the Irish primary curriculum, before and after a short intervention (Figure 1), excepting science. Generally, but not statistically, the results showed an increased diversity of subjects which can use ocean literacy as a vehicle for learning, the most marked being geography, mathematics, physical education and religion.

![Figure 1. Perception of relevance of marine literacy to subjects in the primary curriculum other than science in student teachers (Nmax = 32). The subjects read: geography; history; mathematics; languages English; languages Gaelic; arts Visual; arts Music; arts Drama; social, personal and health education; physical education; and religion.](image)

It was surprising that initially, in the pre-test, student teachers did not think that the marine was pertinent to studies in geography at all, low in mathematics and physical education which might seem to be cornerstones in students' interactions with the marine environment. Physical education would include water sports of any kind but this was overlooked presumably because students understood PE to be conventional land-based sports only. Whereas it was not surprising that religious education did not feature strongly in the pre-test, it was equally surprising how this was reversed since the only input in the intervention in this regard was the recalling of the 7th century voyage of St. Brendan the Navigator and the use of remote islands as monastic centres on the western seaboard of Ireland.

The remaining sections of the OLQ were subjected to MDS and a plot of the extracted 1st and 2nd dimensions plotted on Cartesian planes. Non-metric multidimensional scaling, MDS, also known as principal co-ordinates analysis, PCA, was applied to the transposed data matrix using the ASCAL protocol in R, which uses the Takane-Young-de Leeuw S-stress – formula #1, and a plot was made of the emerging dimensions. Jaworska and Chupertovska-Anastasova (2009)
reviewed the possibility of using MDS in a range of psychological domains, and McCloughlin (2015) explored the use of MDS in student and serving teacher perceptions of self-efficacy in teaching science. They do, however, view MDS as an ‘exploratory data analysis technique’ but point out its key features, namely that MDS can ‘handle nominal or ordinal data, and does not require multivariate normality’. de Leeuw (2000) in a meta-review of the literature using MDS, claims that “MDS, as a set of data analysis techniques, clearly originates in psychology”, and as such the early history starts with Carl Stumpf around 1880 (de Leeuw & Heiser, 1980). The most common approach to determine the elements and the underlying configuration is an iterative process, commonly referred to as the Sheppard-Kruskal algorithm. A simplified view of the MDS algorithm is as follows (Borgatti, 1997; Cízek, Härdle, & Weron, 2005; UNESCO, n.d.), but see Fahrmeir and Hamerle (1984):

1. Assign points to arbitrary coordinates in a p-dimensional space.
2. Compute Euclidean distances among all pairs of points, to form the DHAT matrix.
3. Compare the DHAT matrix with the input D matrix by evaluating the stress function.
4. Adjust coordinates of each point in the direction that maximally reduces the stress.

After determining the dissimilarity matrix D and the corresponding scaling matrix A, an iterative process begins, which successively revises the dissimilarities and object coordinates until an adequate fit is obtained. The objective of the iterative process is to obtain a spatial representation in p dimensions, such that the Euclidean distances among the objects are monotonically related to the original dissimilarities.

The iterative process comprises four steps:

Step 1 – Initial phase – selects the dimensions and determines the initial configuration and the resulting distances.

Step 2 – Non-metric phase – uses monotone regression. The estimated regression produces a new set of dissimilarities, called disparities that are monotonically related to the distances.

Step 3 – Metric phase – revises the spatial configuration to obtain new distances, which are more closely related to the disparities generated in step 2.

Step 4 – Evaluation phase – determines the goodness of fit of the distances and the disparities.

If the fit is not adequate, Steps 2 and 3 are repeated.

In the examples following, a Euclidean distance model was used which produces a projection identical to principal components analysis. The statistic allows any measure of similarity to be examined, MDS can use any distance matrix and as a result, the analysis focuses on the cases – the teachers – no information is provided about the contribution of individual questions answered (Fielding, 2007). Since the data are non-metric, they are interpreted as ‘distance-like,’ but not actual distance.

The aim of the MDS is to transform such data into a set of genuine Euclidean distances. The outcome consists of an arrangement of points in a small number of dimensions, usually two,
and located in such a way that the distances between the points relate as closely as possible to the dissimilarities between the objects. In non-metric MDS, only the rank order of entries in the data matrix – not the actual dissimilarities – is assumed to contain the significant information. Hence, the distances of the final configuration should as far as possible be in the same rank order as the original data. The purpose of the non-metric MDS algorithm is to find a configuration of points whose distances reflect as closely as possible the rank order of the data. Figure 2 is plot resulting from section 2 which concerned the student teachers’ perceptions of relevance of an external experience e.g., trips or visitors. We see two main clusters, and the fact that no one cluster is exclusively PR or PO means that the students changed their opinion as a result of the intervention or time to reflect. In Figure 3, the pre-test scores tended to overlap in pairs or three individuals indicating consensus in a range of variables: some thought that staff, the principal or board of management – equivalent to board of governors – might hinder them developing marine literacy strongly on the right and not so on the left of the figure.

![Figure 2. MDS plot of section 2 of OLQ, ‘PR’ refers to the pre-test scores; and ‘PO’ refers to the post-test scores](image)

**CONCLUSION**

The starting point for this work was Richard Louv’s (2005) phrase ‘nature deficit disorder’ which we view as the collective term for a range of lacunae in the experiential world of modern, western, humanity. ‘Marine deficit disorder’ – while this might be understandable, or even acceptable in a completely land-locked country which lacks any connection with the marine environment including commerce and trade – it is a real issue in Ireland; which is not such a land-locked country. The relationship of Ireland with the marine is fundamental to the existence of the country, not merely because Ireland is the most westerly country and island nation in the Atlantic Ocean but because all the peoples of Ireland have moved to these western isles by crossing the sea in the hope of a better future. It behoves every citizen therefore, to be cognizant of the sea, its importance and its fragility.
Figure 3. MDS plot of section 3 of OLQ, ‘PR’ refers to the pre-test scores; and ‘PO’ refers to the post-test scores.

Much work is needed to bring student teachers to an acceptable level of marine or ocean literacy. The OLQ requires further fine-tuning in order to specifically target key indicators of marine deficit disorder. The results demonstrate disordered thought evidenced by a disconnect between the two administrations of the OLQ. In our on-going work involving a mixed methodologies framework of lab sessions / beach visit / marine aquarium / printed resource use / expert visit adapted to local conditions and linkages, we anticipate an amendment to the Irish revised Primary School Curriculum to include explicit mention of the marine in the relevant sections of the curriculum whereas at present it is left to the teacher to adapt their plans and schemes to include any mention of the marine.

The OLQ did outline deficits in marine knowledge and understanding which for people who had completed their secondary education to a high level is particularly worrying; however, rather than merely filling the gaps, intervention does enhance and adapt and restructure the students' perceptions of the marine, and the picture becomes somewhat more complex. With continuing on-going work, it is anticipated that specific key experiences at a child's development may cascade specific understandings of the marine will be elucidated.

The OLQ is available on request from the corresponding author: tom.mccloughlin@dcu.ie.
REFERENCES


