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REVUE D'ÉDUCATION

Une publication de la Faculté d'éducation

EDUCATION REVIEW

A Publication of the Faculty of Education

At the Crossroads of Science and Environmental Education: International Perspectives.

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The present issue of the Education Review has its origins in the International Research Symposium *At the Crossroads of Environmental and Science Education: A Collaborative Agenda*. The main goal of that daylong conference was to advance the scholarship on the intersection of two sister fields: environmental and science education. Here, I share with readers a brief history of the (rather fortunate) events that culminated with the organization of the event. In doing so, I want to also publicly acknowledge my most heartfelt gratitude for the remarkable contributions made by those individuals mentioned here and without whom this important project would not have come to fruition.

In 2014, our faculty had the privilege of welcoming two visiting scholars to work on research projects related to the overall theme of the symposium. Dr. Rute Monteiro (University of Algarve, Portugal) was here to work with me on a study that aimed to investigate the learning opportunities created by adult-mediated interactions amongst children and non-human animals (e.g. Monteiro & Reis, 2014; Komesch, Reis & Monteiro, 2015). As for Dr. Kjellrun Hiis Hauge (Bergen University College, Norway), she came to work primarily with Dr. Richard Barwell on the use of post-normal science (Funtowicz & Ravetz, 2003) as a framework to analyze environmental discourses (e.g. Hauge, Reis & Barwell, 2014; Hauge & Barwell, 2015). In addition, I had just finished organizing a special issue of the Brazilian Journal of Research in Science Education – or RBPEC as the acronym goes in Brazilian Portuguese – with a good colleague: Dr. Alandeom "Alan" Oliveira (State University of New York at Albany, USA) (Reis & Oliveira, 2014; Oliveira, Reis & Mattos, 2014). Through that same guest-editorship work – and also a then recent contribution to one of his books (Kerckhoff & Reis, 2014) – I had a chance to work more closely with Dr. John Lawrence "Larry" Bencze (University of Toronto, Canada), a household name in the field of science education (e.g. Bencze, J., Carter & Krstovic, 2014). More importantly: I knew that both Dr. Oliveira's and Dr. Bencze's work would be invaluable additions to the symposium.

Volume 5, No. 2, FALL 2017

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My international (and stellar) guest list of speakers was almost complete.

Then, one day, when searching for a picture that would capture the essence of the event's theme and that could be used to illustrate the poster I needed to design to publicize the event, I came across the astonishing picture below—and I knew I had to use it. So, I contacted the author, Marie Cameron, only to find out that she is a talented and passionate artist whose work is undeniably committed to promoting a healthier relationship between humans and the environment. Better yet: she kindly accepted my invitation to join the ranks of guest presenters to talk about the picture (via teleconference all the way from California).

This picture illustrated the symposium poster (www.crossroads2014.blogspot.ca).

Photo and copyright by Marie Cameron (mariecameronstudio.com).

Marie wrote in her blog about her participation in the event:

> Today I spoke at my first international symposium (albeit from the comfort of my own studio in Los Gatos)! (...) At first I was a little intimidated: Crossroads of Environmental and Science Education – what did I have to contribute? The more I thought about it the more I realized that we were all concerned with communicating our ideas. Artist [sic] are particularly skilled at identifying engaging images, laden with symbols and metaphors that communicate directly to the heart and tug at the deeper recesses of our minds for truths we already hold dear. I spoke about what that barnacle encrusted bottle in the poster represented to me, a triumph of the marine environment to overcome and even appropriate the trash we throw at it. The fragile glass bottle symbolizes not only a human technological achievement but our frailties and by throwing this into the sea our wanton disregard for the environment. It's a symbol of hope in the face of our carelessness. What makes the image work though are other aesthetic elements: disparate combination of elements (barnacles and bivalves living in and on something that is not natural to the ocean) beauty, a pleasing palette, the bottle symbolizes the human element – which is important to engage people on an accessible, personal level. I guess a key to a powerful image that will stay with you is that it should not be didactic, it should just layout some things to mullover and puzzle out in your own head. Nobody wants to be told what to think. Everyone one needs to come to it on their own journey.[1]

Wow! (Really...what else could I say?)

If presenters came from diverse backgrounds (albeit having common interests), the audience was equally rich: university professors (from different faculties and institutions), teachers from local school boards and teacher candidates from the uOttawa's Bachelor of Education program. We were in for a day of high quality scholarly conversations that opened exceptional opportunities for collaboration, one of the many overarching purposes of the symposium.

The partnerships established that day continue to bear fruits: for example, Dr. Adam Brown (University of Ottawa), who was an active audience member during the symposium, has become a cross-appointed member of the Faculty of Education and has been working with Dr. Oliveira and myself on different research projects (Oliveira & Brown, 2016; Reis & Brown, 2016). Another attendee, Dr. Luiz Marcelo de Carvalho (State University of Sao Paulo, Brazil) has a forthcoming contribution in a book that I am currently co-editing with a colleague who was also in attendance that day, Dr. Jeff Scott (Nipissing University) – and so do Dr. Bencze and Dr. Oliveira. I personally look forward to continuing jointly working with them for years to come. (Let's not forget that the articles published here too attest to the incredible partnerships that were either established or strengthened at the symposium).

In preparation for the event, four guest speakers wrote short never-published-before manuscripts that were made available online to participants in advance to their presentations. They served as basis for the exchanges that took place throughout the symposium. Notwithstanding, I wanted to extend the impact of the research presented beyond the physical and temporal confines of the LMX 217 (a room that no longer exists). Therefore, and copying a model adopted by the journal Cultural Studies of Science Education[2], I invited four participants to write each a commentary to one paper / presentation of their choice. The complete "forum" (i.e. original papers and their accompanying commentaries) has been carefully reviewed and is now being published for the first time in this issue of Education Review. All to say that the articles published here are more than just a collection of manuscripts. They are truly scholarly contributions to those academics and professionals interested in the existing connections between the fields of environmental and science education.

Finally, I must express my thankfulness to the following people, in no particular order:

- Alishia Valeri, for the excellent copyediting of the original articles submitted;
- Anne-Sophie Ducellier and her team at Marketing & Communications, for

providing the high quality posters for the event;

- Dr. Christine Tippett, Dr. Louis Trudel, Dr. Richard Barwell and Dr. Jeff Scott for acting as skilled mediators who knew exactly how to engage people in meaningful conversations around the presentations;
- Dr. Raymond Leblanc, Dr. Stéphane Lévesque and Marlene Hoff, whose financial, logistical and collegial support to the symposium and this journal has been imperative for their success;
- Martine Clement and her team at Support Services as well as Sébastien Lacasse from Teaching and Learning Support Service, for the superb technical support provided; and
- Mohammad Alavi, for his instrumental logistical assistance.

Enjoy your reading!
Giuliano Reis (Guest editor).

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[1] October 8th, 2014, www.mariecameronstudio.com/blog/inner-artist-inner-scientist/.

[2] www.link.springer.com/journal/11422

Abstracts and Keywords

1. Students' actor-network-informed motivation for tackling socioscientific problems

Abstract
The wellbeing of individuals, societies and environments seem under considerable threat that appear to stem from decisions by powerful individuals/groups about the nature and uses of professional science and technology. In light of the apparent seriousness of personal, social, and environmental problems associated with affected science and technology, many academics have argued that school science, partly through teacher education, should help to prepare citizens to go beyond negotiation of personal positions on issues to actively address potential problems to contribute to a better world. Although this task is often met with various structural and cultural barriers, some evidence suggests that student motivation to act can be enhanced when they self-direct research to inform their actions. In the study reported here, we concluded – based on constant comparative analyses of qualitative data – that students' engagement in research-informed actions to address socioscientific problems can be enhanced through their uses of actor network theory and practices. Implications for promotion of socio-political activism in and through school science are discussed.

Keywords
Actor network theory – socioscientific issues – socio-political activism

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Lyn Carter
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Mirjan Krstovic
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2. Political dimension of the educational process: Environmental education (EE) and science education (SE).

Abstract
This article is a commentary on "Students' actor-network-informed motivation for tackling socioscientific problems."

Keywords
Environmental education – science education – political dimension of education

Luiz Marcelo de Carvalho
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3. Students' informal knowledge on risk: A study on students discussing oil exploitation close to their hometown.

Abstract
Risks are intrinsic in modern society and are frequently debated. Decisions on risks are often based on risk assessments, where impacts of unfortunate events are quantified together with their probabilities. Such assessments give the impression of controlling the uncertainty of unpredictable futures, while simplifications and assumptions may turn assessments irrelevant for complex risk issues. Critical citizenship and solutions to complex problems thus benefit from understanding characteristics of the risk issue, its implications for stakes and risk bearers, underlying complexities and uncertainties. In the presentation I investigate students' capabilities related to risk when 50 students in lower secondary school (14 year olds) discuss whether their local offshore area should be opened to petroleum exploitation. I show how insights are expressed regarding the complexity of the problem, what is at stake and various characteristics of associated uncertainties.

Keywords
Risk – oil exploitation – secondary science

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4. The role of values in the effectiveness of public communications of science for sustainability.

Abstract
This article is a commentary on "Students' informal knowledge on risk: A study on students discussing oil exploitation close to their hometown."

Keywords
Science education – sustainability – science communication

Adam Oliver Brown
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5. Young zoo visitors' prior knowledge about sharks: Opportunities and challenges for environmental and science education.

Abstract
In this study, the prior knowledge of young zoo visitors about sharks was assessed with the aim of building a Learning Progression Hypothesis (LPH). The research study took place at an oceanographic park located in southern Portugal, with visitors aged between 8 and 16. The resulting LPH is composed of three knowledge levels and has shown a clear predominance of anthropomorphic, anthropocentric, and utilitarian views of sharks. Are these perspectives obstacles to environmental and science education? How can these results assist researchers and teachers in the rethinking of educational strategies that promote more effective environmental and science education in schools?

Keywords
Zoo – environmental education – science education

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Giuliano Reis
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6. Mass media and environmental science education in the modern age.

Abstract
This article is a commentary on "Young zoo visitors' prior knowledge about sharks: Opportunities and challenges for environmental and science education."

Keywords
Mass media – environmental science education – zoo

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7. Socioscientific intertextuality: A text-based framework for environmental and science education.

Abstract
This article focus on the findings of a study that examined patterns of intertextuality (textual and contextual interconnections) that emerged when a group of biology teachers implemented units wherein students had to investigate and write in response to socioscientific cases. In addition to drawing attention to the analytic value of intertextuality, a text-based framework will

be presented that can serve as a new tool for conceptualizing and enacting instructional approaches centered on writing and can be used by educators to engage students in science and engineering practices of argumentation and communication based on evidential, ethical, and societal considerations.

Keywords
Socioscientific intertextuality – school science – biology teaching

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8. Envisaging socioscientific education for participatory democracies: Intertextuality as an organizing heuristic.

Abstract
This article is a commentary on "Socioscientific intertextuality: A text-based framework for environmental and science education."

