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Beyond contradiction: Exploring the work of secondary science teachers as they embed environmental education in curricula

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Traditional secondary science education draws on markedly different pedagogies than those made use of in contemporary environmental education, therefore, embedding environmental education within secondary science curriculum presents both epistemological and practical difficulties for teachers. This ethnographic study examines the work of six secondary science teachers in Northern Ontario, Canada, as they engage in an action research project focused on merging environmental education in their science lessons. Over the course of five months the teachers examine and discuss their views and their professional development related to the project. In the place of definitive conclusions, six propositions relating the work of secondary science teachers to environmental education, form the basis for a discussion of the implications of the study. The implications are particularly relevant to secondary schools in Ontario, Canada, where the embedding of environmental education in science studies has been mandated.

Keywords: enculturated practice, environmental education, science teachers, science textbooks secondary science, action research, STSE, integrating environmental education

Introduction

Many years ago I stood on a high vantage point above the confluence of two mighty rivers, the Colorado and the Green, in the Canyonlands of Utah. I marveled at how the brown silty waters of one river met and mingled with the dark, clear waters of the other. Eventually further downstream the two rivers merged into one, melding their distinct qualities and strengths, and while neither was the same as it had been, the waters that flowed on from the juncture were more magnificent than before. It is that image that comes to mind in this research study that explores the confluence of two important rivers in teaching: science education and environmental education.

Traditionally, secondary science education, consisting of the three disciplines of biology, chemistry and physics, has been well-defined by curricula distilled after years of classroom delivery. Moreover, those three science disciplines have been generally considered, by teachers, to be socially and politically neutral, purely objective, rational, and value free (Hodson, 2003). Environmental education (EE), on the other hand, a fringe topic usually attached to either the science or geography curriculum (Greunewald, 2004) most often addresses current environmental dilemmas such as global warming, loss of bio-diversity, depletion of global food resources, and global water issues. Environmental issues have been viewed by educators to be politically and

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socially messy (Greunewald, 2005), not at all like the clean and ordered content of current secondary science classes (Chapman, 2007).

This research study undertook to examine how six science teachers merged the significant traditions of secondary science and environmental education in their high school classrooms in Northern Ontario. Specifically the questions that drove the research were:

- What theoretical foundations, epistemologies and values underlie secondary science teacher praxis?
- How do secondary science teachers perceive EE? How do they understand it?
- In what ways will EE challenge the classroom practice of secondary science teachers?

Literature Review

Many scholars (Greunewald, 2004; Hart, 2007; Hodson, 2003; Jickling, 2001; Stevenson, 2007) have been calling for a formal inclusion of EE within existing school science curricula specifically to address students' weak ecological literacy skills (Orr, 1992), and to introduce a more authentic, relevant and action-based science curriculum (Bencze & Hodson, 1999; Gough, 2002; Jensen & Schnack, 2006; Smyth, 2006).

In Ontario, Canada, two documents addressing the inclusion of EE in science curriculum were recently released by the Ministry of Education. In 2007 Ontario's Curriculum Council produced a report titled Shaping Our Schools, Shaping Our Future (also known as The Bondar Report) which examined the state of environmental education in Ontario. The Bondar Report strongly confirmed the importance of EE as a component of Ontario curriculum and called for environmental education expectations and topics to be embedded across all subjects, disciplines and grades (Ontario Curriculum Council, 2007).

In 2008 the Ministry of Education of Ontario released a revised Science Curriculum for Grade 9 - 12 in which an even greater emphasis is placed on a contextual treatment of science based on the Science, Technology, Society, Environment (STSE) model. The curricular expectations for STSE within the secondary science education documents in Ontario have a very strong environmental component that is positioned to introduce and define each of the topics studied. This move in Ontario, precipitated by the two documents, towards an integration or embedding of EE in science curricula provides unique and challenging opportunities for teachers of secondary science, both for their philosophical and epistemological positions and for their classroom practice.