Keywords
Socioscientific education – intertextuality – participatory democracy

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Students' Actor-Network-informed Motivation For Tackling Socioscientific Problems

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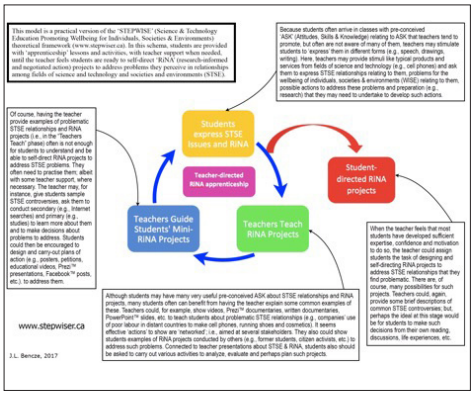
For about forty-five years (Pedretti & Nazir, 2011), educational "stakeholders" have placed at least some emphasis in science education on socioscientific issues[2] (SSIs), such as climate change debates (Lynas, 2008). Although much progress has been made, students often are limited to negotiating issues and defending their positions on them (Levinson, 2013). While argumentation-based approaches appear to help students achieve various outcomes, such as socioscientific reasoning skills (Sadler, 2011), students are rarely asked to develop and implement plans of action—such as petitions to power-brokers—to tackle potential problems within issues (Hodson, 2011; Levinson, 2010; Santos, 2009). Given the severity of potential problems associated with SSIs, we need to orient science education towards generation of more critical and activist societies to try to bring about a better world. Such a transformation will not be easy, however, in light of school science systems' orientation towards celebratory instruction in products—such as laws and theories of science and technology (Hodson, 2011). One promising line of research and practice, however, has been to encourage and enable students to self-determine focus questions, methods, data and conclusions regarding SSIs, a tack that may help build their self-esteem (e.g., Bencze, Sperling & Carter, 2012; Wenger, 1998). In light of the complexity of issues and challenges promoting actions on them, however, students could still benefit from additional approaches towards this end.

Research Context and Methods

Since 2006, based on the STEPWISE framework[3], Larry Bencze has been supporting teachers in efforts to encourage and enable students to conduct research-informed and negotiated action (RiNA) projects to address SSIs (Bencze & Carter, 2011). In this paper, we report some of the work of Mirjan Krstovic (co-author here), who has had considerable success in this regard (e.g., Krstovic, 2014). In his eighth year of teaching, having promoted RiNA projects with students in the last 3 semesters using the framework in Figure 1, he explored—facilitated by Larry—uses of actor-network theory (ANT), as recommended by Pierce (2013), to expand and "democratize" (highlighting often hidden actants) his tenth-grade "academic" (university-bound) science students' conceptions of SSIs.

Figure 1

Pedagogical framework for promoting student-led research-informed and negotiated actions on socioscientific issues.



To understand the nature and extent of students' socio-political actions as influenced by actor-network theory, our research had rationalistic and naturalistic characteristics (Guba & Lincoln, 1988). Data collected from students (ages 14-16) and Mirjan included:

- **Project Work Artefacts:** Samples of products generated by most students (57) were collected, including issue descriptions, research plans, data collected, written reports, project reflections, action plans and forms of

action (e.g., posters, petitions, videos);

- **Project Instructional Materials:** Copies of all of Mirjan's pedagogical plans and instructional materials were made (e.g., paper handouts, videos, PowerPoint™ presentations, and internet site web addresses);
- **Digital Recordings of Students' Project Work:** Photographs and videos were produced depicting youth presenting and defending their forms of action in public fora (e.g., to fellow students within and outside of class);
- **Semi-structured Interviews:** Eight volunteering students were interviewed twice, near the beginning and at the end of the course. Questions focused on their views about issues, research & actions. Mirjan was interviewed 11 times, for about 60 minutes each, about project progress. All interviews were audio-recorded and later transcribed.

Regarding analyses, each of us coded data for categories and then developed encompassing themes—using constant comparative methods based on constructivist grounded theory (Charmaz, 2006). Categories and themes were then negotiated between us (Wasser & Bresler, 1996). Member checks with participants were conducted to help ensure trustworthiness of claims, each of which was based on at least three supporting data sources.

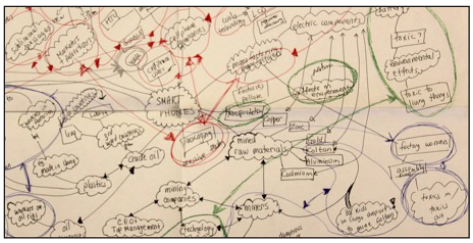
Results, Discussion & Scholarly Significance

Mirjan's first effort at infusing actor-network theory for promotion of students' research-informed and negotiated actions seemed relatively successful. Students' actor-network maps indicated they had relatively broad conceptions of SSIs, including in terms of recognition of possibly-problematic ones—like corporations. A typical student-generated actor-network map of a chemistry-related commodity (student-chosen) is given in Figure 2. Although some actant types, such as think tanks and transnational advocacy organizations (Ball, 2012) were omitted, her network included a wide range of actant forms, including: living things (e.g., children, activists, consumers), human organizations (e.g., media, mines), technologies (e.g., incineration [equipment]), non-living things (e.g., citric acid, inscriptions (e.g., movie), semiotic messages (e.g., perceived … obsolescence, national happiness).

Figure 2
Student-generated Actor-network Map depicted actor relationships for hand lotion.

As in many instructional situations (Barnett & Hodson, 2001)—myriad factors likely influenced results similar to those reported above. Firstly, it seemed clear that Mirjan's status as a part-time graduate student, "Left" political leanings, relatively Naturalist-Antirealist (Loving, 1991) views about the nature of science, strong professional growth agenda and three semesters of experience in promoting RiNA projects were helpful. At the same time, strategies he used to educate students about ANT in the context of an apprenticeship for RiNA also seemed very important. Particularly helpful were the strategies that educated students about the ANT phenomenon of *punctualization* (Latour, 2005); a "black boxing" process in which people are unaware of networks of actants linked to particular entities (actants). In association with a Socratic discussion with students focused on co-constructing an actor-network map of cell phones (Figure 3), for instance, Mirjan used the Trojan horse[4] metaphor, along with videos (e.g., Story of Cosmetics[5]) from The Story of Stuff[6] programme.

Figure 3
Excerpt of Actor-network Map regarding cell phones used in Mirjan's teaching.



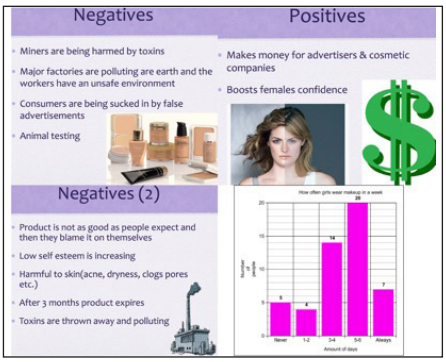
Influences of these strategies can clearly be seen, for example, in "Julie's" RiNA project. Her actor-network map (Figure 3) makes relatively-explicit reference to the Trojan horse metaphor—indicating prominent pro-capitalist actants (e.g., happy companies, advertising, planned obsolescence) perhaps distracting consumers from such negative effects as: [human] depression, fake results [of animal testing], non-renewable energy use. In a similar fashion, based on work on her network and her primary research (a study of females' uses of make-up), 'Connie' then developed and posted to YouTube™ an excellent educational video advising viewers of "positive" and "negative" aspects of liquid foundation consumption (see Figure 4 for screen shots from her in-class PowerPoint™ presentation). The video, which is structured around the stages of the materials economy (i.e., Extraction, Production, Distribution, Consumption & Disposal) from The Story of Stuff, again (like her actor-network) emphasizes the Trojan horse metaphor, with the following beginning and ending:

- **Beginning with:** [Foundation is about] hiding what we don't want others to see because we are scared to get judged. … This is what advertizers do [showing a woman's picture being edited with Photoshop™], hiding what they don't want their audiences to see so they can promote their businesses

as best as possible.

- **Ending with:** So, this is foundation's life. Just like a human, it goes through many experiences that people would never know about. Just like a book, never judge it by its cover (April 25, 2013).

Figure 4
A student's secondary and primary research findings about foundation make-up.



Actor-network theory can, therefore, not only, as Pierce (2013) suggests, provide students with critical ontological insights about SSIs but also provide them with rich, perhaps especially critical, contexts that can motivate them to (co-) construct social actions towards a better world.

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[1] Socioscientific issues are addressed, essentially, in different jurisdictions under various names, including STSE (Science, Technology, Society & Environment) issues (Pedretti & Nazir, 2011) and Socially-Acute Questions (SAQ) (Simonneaux & Simonneaux, 2009).

[2] See summary for teachers at http://webspace.oise.utoronto.ca/~benczela/a-STEPWISE4SEds.zip

[3] http://en.wikipedia.org/wiki/Trojan_Horse

[4] http://storyofstuff.org/movies/story-of-cosmetics/

[5] http://storyofstuff.org

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Political Dimension of the Educational Process: Environmental Education (EE) and Science Education (SE)[1]

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Environmental and science education: towards a political dimension of the educational process.

In their paper, presented at the International Research Symposium "At the Crossroads of EE and Science Education," Bencze, Carter, and Krstovic (2014) raised the potential and limitations of science and environmental education to deal with socio-scientific issues (SSIs) in classrooms. On one hand, they recognized that "much progress has been made" (p. 2) in terms of the development of argumentation-based approaches and socio-scientific reasoning skills in schools. On the other hand, they pointed out that students "are limited to negotiating issues and defending their positions on them" and that they "are rarely asked to develop and implement plans of action." In sum, the authors acknowledge the existing close relationship between the educational process and the political dimension of the human reality:

> Given the severity of potential problems associated with SSIs, we need to orient science education towards the generation of more critical and activist societies to try to bring about a better world. (Bencze et al., 2014)

In the same vein of the original article, I have chosen to discuss three different propositions that I consider to be the crux of the matter when dealing with socio-scientific issues and, consequently, with the political nature of science and environmental education. As science and environmental education researchers, we need to (1) make explicit in our research our views on the relationship between educational processes and the political dimension of human reality, (2) creatively construct science teaching and environmental education practices towards the generation of more critical and activist societies, and (3) explore science and environmental education practices that contribute to expand and democratize science student's conceptions of SSIs. My purpose in choosing such propositions is to emphasize those features in Bencze et al's paper that seem essential in other research reports that seek to explore the political dimension of our teaching practices in science and environmental education.

Proposition 1: The need to make explicit our views on the relationship between educational processes and the political dimension of human reality.

If we understand one's commitment to education as a process to ensure sociability, to build both human and non-human / human and human relationships, then we can characterize it as politically oriented. The available environmental education literature has comprehensively shown and emphasized this political characteristic of the educational practice. That is, the need to consider the political dimension of education—or the fact that environmental

education is related to the concept of political literacy—is likely one of the most stressed ideas in EE pedagogical projects, curriculum policy documents and academic texts (see for example Scott, 2011; Santos, Carvalho and Levinson, 2014; Reis and Oliveira, 2014). So, there seems to be no alternative other than to understand such proposition in more depth and explain the irreconcilable contradictions that emerge.

According to Rodrigues (2001), there is the need to raise doubts and ask questions about key concepts that are always linked to the aims and purposes of education, such as democracy, citizenship, autonomy, participation and social justice. It is not enough just to consider them an integral part of our common practices in education. He argues that when we consider any key concepts to be sufficiently clarified, this eventually limits our views of the educational process to aspects of pragmatic and utilitarian nature. Put differently, the eagerness to implement changes deemed necessary can mislead us to pose superficial questions and propositions to important practical problems. For example, when wanting to change the environmental footprint in schools, teachers and students take the risk of turning their attention only to the most immediate problems – not necessarily the most important ones. That way, they miss the opportunity to more deeply question and criticize the economic, political, social and cultural models responsible for causing those environmental issues at stake. Considering that this immediate perspective imprisons the social and cultural project of education, Rodrigues (2001) also suggests that we should always try to raise new questions about the essential concept of education – and Bencze et al.'s (2014) paper is an exciting exercise along those lines. In their study, these authors examine the possibilities of supporting teachers in efforts towards encouraging and enabling students to conduct projects that address SSIs based on some specific backgrounds, like research-informed and negotiated action (RiNA) and actor network theory (ANT). This, in turn, makes explicit that the authors take into account the political dimension of their own research and pedagogical practice when dealing with SSIs in the classroom; thus pointing out the paths taken "to provide students with critical ontological insights about SSIs."

From the article, we can also learn that it is not sufficient just to merely recognize the educational process as political – and, therefore, with the potential to promote the desired social change. First and foremost, it is necessary to recognize the profound meaning that the statement "science and environmental education are political acts" has for the planning of educational proposals that are truly political in nature.

Proposition 2: Science teaching and environmental education towards the generation of more critical and activist societies.

As I have already mentioned, the authors' main intention concerning the pedagogical activities that were carried out was "to orient science education towards the generation of more critical and activist societies." In this way, it is clear that they are assuming a critical perspective for dealing with SSI issues. In their own words:

Actor network theory can not only... provide students with critical ontological insights about SSIs, but also provide them with rich, perhaps especially critical contexts that motivate them to (co-) construct social actions **towards a better world. (**Bencze et al., 2014, bold emphasis added)

It is worth noting that this clear affiliation with critical perspectives on environmental and science education related to SSI issues is shared by many other researchers (see Bencze et al.'s references for more examples), who have tried to understand possible ways of dealing with these complex topics.

Bencze, Carter, and Krstovic's (2014) paper invites us to raise questions around environmental and science education research and their relationship with political dimensions of our reality (see also Trein, 2012; Layrargues and Lima, 2014):

- To what extent are we really making explicit our starting points and epistemological and ideological perspectives, thus avoiding the re-enforcement of apparent consensus in this kind of discourse?
- To what extent have critical perspectives that focus their analysis on economic production models been able to withstand the onslaughts of the pragmatism of green economies and consumption?
- How long can our theoretical frameworks and arguments resist the siren sound of environmental discourses that focus only on immediate results?
- Which answers can critical perspectives for environmental education and science education offer to the accusation of economic reductionism in the field?
- What critical perspective is at the center of this criticism? What are we criticizing?

It is important to consider, as Goergen (2010) points out, that different political options carry different social patterns. In this sense, we need to go beyond the surface and make our option explicit in terms of models of relationship between human-human and human-non-human elements. Similarly, in her suggestive paper entitled "Critical environmental education: but critical of what?", Trein (2012) claims that it is necessary to "make it clear that knowledge production, as a social production, is not separated from its ideological dimension and its class compromise" (p. 316). Bencze et al.'s paper is an example of academic reflection that does not neglect this political dimension of research.

Considering these questions and perspectives, Bencze et al. (2014) do not leave their readers without an answer. They

remind us that one basic task of education, as a political practice, is to contribute to explain power relationships, socially and historically built and imposed. It is important to provide students with critical tools that encourage and enable them to identify and understand mechanisms that maintain these power systems unchangeable. As Severino (2001) states,

> The educative process must help students to unveil the ideological bias of the social process. By criticizing the distorted meanings, education can contribute to a new social consciousness in students. In doing so, the education process can help avoid maintaining social current processes and will act as a force for change, helping to root out the alienation outbreaks. (p. 89)

Taking into account these considerations, we can understand how opportune it was the choice of this topic as the central theme for the for the 13th International Seminar on Environmental Education held in Brazil in July, 2015: "What is critical about contemporary 'critical' environmental education research? Theoretical challenges, tensions, applications, methodological implications." In that seminar, which has an ethos of being generative and critical about trends in the field of environmental education research, participants joined different working groups seeking to answer a question, which, among others, seemed crucial to the critical perspectives on science education and environmental education: what do we mean by "critical" and how do we practice it as research? What are we criticizing when we deal with critical environmental education?

Proposition 3: Science education and environmental education to expand and democratize science student's conceptions of SSIs

Last but not least, the other core idea that is present in Bencze et al.'s (2014) contribution is the link proposed between the educational process and democracy. As already pointed out: "he [the teacher] explored – facilitated by Larry – uses of actor network theory (ANT)... to expand and "**democratize" (highlighting often hidden actants**) his tenth-grade 'academic' (university bound) science student's conceptions of SSIs" (Bencze et al., 2014, bold emphasis added).

I would like to take the opportunity provided by this article to raise questions considered relevant in proposals that take into account that education is also, in some way, co-responsible with the task to construct a democratic society. Apple and Beane (2007) reported some experiences in US schools as exercises of democracy. For these authors, one of the tasks of education is "to empower young people to become members of the public to participate and have an articulated role in public spaces" (p. 8). They mention that, on one hand, the attempts to construct democratic schools in practice reveal limitations, difficulties and conflicts – such as, school structure, traditional curriculum views, control policies in school projects and pedagogical resources, different ideological views among teachers and administrative teams. On the other hand, they emphasize some important and crucial questions for this debate. For example, convinced that a democratic school demands intentionality and involvement of teachers and school administrators, they are in favour of the establishment of democratic structures, allowing democratic experiences regarding the organization of school life and the construction of the curriculum.

The extensive literature review, produced by Levinson (2010) and referred to in Bencze et al.'s (2014) article, focuses on the relationship between education for science and democratic participation, in which the author problematizes the relationship between science education and democracy. In his review, Levinson (2010) raises some controversial perspectives regarding the relationship between education and democracy: although, at first glance, this relationship may appear to be consensual and uncontested, it is actually problematic and involves different political positions. In his attempts to explore the possible tensions in the field, the author proposes four models to describe different ideological views regarding possible interpretations for the existing relationship between education and democracy. As Levinson (2010) presents it in his paper,

> The first two – deficit and deliberative democracy – fulfil a limited role for democratic participation. "Science education as praxis" and "science education for conflict and dissent" present more radical programmes but reflect tensions with the dominant discourse of scientific literacy and citizenship as reflected in school curricula. (p. 1)

In highlighting tensions in the proposal regarding environmental education / science education and democracy, Heila Lotz Sisitka (University of Rhodes, South Africa) and Katrien von Poeck, her doctoral student at that time, also brought some provoking reflections to their presentation at the 12th International Seminar on Environmental Education Research held in Sweden in July, 2013. When discussing "the democratic paradox and education: transboundary practice challenges," they explored the meaning of this so-called "democratic paradox". They argued that some authors advocate for a pluralistic approach (called "democratic approach") for environmental education or education for sustainable development. The expectation is that students become closely involved with different perspectives, views and values associated with environmental issues. While intended to develop independent thinking, participation in decision-making processes should prepare students to participate in debates by preparing them to evaluate for themselves the merits of conflicting positions. The pluralistic perspective proposes a scathing critique of approaches that focus on behavioural changes, where students are seen as nothing more than puppets of well-intended environmentalists and environmental educators.

On the other hand, as Sisitka (draft notes for the 13th International Seminar on EE Research, 2013) has pointed out, the most open perspective of the pluralist stance is also criticized by its opponents, who consider it insufficient to deal with urgent questions as posed by the environmental movement. The risk of these critics, according to her, is an exaggerated relativism where any democratic educational process is deemed positive regardless of the results. Finally, the mistrust is that this pluralistic approach is not able to cope with the anthropocentric hegemonic view of our societies, thus not being able to develop an ecocentric vision.

Thus, the questions raised by Sisitka and von Poeck along their paper, no matter how controversial and polemic they are, seem more than sufficient to explain the great challenges that are imposed for those of us, researchers and educators, who are convinced about the inherent connections between education and politics. From my vantage point, this issue must be included in the agenda of research in environmental education and science education—and Bencze, Carter and Krstovic's paper is a good example of this possibility.

Final considerations

I wish others would take Bencze, Carter and Krstovic's experience as an example of how to plan and investigate possible pedagogical practices to deal with science, environmental education and the political dimension of SSIs. It is important to continue to develop specific theoretical and methodological frameworks that can clearly guide our pedagogical practices and research towards our intended destination with our students. Likewise, it is necessary to make our ontological and ideological perspectives clear, thus pointing out our expectations regarding the political dimension that we intend to carry out with our students. Exercises like this, in which possibilities and constraints are revealed, play a key role beyond being a "safe haven." They present concrete, real and contextualized insights and possibilities that can inspire and help other researchers and educators to deal with different realities. Otherwise, there are great risks of inconsequent spontaneism and pragmatism when we face the different interconnections of education with the political dimension of life (see also Carvalho and Souza, 2016).

Référence bibliographique page 28

[1] This is a response to *Student's actor network-informed motivation for tackling socio-scientific problems* (Bencze, Carter and Krstovic, 2014), a paper presented at the International Symposium "At the Crossroads of Environmental and Science Education: Towards an International Collaborative Research Agenda" (University of Ottawa, Oct. 9, 2014).

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Students' informal knowledge on risk: A study on students discussing oil exploitation close to their hometown

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Risks (social, economic, environmental, etc.) are an intrinsic element of modern society (Beck, 1992). They are unpredictable and uncontrollable as the future is unknown (ibid). Defining what acceptable risk is in a given set of circumstances may vary considerably from one person (or one expert) to another. Furthermore, when risk issues are complex, experts need to simplify and make assumptions in order to quantify risk. Decisions on risks are therefore often a mix of facts and socio-political values (Funtowicz & Ravetz, 1993). Yet, risk is often dealt with as a techno-economic problem accompanied with an appearance of objectivity. In many countries, public hearings on risk issues are a common way to make the decision processes democratic. Such critical citizenship requires that the above attributes of scientific or mathematized knowledge are recognised.

Researchers from both science and mathematics education have argued that an essential part of preparing students for critical citizenship is to discuss attributes of mathematical and scientific knowledge in society. For example, Skovsmose (1992) argues that a crucial aspect of mathematical literacy is to know, what he calls, "the formatting power of mathematics"—i.e., how mathematics shapes society and our understanding of reality. Collucci-Gray, Camino, Barbiero and Gray (2005) argue that science education needs to break with the idea of science being a truth searching enterprise and instead see connections between science and values in controversial issues. Further, they emphasize uncertainty and complexity as important concepts to be included in environmental science education.

This paper is based on a study of students discussing whether their local offshore area should be opened to petroleum exploitation. The aim here is to see how students express their informal knowledge related to key risk concepts: complexity, uncertainty and conflicting values. The backdrop of this study is that there is a heated debate in Norway on whether to open the Lofoten area in northern Norway to offshore petroleum exploitation. The area is known for its stunning scenery, its rich marine fauna and the thousand years old tradition of drying cod for international trade. However, the offshore area also contains promising petroleum reservoirs. Although these students had not worked with the petroleum issue in school or in other discussions per se, I expected that the vigorous debate in their everyday surroundings had given them background experiences. Ultimately, the analysis of the interactions that took place during the discussion can give insights into the students' basis for developing critical citizenship in relation to risk issues.