Science Education

The discipline of science as it is taught in most North American secondary schools is constructed largely from the Western rational, positivist, reductionist position (Bowers, 2002); a position that privileges scientific study and the scientific method by creating the illusion that it is giving teachers and students the most value-free, reliable and secure knowledge possible about the world (Bencze & Hodson, 1999; Hodson, 2003); a position that regards science as the highest embodiment of human progress (Bowers, 2002). Traditional science classes, that is, science lessons based on a Western positivist paradigm, are replete with right answers, bodies of discrete content knowledge that are considered beyond dispute, and laboratory activities that are not investigations into the unknown, but recipes to be followed (Bencze, 2001; Gough, 2002; Hodson, 2001, 2003; Hodson & Bencze, 1998). Traditional science classes are most often understood to consist of science-based teaching strategies used by a science-trained teacher working within a science department, resulting in an over-valued single-discipline view of knowledge that is very difficult to transcend (Venville, Sheffield, Rennie, & Wallace, 2008). Stevenson (2007) calls traditional science teaching a "passive assimilation and reproduction of simplistic factual knowledge and an unproblematic 'truth'" (p. 140). Rather than thoughtful, active citizens in a democratic society who might have the capacity for transformation, it is suggested that schools are continuing to train students to be skilled workers and consumers who perpetuate the status quo (Gruenewald & Manteaw, 2007; Hodson, 2003).

Environmental Education

A precise definition of environmental education continues to be pursued by its scholars, made difficult in part by its interdisciplinary and diverse nature both in content and pedagogy. Environmental education is described in either general terms (Gruenewald (2004) states its purpose as that of providing experience and knowledge necessary for caring for environments) or in what appears to be a miscellany of topics (Hart (2003) calls it a post-modern study of political, social, cultural, ethical, religious and philosophical issues as they pertain to humans in the environment). Generally it is agreed that through a variety of learning experiences both in and out of doors, EE should provide students with the knowledge and skills to become citizens who are able to work towards finding a balance between human agency and the preservation of the natural environments of the planet (Greunewald & Manteaw, 2007; Hungerford, Peyton, & Wilke, 1980; Smith & Wheeler, 1999; Smyth, 2006). Together Orr (1992), Sauvé (1996), Hart (2003) and Stevensen (2007) agree on the complexity and interdisciplinarity of EE, on the non-traditional pedagogies that it engenders, on its necessity for critical and place-based perspectives, and on its social and political relevance.

Even within these definitions and guiding principles however, environmental education is enacted in numerous ways and in a broad range of venues, from the formal classroom, to outdoor education centres to naturalist clubs and beyond. Environmental education embraces related fields like outdoor education, experiential education, place-based education and environmental science. These all have at their core the goal of experiencing, learning about and caring for natural environments, including the plants, animals and people that inhabit them.

Contradictions

Because environmental science and ecology are found as topic areas in science curricula, as are those, for example, in Ontario (see course expectations in Ministry of Education of Ontario, 1990, 2008a, b), it has long been a general assumption of educators that science dovetails nicely with environmental education. However, the divergent natures of traditional science education and an evolving EE suggest that traditional secondary science and EE are in many respects incompatible and that merging them presents significant difficulties for both.

The dilemma of combining science and EE in some way has been the topic of substantial academic discourse, directed particularly at their differing philosophies and dissimilar pedagogies. While science education is based on a positivist, rational cataloguing of the world, EE stems from a post-modern desire to understand and act upon our relationships within the world (Robottom & Sauvé, 2003). Both Hodson (2003) and Smyth (2006) contrast the reductionist approach of science with the systems approach of EE; the first takes things apart to see how they work and loses sight of the whole, while the latter considers the whole and its interconnections. Hart (2007) points out the incongruity between science as knowledge transmission and EE as active deliberation, debate and independent learning. Stevenson (2007) refers to the contradictions between the two, particularly with reference to their treatment of discrete disciplines: traditional science is balkanized in its disciplines while EE calls for an interdisciplinary approach (Robottom & Sauvé, 2003). Bernstein (in Stevenson, 2007) suggests that interdisciplinary pedagogy creates difficulties for teachers in terms of teaching strategies and assessment in that single-discipline pedagogies are much simpler to enact (and thus more prevalent). Environmental education adds ethical/moral, political, social and cultural components to curriculum (Hart, 2003) thereby challenging teachers' views that science should be value-free (Dillon, 2002). In a recent paper Pedretti, Bencze, Hewitt, Romkey and Jivraj (2008) noted that traditional science education has been a review of disciplinary knowledge and that teachers defined themselves as gatekeepers of that discreet information without much consideration for the messiness presented by real world issues. Pedretti et al. found that teachers were reluctant to broach the social and environmental issues (SE) of STSE fearing that it "devalues the curriculum, alienates traditional science students and jeopardizes their own status as gatekeepers of scientific knowledge" (p.943). Indeed Venville et al. (2008) point out that specialized knowledge gives a sense of order to a complex world and provides specialized problem solving skills, both compelling reasons to sustain traditional science curriculum.