Scenario-based tools (van Notten, Sleegers, & van Asselt, 2005) were used to catalyse discussion among 50 lower secondary school students (14 year olds). My fellow researchers and I were in charge of the day's program. Three anticipated future scenarios, one page each containing photos and questions, were given to the students: 1) full oil exploitation in Lofoten, 2) oil exploitation prohibited and 3) oil exploitation step by step. The students first worked in groups developing arguments defending or challenging their scenarios. The data used for this analysis were the audiotaped plenary discussion (1.5 hour) following the group session.

As the following excerpt from the plenary discussion shows, a student has favoured oil exploitations due to job opportunities (I have skipped the parts where I more or less repeat the students):

Melissa: There will be job opportunities, but in the end, there will be no more oil, so it isn't very sustainable. In the end it's over. And then we lose the jobs again. So, yes, you get jobs for a while. But it ends, and then it's not so sustainable over time.

Anne: It was just that we agreed that there would be more people, and that there would be more jobs and income and stuff. But then, it's also. It's sustainable, you know, but I agree that it will end, after a while, but that will take some time, you know, before it happens.

Joe: I think that if the job opportunities end, then I would think that we would go for more tourism, and that we would spend the income on getting more shopping malls, parks, things that bring the tourists here.

Anne: In my opinion, we could rather. Oil installations, rather subsea installations, then they won't show as much, and that would be better, that you don't see it. And then it may not be as damaging.

Mary: The fish may be frightened off, and tourism may decline. And the fisheries may be affected, sort of.

Roy: Most of the tourists come to [the students' hometown] because, you know, they want to view the scenery, and the fish. But, if we assume scenario A, it will be crowded with oil platforms out there, and if we then go to [the students' hometown] and, kind of, see how it looks here, then the oil platforms are likely the first thing we see. News on the debates, and how it ended. And there won't be many who will come to see the oil platforms… Yeah.

Joe: I would think that if they stop coming here because of the scenery, they will start coming because of the town. And that, if we then increase shopping malls and shops, those kinds of things, then they would rather come here to visit the town, rather than viewing the scenery.

Melissa: And then it's possible to have those below the sea surface, but, then someone said, it was kind of, tourism is not only to watch, they come to fish too, and stuff. And regardless whether we keep them subsea, the fish might be scared off, and stuff, and then we can't do it. And, it's a tourist attraction, to catch fish. Many come to fish. And then, and then there's no point in coming if there's no fish.

Lisa: And when there's, you know, a world championship in the cod fisheries, and we have subsea platforms, then it's not so certain it will thrive so well, because it is very selective on where it spawns. And if the machines are in the way, then it will go somewhere else to spawn.

For the sake of space, I will briefly sketch what I find interesting in how the students' expressions and interplay relate to complexity, uncertainty and conflicting values. A number of values are addressed in this excerpt, which is dominated by a concern for future job opportunities. Some of the students (Anne and Joe) express job opportunities as a positive consequence of oil production, while others (Roy, Melissa and Lisa) implicitly express concern for the existing jobs within fisheries and/or tourism. However, there is also disagreement about whether there is a conflict between these sectors. In refining their arguments, the students specify what they see as values at stake at another level: Mary argues that the availability of fish is a value at stake for tourism, compromised by the installations, Roy conveys the scenery as a value at stake for tourism and Lisa expresses concern for the well-being of cod.

Several of the expressed disagreements imply uncertainty about consequences: whether oil installations will influence Lofoten's appeal to tourists, whether cod will be disturbed, whether the job opportunities provided by the oil industry are significant and whether the oil industry will be a threat to other sectors. These are implicit statements about uncertainty as they represent counter arguments to others' arguments. The excerpt also includes explicit uncertainty statements through expressed assumptions or doubts, for example: "the fish might be scared off" (line 29) and "it's not so certain it will thrive" (line 33).

All contributions in the excerpt are interlinked, where the students continuously question previous claims and add value aspects. The combination of the interlinked elements and their associated uncertainties reflected in the discussion, gives an outline of complexity. The students achieve insights into the complexity of the oil exploitation issue through experiencing the responses from their classmates.

I see such discussions as developmental for critical citizenship in several ways. First, the students exercise discussion: listening to others, waiting for their turn, building and expressing their argument and responding to others' viewpoints and statements. Such capabilities are paramount for critical citizenship (Johnsen-Høines & Alrø, 2012). Second, they experience that real-world problems can be complex and associated with uncertainty and conflicting values. In our case, the students are not familiar with these concepts, but they demonstrate that they are capable of critically reflecting upon claims and assumptions and conflicting values. The discussion thereby supports the students' awareness of what is at stake and why there is disagreement. If the students were introduced to key concepts of the paper, this awareness could have been strengthened. Third, the public discussion on oil exploitation in the Lofoten area includes similar viewpoints and disagreements. One difference is that the public discussion is more shaped by mathematized and science based arguments. On this occasion, we did not present quantified or scientific information, but the classroom discussion illustrates that the students do have informal knowledge on complexity, uncertainty and conflicting values. I find it crucial for understanding risk issues that one has insights into the complex backdrop of quantified and science-based information.

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The Role of Values in the Effectiveness of Public Communications of Science for Sustainability[1]

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Introduction

It was a great pleasure to have been invited to the international research symposium entitled "At the Crossroads of Environmental and Science Education," particularly as a science professor with an interest in science education. As such, I found the nature of the presentations and the lively discussions that followed to be both refreshing and intriguing, most notably Kjellrun Hiss Hauge's emphasis on the values and emotions of a group of Norwegian secondary students in relation to oil exploitation. In scientific circles, conversations around themes like resource extraction tend to mostly focus on the scientific facts in support or against "universal truths" and great pains are often taken to avoid infusing any emotion or subjectivity into the discussions (Ziman, 1996).

The linking of the themes of science education and environmental education was also *à propos*. There is an ever-increasing prevalence of scientific issues relevant to society, through their implications towards environmental or public health, technology and industry, as well as its role as a driving force in the economy (Council of Canadian Academies, 2014). At the same time, humans are also negatively impacting upon the environment and ecosystems through activities such as resource extraction, urbanization and atmospheric and aquatic pollution at ever-increasing levels (Lubchenco, 1998). It is imperative therefore that members of the general public – especially young students – be informed by science in order to make evidence-based decisions as responsible citizens in a democracy (Siune et al., 2009). If properly understood, science can be useful in informing us with ways to deal with the degradation of the earth's systems, its biodiversity and our life-support mechanisms, not to mention personal and public health issues. Hence, it is essential that our scientists and science educators have a strong foundation in the impacts – desirable or not – of science on all matters related to the environment, as well as an effective way to share that crucial information with the public. However, we may have a long road ahead of us. In the timeless words of Carl Sagan: "We live in a society exquisitely dependent on science and technology, in which hardly anyone knows anything about science and technology" (Sagan, 1993).

Making sense of sustainability

In her article, Kjellrun Hiis Hauge documents aspects of the conversations that occurred amongst teenagers in Norway, as they talk about their concerns and expectations surrounding potential resource development projects in their small northern fishing community. Those conversations on the complex interplay between environmental risks and socio-political dynamics embody the essence of the sustainability paradigm, that is, to attempt to strike a balance between the sometimes competing environmental, social and economic interests of society (Shields et al., 2002). In particular, sustainability acknowledges that economic growth is an important feature of human society, but that it should not come at the expense of environmental or social equity (Cordes, 2000).

The concept of sustainability (here considered interchangeable with the notion of sustainable development) has its roots in the conservation movement for the environment (Brundtland et al., 1987) and has grown to encompass the human dimensions of social and economic sustainability as well (Asheim et al., 2001). Sustainability, therefore, is an ethical stance rather than a particular field of science (Norton, 1992). This fusion of the scientific and the socio-economic values of conservation, preservation and heritage represent a new union between the empirical and value-laden aspects of our relationship as humans to the planet and to one another. Consequently, sustainability has varying definitions based-on equally legitimate viewpoints from different public groups in any population (Shields et al., 2002).

It may be argued that we are undoing our progress in environmental stewardship due to the discord between sustainability leaders and those in corporate or political power. One needs only to point to the recently elected business tycoon celebrity turned politician, Donald Trump, to the Office of the President of the United States, as someone who embodies all aspects of disdain for science and environmental sustainability. So, the question remains: if the policies and objectives of society are meant to be guided by our perspective on the world around us (Fairweather, 1993), then why does it seem that sustainability indicators – although urgent and alarming – have not taken a more prominent role in social change, especially in the spheres of political leadership and corporate or personal behaviours? Despite the challenges associated with bringing the ruling classes on board the science-and-sustainability bandwagon, the answer may lie in recognizing the current deficiencies in sustainability communication towards engaging the public more directly and efficiently (Nisbet and Schefele, 2009).

Given that the basis for the environmental/ecological pillar of sustainability is founded

in complex scientific principles and concepts, such as the conservation of energy and nutrient flow through ecosystems, how are we to expect that non-specialist members of the general public may make informed choices for sustainability without the scientific credentials required to make sense of such complexities of nature? Furthermore, the relative poverty of celebrity science communicators – the likes of Neil deGrasse Tyson, David Suzuki, David Attenborough, Brian Cox, and Bill Nye – only limits the prevalence of engaging science stories in the news and entertainment media. Moreover, few scientists are skilled in public relations and public communication, thus perpetuating the stereotype of an awkward and unintelligible specialist who is unable to address the real or everyday concerns of people (Carrada, 2006; Somerville and Hassol, 2011). Consequently, there has been a movement within the scientific ranks to officially recognize our need as scientists to acquire and practice our communication skills when it comes to explaining science to the public (Bubela et al., 2009; Besley and Tanner, 2011; Brownell et al., 2013).

Indeed, scientists have long tried to effectively engage the public in enthusiastic understanding and support for scientific issues of importance to society, often to little or no avail (Kahan, 2010). In many respects, it would appear that we have largely failed in our abilities to communicate the scientific facts to the general public on topics such as the probability of risk associated with genetic modification of food, the safety of vaccinations or the relevance of human-impacted climate change, for example. Thus, the most important function of scientific communication to the public should be to clearly disseminate that knowledge to citizens, so that people can make appropriate evidence-based decisions on scientific issues of relevance to their lives, such as on the environment, their personal health, and consumer choices.

Science communication: from deficit to engagement

In engaging the public, the traditional approach from within the science community has often taken the form of administering a scientific lecture in order to alleviate their "knowledge deficit" (House of Lords, 2000; Bauer et al., 2007; Scheufele, 2013). This deficit model implies that the cause of public apathy towards the importance of science is rooted in their misunderstanding or general ignorance of it. Therefore, it was assumed that if members of the general public could simply be informed or educated about the workings and the results of science, they would quickly fall in line to support whatever conclusions scientific research had found. It was soon discovered that simply *talking at* a passive public about science did not significantly improve their *understanding of*, *interest in* or *engagement with* it (Gross, 1994; Sturgis and Allum, 2004). As a result, a new synthesis of the public communication of science has since emerged and, as we shall see below, it is one that factors in the role of emotions in how people learn and make decisions (Nisbet, 2008; Nisbet and Mooney, 2009).

It has become apparent that some of the source of disparity between scientists and the public on issues related to science and sustainability may not simply be due to the differing abilities of each to comprehend the technical scientific information, but also due to their differing values (Kahan and Slovic, 2006). A central element to risk perception, a necessary component to the cost-benefit analysis of sustainability issues, is the role of the affect – i.e. the positive or negative emotions and feelings it provokes towards the perceived benefits and harms (Kahan, 2012). In other words, when making decisions, people in the public sphere – including scientists in their private lives – may act on feelings as much as they do based on facts. Therefore, effective discussions about scientific issues of relevance to sustainability must also be accompanied by an exposition and sharing of the importance of the values of all parties affected by the situation. This is particularly true when we are dealing with highly complex socio-environmental systems, such as those associated with large-scale resource development projects close to human communities, which are characterized by high levels of risk and uncertainty (Funtowicz and Ravetz, 1995). In such cases, values may be more important than facts to many decision-makers.

In order to allow people to make the links between science and society, they must not only be able to understand and appreciate the process and applications of science, but also the social, cultural, emotional and ethical dimensions of the scientific issue, such as the possibility of balance between conflict/risk and equity (Colucci-Gray et al., 2005). Thus, due to the value-laden advocacy component to environmental science and sustainability, there is a great need for means by which scientists and science educators can engage citizens – especially students – in such a way that discussions on these topics lead to a healthy constructive conversation and learning on both sides of the table. This would be in stark contrast to the sometimes hesitant or hostile response from the public when they were to receive the traditional top-down lecture that specialists have been known to unload on non-specialist members of the general public in an attempt to inform them of the scientific facts of an issue (Royal Society, 1986).

Public communication of science: the new synthesis

In light of these social, cultural, emotional and ethical aspects of the effectiveness of science communication, the current model of the public communication of science (PCS) involves recognition of the need for dialogue among and between experts and members of the public. The dialogue has been improved upon by the use of techniques borrowed from the fields of communication and media studies and attempts to bring non-specialists onboard in a discussion of the issues, rather than appearing to talk down to them from a position of scientific authority (Nisbet and Scheufele, 2007).

One of the more fundamental ways

in which scientists can engage the public in conversations about science relies on these specialists losing the hard-wired communication tactics they were trained to use in specialized communications among their peers (Somerville and Hassol, 2011). Among many possible "tricks", scientists must try to get to the point, to lose the jargon and to avoid trying to explain the minutia of complex concepts or phenomena.

These seemingly simple adjustments may make all the difference in the effectiveness of non-specialized scientific communication, but they do not necessarily come naturally to academically trained scientists (Royal Society, 1986). At most universities around the world, students of science receive abundant training in highly specialized forms of communication (Carrada, 2006), which emphasizes the scientific method as a framework, speaking with the use of technical terminology and dwelling on detail. These aspects of specialized scientific communication are key to within-disciplinary discussions, as they are informationally dense and reduce interpretive ambiguities but do not lend themselves well to information transfer towards non-specialized audiences. Instead, simple adjustments to the communication strategy exist that would allow specialists to convey the crux of their message without alienating their non-specialist audiences (Nisbet & Scheufele, 2009). For instance, by simply stating your conclusions upfront (instead of at the end, such as would be the case in a seminar on the topic), using more common language and to explain ideas using analogies and metaphors rather than detailing all aspects of the scientific process (Somerville & Hassol, 2011). This shift in the approach towards a more generalized form of scientific communication is not meant to dumb down the messaging. It simply recognizes the desire of the non-specialist to understand the take-home message, without needing to delve into all the details surrounding it. This restructuring and simplifying of scientific communications directed towards non-specialists is essential to the effectiveness of dialogue, especially in these times with the dominance of social media in the lives of so many people.

The missing ingredient: framing for values

Finally, as elucidated above, a critical aspect to consider when discussing scientific issues that involve aspects of sustainability is that of the intended audience's values. This comes from the understanding that public audiences are not uniform, but, instead, are made up of different demographic and/or interest groups, each with their own set of values. People's values are formed by cultural, social, institutional and economic factors in their lives and therefore create a social context that may affect which aspects of an issue are chosen as the most important ones when making decisions about risks and benefits (Shields et al., 2002). For example, people in communities that have suffered from an economic downturn may be willing to sacrifice some considerations over environmental concerns in favour of the possibility of getting a well-paid job.

Herein lies the most significant challenge to the public communication of scientific issues related to sustainability (Kahan, 2010): science communication has traditionally emphasized a politically or socially neutral manner of information flow, but people's values and goals are intrinsically biased and personal; values may impact a person's leaning towards or away from certain risks and benefits, even in contradiction of factual information.

In communication fields, the key to proper information flow is in the accurate identification of one's audience; information content may be tailored to suit the motivations and interests of each particular group in a process known as "framing." This is the process by which a particular narrative is chosen to convey the importance of a societal issue and what is at stake in order to most effectively reach a particular audience type (Gamson and Modigliani, 1989). Ideally, contextual frames and a discussion of values should be integral to any scientific discussion on sustainability with members of the public. This enables dialogue, cooperation and learning, as well as the kind of social engagement that allows members of the public to become interested in an issue and empowered to make informed decisions of relevance to their lives (Nisbet and Sheufele, 2009). As such, it should also be a component to the training both of science educators and of future scientists.

Conclusion

The subjects of Dr. Hauge's study were youth at secondary school in Norway, and unsurprisingly, their values were front and center in their considerations of sustainability as it related to their perceptions of risk regarding future economic development in their relatively rural coastal town. These youths showed a high level of engagement with sustainability considerations when the framing of the issues related to off-shore oil exploration directly addressed values that were of close interest to them (e.g. the benefits from the creation of jobs and the building of shopping malls vs. the negative impacts on the local fishery and tourism industries).

The dialogue generated on the environmental, cultural, social, economic and ethical aspects of this proposed resource development project allowed the students to resolve some contradicting values, both personally and inter-personally, in order to agree on a common approach to the decision-making. Thus, this study of Norwegian youth may act as a microcosm for an approach aimed at resolving the push-and-pull of considerations that need to occur when we talk about sustainability. Hiis Hauge's study may also form a framework for the teaching and learning of effective communications of complex scientific, social and economic issues that address public concerns at the regional and global levels.

Modern society is a complex place, with many scientific issues at play that have direct impacts on our lives and well-being. In the face of widespread environmental destruction, there is an ever-

increasing need for an engaged public with a proper understanding of science to guarantee a functioning democracy and thriving ecosystems (Council of Canadian Academies, 2014). The meaningful development of this public understanding of science should be considered as an inherent responsibility of concerned scientists and science educators alike.

Acknowledgements

The author would like to thanks G. Reis and T.W. Butterworth for their helpful comments and edits on earlier drafts of this manuscript.

Référence bibliographique page 29

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Young zoo visitors' prior knowledge about sharks: Opportunities and challenges for environmental and science education

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Introduction

Overall, zoos identify education as a primary objective of their facility (Patrick, Matthews, Ayers & Tunnicliffe, 2007; Roe & McConney, 2015). For example, partnerships between these types of institutions and schools have been proven positive for science learning in urban contexts (Weinstein, Whitesell & Schwartz, 2014). In addition, there is the potential that visitors develop caring relationships with other non-human animals (Mayers & Saunders, 2002).

In the context described above, people's previous knowledge on the living organisms on display may influence what they learn at zoo education programs. For instance, if the program goals and content are in line with people's previous knowledge—or personal narratives—about animals, then learning tends to take place more seamlessly and without great difficulties. On the contrary, if the educational focus of the program is opposite to the visitors' personal narratives with the animals, then learning might not occur as comfortably. In such cases, the cognitive restructuring required from the zoo visitors to understand the animal in front of them is likely more complex and demanding. In other words, if one considers learning to be a transformative process where the whole learner changes as the result of what is now known (Ausubel, 2003), then any background knowledge—or entrance narratives—that zoo visitors bring to the encounters they have with the animals in captivity becomes relevant for

the zoo experience. This is especially true in the case of sharks, culturally perceived as dangerous man-eating animals by the general public (e.g. Nosal, Keenan, Hastings & Gneezy, 2016). This, in turn, can be counterproductive to learning about those animals in zoos. (Here, the term "zoo" is generically used to designate a place where animals live in captivity and are displayed for humans to view, which would also include aquaria.)

In the present exploratory case study, we accessed the prior knowledge of young zoo visitors about sharks. Our main objective was to build a Learning Progression Hypotheses (LPH), which is a benchmark for understanding the way knowledge is constructed (García, 1996; Pozo & Porlán, 2005). In this way, we were able to identify those learning obstacles that could prevent the learning of target concepts chosen by the zoo staff (like those associated with shark biology and behaviour) by an important segment of zoo visitors worldwide: young children (e.g. White, 2009). The understanding of how these young visitors perceive sharks prior to their visit to the zoo offers a pedagogical advantage to zoo educators, who then become better equipped to tackle the learning obstacles that visitors might face when encountering sharks as well as other animals during their visitation.

Young zoo visitors' drawings and interviews: What is a shark to you?

Data collection took place at an oceanographic park located in southern Portugal, where 235 young people answered the following question at the entrance room of the zoo: "What is a shark to you?" No posters or informational displays about sharks were available to participants in the space where they answered the questionnaire. Moreover, participation was entirely voluntary and individual, with no time limitations imposed to completing the task.

Immediately after the initial data collection, an intentional sample of 5 single-day zoo visitors was selected for a follow-up in-depth semi-structured interview, conducted by the lead author in a quiet place meeting room at the central office building. The age of the individuals selected for this part of the study ranged from 8 to 14. In cases where participants were accompanied by their parents to the interview, those adults did not intervene during the session. The interviews were 25 minutes long on average and focused on participants' perceptions of sharks as well as drawings that participants produced as part of this second data collection. The interview questions were based on four main general learning objectives as stated in the zoo's education mission: Biology (e.g. Which group sharks belong to? How many senses to sharks often use?), Anatomy (e.g. What are the teeth function? How many fins sharks have?), Ecology (e.g. Are sharks social animals? Are sharks important for the oceans?), and Environment (e.g. Where do sharks live? Are there sharks in Portugal?).

The interview transcripts and drawings were codified and categorized with the aim of interpreting communication through systematic and qualitative content descriptions expressed therein (Bardin, 1994). After our analysis, the initial 4 categories used during the interviews were modified and expanded to 13: anatomy, community, population, classification, senses, reproduction, movement, environment, trophic relations, conservation, behaviour, physiology, and longevity. Three of these are discussed in the next section, namely anatomy, behaviour and environment. They were chosen as we believe they illustrate important categories related to the conservation goals of zoos (e.g. Miller et al., 2004).

Learning Progression Hypothesis regarding the sharks

The resulting LPH for sharks is composed of three knowledge levels: initial, intermediate and reference. For example, within the anatomy category, in the initial level, the young visitors' prior knowledge is simple and real (e.g. presence of caudal fin), whereas in the reference level, the prior knowledge is more complex and abstract with more relationships (e.g. presence of caudal, dorsal and pectoral/pelvic fins, with fins related to maneuverability). Finally, in the intermediate level, the knowledge presents features of both (e.g. presence of caudal and dorsal fin, where fins are related to propulsion and swimming). Notably, not all categories had the three knowledge levels represented: behaviour had initial and intermediate levels only and classification had initial and reference levels only. The following is a more detailed sample of the results.

Anatomy

Overall, this category suggests that all participants held anthropocentric views of sharks. The *initial level* data showed the presence of neotenic characteristics (juvenilization), such as the head being detached from the body, disproportionate eyes and/or the presence of rectangular teeth, and illustrations of human expressions (such as anger or smiling). Additionally, the occurrence of blood on the teeth and mouth could be associated with chewing, a process that is absent in sharks.