Several years earlier in Australia, Gough (2002) made the observation that science education has been unable to overcome its traditional structures despite mandates calling for social relevancy and scientific literacy; she calls this the rhetoric-reality gap. Gough lists five reasons why she believes that science curriculum is a limited vehicle for EE enactment: a) a global trend towards standardized curricula that further removes teachers' abilities to plan their own curriculum; b) the content of science curriculum as heavily influenced by the science community in its desire to further tertiary studies; c) EE is perceived as another of a long line of topics requiring inclusion in an already crowded curriculum; d) many science teachers are disciplinary chauvinists who prefer to teach in their specialization rather than tackle an integration of topics, and; e) most science teachers do not have the same understanding of EE as do environmental educators.

Indeed, supporting these points, Gayford's research in 2002 found that science teachers did not willingly address social, political or economic issues, even as they related to science topics (Gayford, 2002). The teachers participating in the study were not comfortable with integrating social or political issues in science and felt that teaching values was not part of their role. In further agreement, The Bondar Report (2007) (Ontario Curriculum Council, 2007) contends that, "many teachers currently lack the knowledge, skills and background in perspectives taking required to teach environmental education effectively" (p.7). In an action research project addressing STS implementation, Pedretti (2001) found that while teachers may find resonance with the rhetoric of STS recommendations (science, technology and society: the forerunner of STSE), their practice was not likely to change due to the inherent complexity of STS and the lack of real time that educators have in their work. With those obstacles to STS in mind, it is disheartening to learn that Hart (2003) contends that it is the E (environment) in STSE science curriculum that will present educators with the most pedagogical difficulty:

> Although the notion of STS as an integrating, broadening, more practical and relevant frame for science is not a new concept, the addition of an environmental dimension brings into sharp relief certain epistemological and pedagogical issues involved in changing science curriculum policy and practice. (p. 1240)

In other words, while a study of science and technology is reasonably aligned and can be presented alongside some social issues with minimal effort and fairly positive results, the inclusion of studies of environment, especially issues of eco-social-justice, will challenge educators working within the safe neutrality and conformity of a traditional science curriculum. Although

EE offers educators the overt opportunity to question systems of educational hegemony, knowledge construction and instruction (Breunig, 2005), unfortunately educators who do not have the time or intent to address an STS focus will be even less likely to tackle STSE. Pedretti et al. (2008) agree that teachers' loyalty to subject matter (which is a large influence on how they form their professional identity) is precisely what stands in their way of taking an STSE approach to teaching science curriculum. "Simply put, issues-based STSE education challenges traditional images of a science teacher and science instructional ideologies" (p. 943).

There is another, somewhat tangential argument that can be made in regards to the STSE model, wherein science and technology as human centered (anthropocentric) endeavours are situated in direct opposition to environment. It is, after all, through human science and technology that we have developed the tools that allow us to *shoot a rapid, conquer virgin territory, exploit and manage resources, rape the countryside, battle the elements,* and *subdue the savage*. Our language is riddled with images of human agency in confrontation with nature and environment, and is an indication of our deeply lodged values (Hodson, 2003). The assumption that studies in science and technology will smoothly ally with EE is naive.

So what will happen when EE meets secondary science in Ontario classrooms? Will they coexist? Will one dominate the other? Dillon (2002) asks the question, "Should science education give up some of its curriculum time to environmental education on the grounds that environmental education is likely to provide richer and more efficacious learning situations?" (p. 1113). Is this even possible given the presumed reluctance of many secondary science teachers to teach beyond knowledge transmission? The current situation in Ontario, wherein EE is to be embedded in curriculum including secondary science, offers a remarkable opportunity to continue to understand how teachers will engage with EE. It seems certain that the inclusion of environmental education will present a variety of epistemological and pedagogical challenges for secondary science educators, whereby change will be inevitable but the nature of the change quite uncertain.

The Research Study

Methodology

Action research, as used in this project, was both ethnographic and narrative in its nature. As an ethnographic inquiry this study was an observation of and a participation in a specific group over time, with myself as the Researcher/Facilitator (RF). Then as the participants told their stories to the RF and to each other, a narrative form of inquiry emerged. The focus of the action research project, as formulated and stated by the participants, was *to model a small group approach to embedding environmental studies into science curriculum.* It was my role as the RF to both facilitate and observe the participants as they worked through their action research project.