As for the *intermediate level* data, the mouth is exclusively associated with feeding, without any reference to the gas exchange process. In the words of a young zoo visitor: "They use their mouth to eat." Within the reference level, the shark has a properly sized head (when compared to its body), including the representation of one or both eyes in proportion to the rest of its head, where the gill slits are properly identified. Three different types of fins (caudal, dorsal and pectoral/pelvic) and their respective functions (maneuverability, swimming and/or propulsion) were represented. The mouth, denoted either semi-open or closed, includes sharp teeth. Participants also associated the concept of teeth with periodic replacement ("[the teeth] are sharp and when one falls, another one appears") and their function in predation.

Behaviour

Initial level data indicates that sharks are

considered naturally aggressive animals that express their aggressiveness directly towards humans: "they can bite them [humans]… and eat them." In the intermediate level, sharks are represented with a preferably overnight circadian rhythm, during which they are more active and capture their prey, "sharks are more active during the night... it's when they prey." Though closer to reference biological and ecological knowledge, this representation still alludes to an innate intolerance for humans.

Environment

The examples within this category are both at the initial level (indicating a utilitarian vision of the shark's environment) and intermediate level (anthropocentric vision because of the presence of boats within the sharks' environment). Participant's *initial level* understanding is exemplified when a young visitor recognized the zoo or tank as the shark's environment. Moving along the LPH, *intermediate level understanding* was seen when young zoo visitors referred to artificial structures on the water surface (like boats). Finally, there was the *reference level*, which is seen when there is the recognition of the coastal and oceanic habitat with a representation containing a seafloor, with both benthonic and pelagic ecology.

Discussion

Across the categories exemplified above, the LPH has shown a clear predominance of anthropomorphic, anthropocentric, and utilitarian views of sharks. Although anthropomorphism can be advocated to help to facilitate learning by increasing empathy for human-like animals (Zohar & Ginosar, 1998), it can also be deemed problematic as its continued use may lead to ingrained erroneous concepts (Kallery & Psillos, 2004). Nevertheless, the predominance of anthropomorphism suggests intrinsic empathy of participants toward sharks. That is, the fact that one sees sharks as containing certain human traits make them more relatable (similar) to us.

Anthropocentric perspectives of nature—where we see ourselves as superior to non-humans—are a legacy from the Greco-Roman culture (Kellert 1996; Zohar & Ginosar 1998; Corbett 2006). Moreover, anthropocentrism is associated with a sense of disconnect from the natural environment, where we feel validated to explore the existing natural resources as if we were *foreign beings* and, thus, not accountable for what we do. More importantly, this utilitarian perspective contributes to deluding us from seeing how our own survival is not possible if we continue to destroy the planet (Weston, 2004). Ultimately, these aspects can be obstacles to young people's scientific and ecological learning.

At the same time, visitors' background knowledge can be used as the foundation for a more critical education. In this case, young people wouldn't have to go far to perceive the reality where they are immersed. It would suffice to be exposed to arguments that defy the notion of sharks as vicious creatures to promote the re-thinking of the way they misrepresent these animals.

Conclusion

Based on our findings, we believe that there is an urgent need to support environmental education strategies in zoos that utilize young visitors' prior knowledge towards to a more ecologically oriented practice of science education. Rather that being seen as obstacles to learning, people's perceptions of sharks can be used to promote a more critical view of these animals and their importance in nature. That is, our findings suggest that one's previous knowledge represents a valuable opportunity to develop environmental and science education in non-formal learning contexts. The confrontation of young visitors' perceptions with information that contradicts them can assist researchers and educators (teachers included) in the rethinking of educational strategies that promote more effective environmental and science education in schools. More so: it can assist our children to develop empathy for non-human animals and motivate action towards animal rights and welfare (Milton, 2002).

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Mass Media and Environmental Science Education in the Modern Age[1]

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As a retired science educator from the Ottawa Carleton District School Board with 30 years experience teaching Biology, Chemistry and Physics at the Senior High School Level I have had numerous occasions to visit, with my family and students, various zoos and aquaria in both Canada and the United States. Over these 30 years, I have noticed a profound change in the way these institutions act as an educational tool, as they have moved from a more passive to a move active participative experience. In my current role as a science educator in the Faculty of Education at the University of Ottawa, I was pleased to be able to attend an International symposium on Environmental and Science Education and share my experience and ideas as a science educator around environmental education. I found Dr. Monteiro's presentation of her research with young aquaria visitors and their experience with sharks to be of particular relevance as it outlined the educational value of aquaria and zoos to a populace that is becoming more and more urban with every generation.

Sharks have become a common attraction in zoos and aquaria around the world, almost becoming as popular as dolphins and whales (Dobson 2011). In this context, and according to Monteiro et al. (2017), aquaria use the prior knowledge of their visitors of sharks as dangerous, aggressive, man-eating fish as an attraction to grab public attention and increase revenue from admission ticket sales. This is not a new practice and started when the dangerous "killer" whales were first introduced into zoos and aquaria in the 1960's (Centre for Whale Research, n.d.). Nevertheless, once the visitor gets in the door, it is the role of the aquaria staff – also known as interpreters – to educate visitors to the great diversity of sea creatures and to change the *anthropomorphic* and *anthropocentric* views that many first time visitors to the aquaria may have of these sea creatures.

This exploratory study of the biological perceptions or misperceptions of sharks by visitors to an oceanographic park in Portugal outlines the major obstacle facing today's educators as a result of the mass media's need to entertain (as opposed to educate). The predominance of anthropomorphic and anthropocentric views of these animals by children between the ages of 8 to 16 are a direct result of how sharks are most often depicted in today's mass media productions. From "good" sharks in the animated movies *Finding Nemo* and *Shark Tale* to "killer man-eating" sharks in motion pictures such as *Jaws* and *Sharknado*, to mention only a few, sharks have been depicted as having many human physical characteristics. For instance, the ability to: speak a know human language, hold objects in their "human-like" fins, express emotions both verbally and facially, such as sadness, shame and deceit, and act with ulterior motives, such as revenge and altruism (Dobson, 2011).

Modern day oceanographic parks, aquaria and zoos have used the public interest generated in such movies to get visitors to their facilities. Once there, the public is exposed to close visual and physical interactions with living sharks and other sea creatures in a more realistic – but nevertheless educational – setting (Frost, 2011). Such interactions hold the potential to change commonly held – not to say misleading – views of animals in general. In a recent visit to Ripley's Aquarium in Toronto last summer, I was greatly impressed by how friendly the interactions between sharks, rays and other sea creatures with their "human handlers" at the aquarium were. There was also a tank where visitors were encouraged to touch living sharks and rays.

In sum, aquaria, zoos and educational television programming (such ad *Animal Planet*, *The Discovery Channel*, etc.) can play a major role in providing a scientific based examination of living organisms and ecosystems to counter the anthropomorphic and anthropocentric views of organisms customarily depicted by the mass media in general. Educators need to use these resources so that students can see the cinematographic depictions of animals for what they really are – great and sometimes not so great entertainment, but definitely never scientifically accurate (Frost, 2011).

As a follow up to this study it would be interesting to look at the perceptions or misperceptions of first time visitors to the aquarium before their visit and then monitor the change in perceptions after the visit. As the world becomes more and more urban many children and their families have lost their connections to nature and rural settings (Louv, 2005). Thus, the educational role of zoos, aquaria and oceanographic parks is becoming increasingly more important in overcoming any distorted views that humans might have of other living organisms. These institutions are needed to help people develop caring relationships with non-human organisms, and understand the importance of natural ecosystems, biodiversity and environmental stewardship to the continued survival of the human race (Frost and Laing, 2011). As human societies move towards a more urban setting and away from their rural roots and direct association with the natural world, one need not to loose sight of the fact that we are not alone on this planet.

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[1] This is a response to *Young zoo visitors' prior knowledge about sharks: Opportunities and challenges for environmental and science education* (Monteiro, Neves & Reis, 2014), a paper presented at the International Symposium "At the Crossroads of Environmental and Science Education: Towards an International Collaborative Research Agenda" (University of Ottawa, Oct. 9, 2014).

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Socioscientific intertextuality: A text-based framework for environmental and science education

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Drawing connections across texts is a practice central to the written construction of scientific knowledge. This linguistic phenomenon is evident in the pervasiveness of in-text citations in published science research articles. Often concentrated in the introduction of research papers, citations provide science writers with a rhetorical tool to situate their work within a field of inquiry, foster persuasion and cooperation with peers, create a research space for themselves, display expert knowledge of the scholarly literature, establish a credible writer ethos, and display allegiance to particular research communities (Hyland, 2000; 2006). As such intertextuality serves important epistemic functions in science writing. Rather than existing in isolation, science texts are produced and interpreted in relation to other texts previously encountered. As Bazerman (2004) writes,

> We create our texts out of the sea of former texts that surround us, the sea of language we live i n. And we understand the texts of others within that same sea… and sometimes the words are so mixed and dispersed within the sea, that they can no longer be associated with a particular time, place, group, or writer. Nonetheless, the sea of words always surrounds every text (p. 83).

Though historically intertextuality has been a term associated with literary theory and research (English and English education), there is increased recognition among science educators of the important epistemic role played by intertextuality in scientific research and instruction. This recognition is evident in current educational policies such as Next Generation Science Standards (2013) and Common Core State Standards (2010) which identify several intertextual practices as important literacy skills for science students to develop, including the ability to "compare and contrast findings presented in a text to those from other sources" (RST.9-10.9), "synthesize information from a range of sources (e.g., texts) into a coherent understanding" (RST.9-10.9) "quote or paraphrase the data and conclusion of others" (WHST.6-8.8), and "integrate information [from other sources] into the text selectively to maintain the flow of ideas" (WHST.9-10.8; WHST.11-12.8).

In alignment with this trend, the present study examined the patterns of intertextuality (textual interconnection) that emerged when biology students were asked to write in response to socioscientific cases—i.e., short texts with spatiotemporally specific and engaging narrative stories with characters, dialogue and a plot about science topics with societal ramifications such as global warming (Herreid, 2005), and biotechnology and environmental issues (Dori, Tal, & Tsaushu, 2003). Used by a growing number of secondary educators as a means to contextualize science and environmental instruction, socioscientific cases are designed to promote student learning of content by means of realistic, engaging, and contextualized written texts enlivened by dialogues and with real-life relevance (as opposed to a disembodied text with all the facts that they need to know).

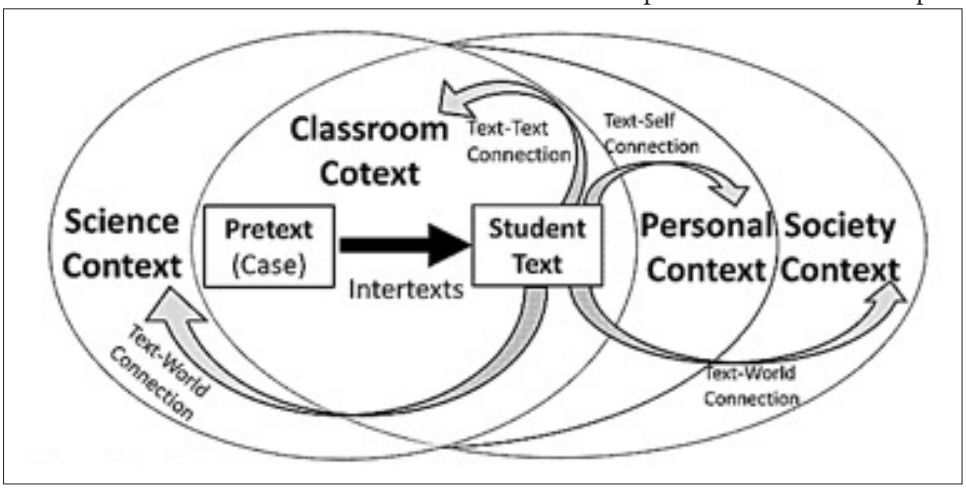
The reported intertextual analysis focused on two biology cases written by high-school teachers in central Brazil. The first case "A Child in Danger" addressed the importance and risks of taking the Measles-Rubella (MR) vaccine during pregnancy. Entitled "What is Wrong with Little José?", the second case told the story of a poor boy who gets infected with Schistosomiasis after swimming in contaminated water, a disease caused by parasitic worms of the genus Schistosoma that typically affects human populations in developing areas that lack basic sanitation and infrastructure.

The cases were implemented in two different local public schools. "A Child in Distress" was implemented as part of the discipline "Maternity and Childhood" in a Grade 11 classroom with 20 students in a technical high school in nursing. "What is

Wrong with Little José?" was implemented as part of the discipline "Biology" at a Grade 10 classroom with 22 students in a regular high school. Both schools were characterized by predominantly traditional forms of biology instruction centered on factual transmission and served student populations with similar socioeconomic, linguistic, and cultural backgrounds. Further, implementation of these two socioscientific cases lasted four days, following a project-based format. Although classes only met for 45 minutes daily, student groups also worked on their projects after school according to their own schedules. On the first day, teachers introduced the cases to students through aloud whole-class reading and discussion. Students then formed small groups and collaboratively defined and planned the nature of the response they wished to pursue. As a part of this planning, students posed questions they had regarding the case, identified questions to be researched, and brainstormed possible ways of obtaining the information needed to answer their research questions (e.g., visits to libraries and hospitals, interviews with doctors and other science experts). On the second and third days, student groups collected the needed information as outlined in their plans (in and outside the classroom), reviewed and synthesized the information gathered in writing, and prepared to share their findings with the rest of the class. On the last day, students shared their findings.

Students' written responses to these two socioscientific cases were viewed as having varied degrees of socioscientific intertextuality depending upon the extent of student social construction of a variety of intertextual links. As shown in Figure 1, the instructional process begins with the teacher providing students with a case, a pretext that prepares the ground for student production of their own texts (interpretations). This activity is mediated by intertexts (Lemke, 1990), that is, other texts that students use to make sense of the pretext and that become intertextually connected to students' emergent texts. Doing so results in the formation of text-to-text connections. Because students' socioscientific texts are produced at the intersection of multiple contexts (personal, societal, and scientific), other forms of connections are possible. For instance, students can make sense of the pretext in terms of their personal lives (in the context of personal experiences such as events lived and people encountered outside the science classroom, hence making text-to-self connections. The students' text can also be linked to elements from the scientific world (e.g., what science experts consider as accepted knowledge) or the societal world (e.g., existing social challenges, the concerns of interest groups, and citizens' opinions) that leads to the formation of text-to-science and text-to-society, respectively.

Figure 1
The Intertextuality of Socioscientific Instruction



A text analysis revealed that, though both cases were designed with the goal of promoting socioscientific intertextuality, only "A Child in Danger" fostered student text production with a variety of intertextual connections to self, society, and science. Student writing included information typically found in the scientific literature (scientific intertextuality) presented in the form of personal texts such as public manifestos (personal intertextuality) with explicit disclosure of their personal moral stance in favor of taking the MR vaccine. Such a moral endorsement of taking the MR vaccine as the right thing for women to do reveals a personal value held by the students. Lastly, societal intertextuality was evident in the fact that students' text had structural similarities with societal types of texts such as public service announcements and a rap famous in Brazilian pop culture. By contrast, "What is Wrong with Little José?" fostered scientific writing devoid of text-to-self and text-to-society connections (i.e., that lacked personal or societal intertextuality). Student sense-making was limited to regurgitation of factual content found in traditional science textbooks as evidenced by students' pervasive use of specialized scientific terminology, an impersonal and detached writing style characteristic of scientific exposition, and generalized statements about schistosomiasis.

The above finding suggests that classroom implementation of the two pre-texts led to the emergence of two distinct structured activity systems. "A Child in Distress" had the effect of organizing a social structure in which students performed a variety of intertextual actions (personal, societal, and scientific) by engaging an interdiscursive compositional process that blended technical vocabulary to everyday language and led to the creation of a written text with relations of meanings to texts drawn from multiple spheres of argument such as pop culture. As part of this socioscientific system of classroom

activity, students were able to express their own thinking with regard to a particular socioscientific issue. In sharp contrast, introduction of "What is Wrong with Little José?" led to a classroom activity pattern centered on knowledge-telling (Bereiter & Scardamalia, 1987). A part of this scientific system, student written activity was limited to scientific intertextual acts wherein factual content was simply retrieved from memory and existing scientific discourse. In the former case, when written intertextuality surpassed the scientific sphere and reached the personal and social spheres, students not only displayed their scientific knowledge but also strategically drew upon cultural knowledge, values, beliefs, and attitudes they shared with the audience to take a moral and personal stand, that is, to persuade teachers and peers that the chosen course action was the morally right one.

The reported research highlights the value of the proposed intertextual framework as a new tool for conceptualizing and enacting socioscientific issues based learning experiences. A long-standing hallmark and goal of socioscientific approaches to science teaching has been to help students establish meaningful links between their classroom experiences and their understandings and interactions within personal, societal and scientific spaces (Sadler, 2009a; 2009b). However, in many cases, designed learning experiences promote little more than superficial exposure to potential links among science, self, society and school science. The intertextuality framework for socioscientific instruction can help teachers, curriculum designers, and researchers more explicitly consider how socioscientific cases developed as contexts for science learning can be designed such that students are encouraged to create texts that prioritize connections to self, society, and science.

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Envisaging Socio-scientific Education for Participatory Democracies: Intertextuality as an Organizing Heuristic[1]

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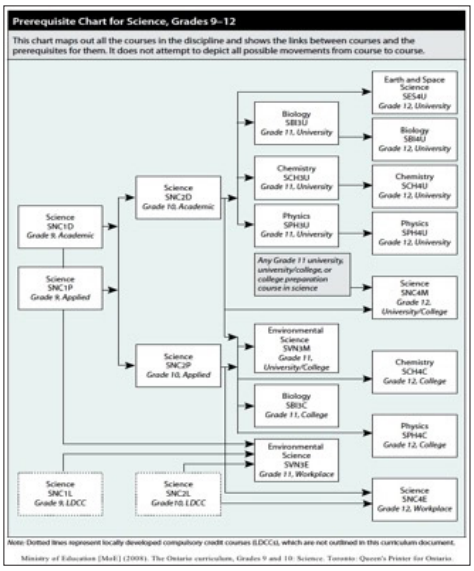
Introduction and theoretical background

It was a great pleasure to be invited to give a presentation in the Faculty of Education at the University of Ottawa (Oct. 9, 2014) on the theme of "At the Crossroads of Environmental and Science Education." The presentations were very interesting and diverse, reflecting the symposium's international flavour. Although learning through this 'cross-fertilization' of environmental and science education seemed significant, the need for such a special gathering seems somewhat problematic — although not entirely surprising. Why are fields of science education and environmental education separate? In the 'real' world (as far as we understand it), isn't everything integrated into environments? While reasons for separation of subjects into 'silos' are, undoubtedly, complex, many of us feel that such isolationism in elementary and secondary schooling is less about educating all students and more about sorting them (Apple, 2001). Indeed, the curriculum for early secondary school science in Ontario (MoE, 2008, p. 13), the site of this symposium, is relatively explicit about this, resembling — as illustrated in Figure 1 — a (human) mass spectrometer (or paper chromatography), sorting students into prospective post-secondary futures (and, likely, socio-economic classes). Such an education seems undemocratic, treating children as so much potential capital

(Bourdieu, 1986) — largely reproducing societal class distinctions (Freire, 1970).

Figure 1
Streaming in Ontario's Science Curriculum.



Despite the apparent continued dominance of subject segregations, Ontario and other national and international jurisdictions have introduced STSE (Science, Technology, Society, Environment) education components over the last several decades — acknowledging that fields of science are intertwined with fields of technology, societies and environments (Pedretti & Nazir, 2011). Among possible foci in STSE relationships, much attention has been paid to socioscientific issues[2] (SSIs) (Zeidler et al., 2005), such as climate change debates (Klein, 2014). This movement has potential for not only acknowledging subjects' integration in the 'real' world, but students could become enlightened about potential harms to individuals, societies and environments linked to problematic decisions made (e.g., by financiers) about science and technology and, moreover, feel prepared and motivated to take actions to address them (Hodson, 2011). Instead, the dominant approaches appear to use SSIs as 'instruments' (read: interesting contexts) for teaching products (e.g., laws & theories) of science and technology. This emphasis was highlighted, for example, in the symposium paper by Oliveira, Sadler and Nash:

> Used by a growing number of secondary educators as a means to contextualize science and environmental instruction, socioscientific cases are designed to promote student learning of content by means of realistic, engaging, and contextualized written texts enlivened by dialogues and with real-life relevance (as opposed to a disembodied text with all the facts that they need to know).

In engaging students in such controversial contexts, moreover, the focus appears to be less about encouraging and enabling students to take socio-political actions to address potential problems, which are often strongly-influenced by the control that powerful people/groups (e.g., corporations) exert over science and technology (Krimsky, 2003; Mirowski, 2011), and more about students making personal logical decisions about specific controversies (Levinson, 2013). This is confirmed in another article written by Zeidler and his colleagues (2009), where they suggest that the approach presents students with opportunities to "reflect on issues in order to evaluate claims, analyze evidence, and assess multiple viewpoints regarding ethical issues on scientific topics through social interaction and discourse" (p. 75).

On the one hand, SSI education approaches that prioritize personal logical decisions seem beneficial to students, including in terms of learning outcomes relating to: products of science (e.g., laws & theories) (Venville & Dawson, 2010), socioscientific reasoning skills (Sadler et al., 2007); and, the nature of science (Khishfe & Lederman, 2006). On the other hand, these approaches appear to conceive of citizens as dependent receivers of knowledge in representative democracies (Wood, 1998). Assuming that many or most decisions in democracies are at least heavily influenced by relatively few elite (along with a range of transnational and national supporting entities, like trade organizations), often those with considerable financial resources (Ball, 2012; Klein, 2014; McMurtry, 2013; Piketty, 2014), one view is that this places voters in representative democracies as performing a kind of immaterial labour (Lazzarato, 1996) on behalf of the elite; that is, processing and development of abstractions. Voting may be considered 'abstract' in representative democracies, given voters' only periodic engagement (e.g., every 4-5 years). Such cooperation in capitalists' pursuits of private profit, moreover, aligns well with corporations' legal rights and tendencies towards cost externalization (Bakan, 2004); that is, processes to ensure costs of for-profit production and consumption are borne by those (e.g., workers, voters, war victims) outside of financial elite.