A number of researchers have used action research in an EE context with favourable outcomes. Wals and Alblas (1997) worked with four instructors at an agricultural college in the Netherlands to develop a list of guidelines for implementing EE in other schools. Chris Gayford (2002) looked at the inclusion of global climate change studies in science curriculum by science teachers in the south of England. He found that while the teachers had very high ideals regarding teaching science, they were reluctant to engage students in political or social issues relating to science. In their work with science teachers, Capobianco, Lincoln, Canuel-Browne, and Trimarchi (2006) engaged in an AR project from a feminist perspective that helped teachers redefine their views of science, and how they could empower all of their students to participate in it.

There is general agreement among scholars that qualitative ethnographic data can be considered trustworthy through: prolonged engagement with participants; member checking through peer/text review and discussion; thick description of data; clarification of researcher bias; and triangulation whereby data is gathered from a variety of sources (Connelly & Clandinin, 1990; Creswell, 2009; Denzin & Lincoln, 2000; Eisner, 1991; Glesne & Peshkin, 1992; Mulholland & Wallace, 2003).

Data collection for this study was consistent with the requirements for trustworthy ethnographic research data: (a) the project spanned five months (b) consideration was given to member checking and thick description (c) data derived from various sources (meetings, interviews, classroom visits and teacher writings) ensured triangulation. Data took the forms of transcribed conversations and stories (meetings and interviews), observations of behaviours / teaching practice (classroom visits field notes) and artifacts (student work and teacher writings). The largest portion of the data, in the form of transcribed conversations, was acquired during participant meetings and interviews. These are rich with stories that describe the work, experiences and attitudes of the participants and their students during the course of their project.

Research Study Overview

The research project took place in Timmins, a town in Northeastern Ontario, Canada (population approximately 60,000) which, in comparison to Southern Ontario with its much larger populations, is only infrequently the recipient of professional development through university-based research studies. As such it was hoped that the location of the study might provide alternative perspectives on issues in education, based on the lifestyles and underlying values of northerners.

Due to the size of the town there are only three English-speaking high schools and these fall under the jurisdiction of two different school boards: the English speaking public board (District School Board Ontario Northeast), and the English speaking Catholic board (Northeastern Catholic District School Board). A significant consideration for the study was the actual number of English-speaking secondary science teachers in the city from whom a group of interested and dedicated participants could be formed. With only three small/medium sized English-speaking secondary schools, the number of science teachers was limited (approximately 16) and many of the teachers already knew each other as acquaintances through school activities such as Science Fair and athletics. Eventually the group of teachers who participated in the project consisted of three males and three females; all but one of them was white and Caucasian, the sixth being of Arabic heritage. It was coincidental that there were two teachers from each of the three secondary schools, and that these pairings consisted of one male and one female. While perhaps not a diverse group when compared to the Canadian demographic, it seemed fairly representative of the overwhelmingly Caucasian population of the town. Missing was aboriginal representation, however, there were no aboriginal secondary science teachers in the city at the time the study took place.

Despite differences in experience, perspective, age, and personality, the six group members very quickly and intentionally sought coherence as a group. Between them they were familiar with and had taught the full range of secondary science courses offered in Ontario, and were able to speak knowledgeably about specific provincial curricula. All of the participants were university educated, with an additional full year of teacher training; the teaching experience of the participants ranged from a novice (1 year experience) to a veteran (30+ years experience). It is also worth noting that two of the participants enjoyed camping and other outdoor activities, while two other participants disliked and avoided outdoor pursuits. None of the participants had been directly involved with formal environmental education prior to the study. In describing the work of the participants the pseudonyms Sharon, Tess, Jane, Harvey, George, Bart are used throughout this paper.

Data Collection

This study was conducted from September 2008 to January 2009, a time framed that spanned the secondary school fall semester. At the outset of the study the participants were interviewed individually. Interviews generally lasted between 20-40 minutes and explored the participants' personal epistemologies and practices in relation to science education and environmental education. The participants were encouraged to speak to their inward feelings, hopes, and values, their outward individual contextual situations, and their backward and forward, or past, present and future thoughts (Clandinin & Connelly, 1992). Interview questions included: What do you think are the goals or purposes of teaching science at the secondary level?; What do you think are some of the most important aspects of science that secondary students should learn? and; What do you think is meant by 'environmental education?

The six participants met six times over the course of the five months, every three weeks, with each meeting lasting approximately three hours. The RF set structured agendas for at least the first three meetings in order to establish the general topics and direction of the action research project. Meeting agendas consisted of a variety of readings, narratives and structured questions. Table 1 displays the topics of each of the meetings. The first two meetings explored perspectives on science, environmental education and action research with the intention of establishing a common understanding of those topics amongst the participants. Environmental education was introduced as a broad area of study that spans many disciplines, with special emphasis placed on the definitions of environmental education by Shaping our School, Shaping Our Future; Environmental Education in Ontario Schools (June 2007) and by the Ministry of Education of Ontario (2008a, b) (referred to earlier): *education about the environment, for the environment and in the environment*.

During the third meeting the discussion focused on changes in the Ontario Science curriculum such that STSE, and EE in particular, are given emphasis equal to content and skills knowledge. Based on the discussion in meeting three, the participants finally decided upon a focus for their action research: *to model a small group approach to embedding environmental studies into science curriculum.* The participants decided to designate a day during which each of them, at

Table 1. Meeting topics

Meeting and date	**Discussion Topics**
1	The nature of Science; teaching secondary science; what is action research?
2	The nature of Environmental Education; teaching EE.
3	Designing an action research project specific to the group
4	Continued planning for their action research project
	Action research project is implemented in participants' classes on Shh! Environment Day.
5	Discussion of the results of their research project
6	Discussion of the effectiveness of action research as a form of teacher development

their respective schools and in their respective classrooms, would continue to teach the curriculum they were currently involved in, but to do so from a decidedly environmental perspective. This was to be, simultaneously, a group project and an individual exploration, inasmuch as they would help each other with lesson ideas and strategies, but each of them would be teaching a different lesson in a different science course.

Subsequent meetings addressed various aspects of the research project, its design and implementation for individual classrooms, and a review and discussion of the results. During the last meeting the participants discussed their project in the larger context of ongoing professional development.

At the outset of the project several of the participants described a general reluctance, on the part of their students, to engage in environmental studies. The introduction of ecology or environmental science topics were often met with audible groans from students. George's students told him that this reflected their experiences of boredom brought on by heavily text-based, teacher-driven environmental science lessons. Harvey offered that environmental studies were, for most students and teachers, a study of the negative with significant finger-pointing and preaching about the gluttony of a Canadian lifestyle. This standpoint is driven home with regularity, beyond the classroom, as different forms of media bombard subscribers with 'green' information. Small wonder that students are neither interested or excited by what has become the mundane, and which amounts to a condition over which they feel they have very little personal agency or control.

Concerned that their efforts to integrate EE into existing science curriculum would be met with the student resistance and eager to tackle a realistic embedding of EE such that it no longer was discernible as a distinct topic, but rather an integration of STSE, the participants decided to make the project a covert operation. They would not mention to students or colleagues that their lessons on that day were specifically designed to embed EE; no one but the group knew that it was to be an environmental day. The challenge was made greater by their intention that the lessons on that day would not veer far off the course of the planned curriculum, yet contain substantial embedded elements of EE. Thus the day came to be known as Shh! Environment Day.

The RF visited each of the participants' classrooms on Shh! Environment Day. The classes were generally 70 minutes in length, and were held in various locations in the schools, including the school chapel, the chemistry lab and the school roadside. Harvey's lesson blended a chemistry lab investigating water from different sources with an ongoing discussion of the environmental implications of water pollution. The students had been required to bring water to class from a variety of sources, such as their faucets, and wells, and then use procedures found in a senior chemistry textbook to determine water quality and mineral content. As they worked, Harvey challenged each lab group to connect their findings to local public water issues. George's lesson was intended to address not only issues of EE, but also the Ontario Catholic School Graduate Expectations (1998) and the grade 11 biology (Ontario Ministry of Education, 1999) STSE requirements. The lesson mirrored George's professional strengths in that it was very reflective, and based in large part on storytelling that aimed at having students consider the impact of the First World's consumption rate on Third World living conditions. George had invited the school chaplain to team teach with him; the chaplain used the story of the Three Little Pigs as a metaphor detailing the manner in which three different people lived their lives in relation to their environments. The students were encouraged to identify with one of the pigs, whereupon a lively discussion ensued as to how the students might balance their lifestyle choices with their footprint on the environment. Finally, since the lesson took place at the beginning of the advent season prior to Christmas, the students were encouraged to commit to one significant act of environmental stewardship over the Christmas holidays. During Bart's physics lesson students explored the nature of sound by experimenting with tuning forks, and then applying knowledge of sound transmission to communication strategies among porpoises. As the third step to their lesson, Bart had the students use the internet to research the ban on leaf-blowers as sources of noise pollution in urban areas. Tess's chemistry lesson addressed fuel efficiency of automobiles used in Timmins; students identified and recorded the type of vehicles passing the front of the school during a set period of time. The students then determined the percentages of fuel-efficient vehicles that they had observed. As part of her human biology/nutrition lesson, Sharon and her class visited a local grocery story to identify the extent of organic food offerings. The students were recording and commenting on not only the availability of items, but also their relative nutritive and health values. Afterwards, Sharon planned for each group of students to prepare a letter to the grocery story outlining their findings. Rather than her traditional lecture and note format, with a possible recipe-lab, Jane took an issues-based approach to teaching about environmental estrogens. Students groups were asked to read a variety of newspaper and magazine articles outlining the costs and benefits of synthetic hormones and then summarize these on chart paper. The students were very engaged in the lesson as they found personal connections to the information on environmental estrogen.