In his analysis of democratic participation in socioscientific issues educational approaches, Levinson (2010) suggests — supporting, essentially, the discussion above — that the dominant paradigm is to promote either a 'deficit' (e.g., dependencies on experts) or 'deliberative' (e.g., limited negotiations with experts) model of citizenship. Such views of the 'citizen' seem antithetical to the concept of 'democracy' and, accordingly, many are calling for societal reforms that that support more participation forms of democracy (Wood, 1998). With regards to SSI education, this would imply, for example, more in the way of co-construction of knowledge, in which citizens not only discuss data and claims about issues, but they also contribute to their own development (Callon, 1999). Pouliot (2014) documents a case, for example, in which citizens of Québec City (Canada) collected data regarding spread of (carcinogenic) nickel dust — ultimately linked to city port activities — and used their findings to lobby the municipal government to enact legislative changes to reduce the pollution. In line with this reality, secondary school students have been self-directing correlational studies to generate knowledge that can be used as partial bases for decisions about socio-political actions they have taken in their communities and beyond (Krstovic, 2014).

Such examples of research-informed actions to address perceived socio-scientific problems represent, according to Levinson (2010), more participatory forms of citizenship — what calls, respectively, 'praxis' (e.g., knowledge co-construction with scientists) and 'dissent and conflict' (e.g., government-corporate complex protests) models of citizenship. Many scholars promote perspectives and practices in science education that may engender more activist societies — at least because a number of SSIs seem to pose significant threats to the WISE (e.g., Hodson, 2011; Santos, 2009).

Socioscientific issues education, participatory democracy and intertextuality

Although there appear to be sound arguments for forms of socioscientific issues education that favour/support participatory democracies, as suggested above, it has been exceedingly difficult for school science systems — comprised, for example, of governments, international comparative tests, transnational organizations like the Organization for Economic Co-operation and Development, textbook publishers, testing agencies, school district officials, parents, teachers, news agencies, etc. — to enact research-informed and activist forms of SSI education (Hodson, 2011). There are, perhaps, many reasons to explain the relative dearth of opportunities for students to act on potential problems. One possibility is that pro-social actions have an altruistic character, asking people to 'spend' some of their cultural and social capital (Bourdieu, 1986) on others and/or the planet — which they may find difficult. As Hodson (2003) said, "[i]t is almost always much easier to proclaim that one cares about an issue than to do something about it!" (p. 657). Giving of oneself seems somewhat antithetical to approaches that emphasize individual decision-making about socioscientific issues. There does, indeed, appear to be pressure on school systems to orient education towards personal choice (vs. actions), which is a major tenet of apparently-dominant neoliberal capitalist economic environments — in which possessive individualism often is prioritized over social welfare acts (McMurtry, 2013). Indeed, it seems reasonable to suggest that an emphasis on controversies — rather than research-informed and activist solutions — may be contributing to avoidance of attention to potential socioscientific problems (SSPs).

In reading, coding and analyzing (Charmaz, 2006) papers presented at the International Symposium in Ottawa (Oct. 9, 2014) dealing with connections between environmental and science education, the paper presented by Oliveira et al. appeared to open up possibilities for promotion of socioscientific issues education aligned with the nature of participatory democracies. They reported cases of two Brazilian teachers' implementation of problem-based learning by students in response to written documentaries of potential problems linked to science and technology. Brief outlines of the two documentaries and students' contexts are provided below:

- **Documentary #1:** "A Child in Danger": This case addressed the importance and risks of taking the Measles-Rubella (MR) vaccine during pregnancy. Students (n = 20) reacting to this case were enrolled in a grade 11 course at a technical school in nursing;
- **Documentary #2:** "What is Wrong with Little José?": This case told the story of a poor boy who gets infected with Schistosomiasis after swimming in contaminated water, a disease caused by parasitic worms of the genus *Schistosoma* that typically affects human populations in developing areas that lack basic sanitation and infrastructure. Students (n = 22) reacting to this case were enrolled in a tenth-grade biology course at a regular high school.

In each class, after students read the documentary, a teacher-led whole-class discussion to help clarify aspects of the documentary was conducted. Students then formed groups and, as instructed by their teachers, were asked to carry out independent (outside of class) research over a 4-day period — by which time they were expected to give class presentations of their reactions to the socioscientific issues presented in the respective documentaries.

The researchers chose to analyze students' responses to the documentaries from the perspective of intertextuality; an ontological concept that appears to signify co-construction of meaning, in which texts are seen as having diverse influences — such as historical precedents in language from a range of sources (e.g., scientists vs. politicians) and personal perspectives from idiosyncratic experiences. Their stated reasons for focusing on intertextuality is that it is considered to be a central characteristic of writing in the sciences, citing its importance in citations of science publications, which they say:

Provide science writers with a rhetorical tool to situate their work within a field of inquiry, foster persuasion and cooperation with peers, create a research space for themselves, display expert knowledge of the scholarly literature, establish a credible writer ethos, and display allegiance to particular research communities (Hyland, 2000; 2006). (p. 1).

Their analyses of students' responses to the socioscientific issues posed in the two documentaries led to the broad conclusion that the degree of intertextuality displayed among students' responses was much greater regarding the first documentary than the second one. They concluded, for instance, that students responding to Documentary #2 tended to simply "regurgitate" explanations, using language associated with professional science, from official textbooks. Meanwhile, students working with the first documentary tended to include:

Information typically found in the scientific literature (scientific intertextuality) presented in the form of personal texts such as public manifestos

(personal intertextuality) with explicit disclosure of their personal moral stance in favor of taking the MR vaccine. Such a moral endorsement of taking the MR vaccine as the right thing for women to do reveals a personal value held by the students. Lastly, societal intertextuality was evident in the fact that students' text had structural similarities with societal types of texts such as public service announcements and a rap famous in Brazilian pop culture (p. 5).

In other words, the documentary dealing with Schistosomiasis appeared to generate reactions appropriate for representative democracies, in which Deficit conceptions of citizenship would be the norm. Issues surround uses of the Measles-Rubella (MR) vaccine during pregnancy, on the other hand, seemed to create conditions that may be useful in participatory democracies, in which Praxis and Dissent and Conflict would be more acceptable. Students' first-hand research regarding pregnant women and vaccination in their communities represents Praxis, while their educational action in the form of a rap song appears to at least represent a step towards Dissent and Conflict.

In principle, it seems that the general pedagogical approach used in both schools in this study had potential to engender student responses to SSI documentaries supportive of life in participatory documentaries. That the problem-based learning approach seemed relatively student-directed and open-ended suggests that strong associations with the contexts of the documentaries and corresponding actions to address them could be developed. Based on knowledge duality theory (Wenger, 1998), learners should develop deep commitments to learning, actions, etc. if they are personally-engaged in reciprocal relations between phenomena (e.g., citizens' views of vaccination) and representations of them (e.g., educational messages about vaccination). However, this does not explain why there was more engagement in the secondary documentary than in the first one. That, in turn seems like a complex question. There are myriad contextual factors potentially explaining differences in educational experiences and outcomes in different teaching and learning situations; including, for example, the nature of the teacher, students, the curriculum and the milieu — e.g., role of school administration, parents, local politicians, media, etc. (Barnett & Hodson, 2001). That said, more contextual information about each school and class may have helped. One possibility is that there was some characteristic of the vaccination documentary that had particular relevance for the students involved and that was perhaps not very present in the Schistosomiasis documentary. A clue to this possibility does, indeed, exist in the results. In terms of the vaccination case, students were able to develop reasonably complex responses, displaying considerable intertextuality. To do so, they seemed to have relatively easy access to pregnant women, doctors and nurses implementing vaccination programmes and perhaps friends and family with various relevant experiences. The Schistosomiasis documentary, on the other hand, may not have had such connections with family, friends and community members. If this is the case, then success in promoting intertextuality in SSI problem-based learning results may depend, to some extent, on matching documentaries to students engaged — or to achieve the same matching by giving students a broader choice of SSI documentaries with which to work.

Summary and conclusions

The article by Oliveira et al. discussed here provided some wonderful and valuable insights into socioscientific issues education. Although their conclusions can be considered tentative, it appears that the intertextuality of students' knowledge constructions in response to SSI documentaries can vary significantly, perhaps depending on the level of relevance of the documentary to aspects of students' personal and social lives. However, another insight seems worth sharing: the problem-based learning methods used here could be enhanced. It appears they were set up as somewhat of an empiricist-inductivist[3] activity for students; that is, after watching the documentary, students were then expected to use information in it to ask their own questions, choose their own methods of investigation for learning more about the two main topics—i.e., Schistosomiasis and MR vaccine—and then synthesize their findings in order to arrive at a solution to the issues posed. Although this may work for some students, it has long been known that many students do not have the conceptual backgrounds to react in ways teachers believe important (Welch et al., 1981). When looking at the famous 'Gestalt' image of an old and young woman[4], some people see only a young woman, others see only the old woman, others see both, and some see neither. About such ambiguous images, in other words, "[w]e don't see things as they are, we see things as we are" (Barlex & Carre, 1985, p. 46; emphasis added). Perhaps more importantly, students' interpretations of phenomena appear to be limited by their cultural and social capital; that is, the richness of their experiences with the dominant sub-culture in a society provides them with a repertoire of conceptions, attitudes, etc. of that sub-culture (Bourdieu, 1986). Consequently, drawing appropriate conclusions may be a kind of 'survival of the richest' experience. Accordingly, it seems more democratic to provide students with a breadth of conceptions and then encourage them to use them for problem-solving situations having meaning for them. Pierce (2013), for example, recommends teaching students to develop actor network[5] maps, with specific examples that provide them with a range of actant types, particularly those to which they would not normally be exposed (e.g., government regulation policies when considering genetically-modified salmon), so that their consideration of socio-scientific issues may be more 'democratic' (read: broad and critical). Similarly, if an aim is for students to develop reactions to SSI documentaries that exhibit considerable

intertextuality, then it makes sense to first teaching them examples of such complex depictions of issues. Moreover, the results of the paper analyzed here suggest that students choosing to investigate a broad spectrum of actants (e.g., sources of texts for intertextuality) can take some steps towards actions to address socioscientific issues. They become, in other words, more prepared for involvement in participatory democracies.

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[1] This is a response to *Socioscientific intertextuality: A text-based framework for environmental and science education* (Oliveira, Sadler & Nash, 2014), a paper presented at the International Symposium "At the Crossroads of Environmental and Science Education: Towards an International Collaborative Research Agenda" (University of Ottawa, Oct. 9, 2014).

[2] Socioscientific issues appear to be addressed in different jurisdictions under various names, including STSE (Science, Technology, Society & Environment) issues (Pedretti & Nazir, 2011) and Socially-Acute Questions (SAQ) (Simonneaux & Simonneaux, 2009).

[3] Broadly, this phrase implies that investigators/students react to specific phenomena with physical materials and/or energy to generate general conclusions. 'Empiricism' refers to physical phenomena; while 'induction' is a process of drawing general conclusions from observations of specific instances (usually several of them).

[4] http://en.wikipedia.org/wiki/Ambiguous_image

[5] Actor network maps depict phenomena ('actants') as part of networks of actants, with reciprocal relationships between most, if not all, pairs. There are based on actor network theory, as described by Latour (2005).

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Education Review

The uOttawa Education Review
is a thematic bi-annual publication
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The Review is an initiative of
the vice-dean (Research).
ISSN# 1925-5497

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