Data Analysis

At the outset of data analysis, and faced with reams of transcription, it became apparent that a set of ground rules would be necessary for deciding which emerging ideas or topics should be considered for further discussion. Consequently it was decided by the RF that a topic or theme emerging from the data would be considered noteworthy if it displayed one or more of these characteristics: (a) the topic had been discussed in the literature review (for example: the various perspectives of EE that educators might hold) (b) the topic was discussed by the participants at great length at least once (c) the topic appeared briefly on numerous occasions in the data (for example: the use of textbooks in science classes) (d) all, or almost all, of the participants held an opinion on a topic (for example: the importance of content knowledge in science was discussed more than once and by all of the participants) (d) a resonance in the data with the personal experience of the RF (for example: EE as a concern of the white middle class). The data analysis produced a number of themes or ideas that are presented in the next section.

The Propositions

Generalizations and conclusions, in this qualitative study, may be seen as presumptuous or premature, thus the findings are presented here with a different intentionality. Wallace and Louden (2000) contend that a story, or in this case a series of statements, will be recognized by the audience as being truthful if there is an agreement with the researcher about what is considered important. Thus, in place of irrefutable conclusions, six statements or propositions are put forward as they relate to the original research questions of this study. The propositions are a consolidation of the themes and ideas that emerged in the data analysis. It is hoped that one or more of these propositions echoes the reader's experiences, that they evoke connections to the reader's perspective, and that they find convergence with the reader's opinions. After all, it is through the parallel reflections of language and reality construction that such statements might be recognized as meaningful and authentic (Wallace & Louden, 2000). (Participants' pseudonyms and source of comments are parenthesized; author's brackets are used to provide clarity in the comments)

- ✓ What theoretical foundations, epistemologies and values underlie secondary science teacher praxis?

1. To a large extent secondary science teachers recognize the importance of non-traditional science pedagogies, however, they continue to enact the discipline of science as a politically neutral and rule-structured human endeavour that values knowledge as sacrosanct.

In initial conversations it was clear that the project participants were eager to explore science teaching pedagogies beyond those that comprised their respective practices. Indeed they were interested in how EE-based pedagogies, for example issues-based teaching, might support an integrated approach to student learning. One conversation addressed how science learning might inform civic duty and ethics:

> "I think if they can develop their own views on any issue and support it then that's what's going to effect change in anything they're involved in. If they're just going to sit there and take in information and do what they're told then that's what you're going to get… (Harvey, meeting four)
>
> Technology, discovery, all of this does advance human kind, so that is a powerful tool. Not only do you want to be able to create it, you want to be able to think about its implications ... much more than just creating it right?... Science can cure disease, it can get us to the moon and beyond. That's powerful information. So you don't just want to inform them, you want them to know what to do with it." (Sharon, meeting four)

However, it was a telling indication of their fundamental perspectives that all of the participants, when asked to describe a scientist, detailed a white male, wearing a lab coat and glasses, working in a chemistry lab. For the participants this iconic image represents a deeply ingrained popular version of science and scientific method: a gendered, Western, elite and rational approach to knowledge acquisition. Although the participants indicated their understanding that scientific research is significantly impacted by political, social and economic elements, nonetheless, they saw the rational nature of the scientific method as a means of nullifying those influences, thereby rendering scientific endeavours as the very best way of acquiring knowledge.

The participants' views on the nature of science echo Bowers' (2002) assertion that Western privilege ascribes to scientific study the highest form of human progress, and what Bencze and Hodson (1999) claim as an illusion that is value-free and produces reliable factual information.

> "What's the goal?... A lot of it is knowledge-based, these are the facts they need to know, this is the information we need to disseminate. There's no real demand for a person to take that one step further into problem solving situations." (Harvey, meeting four)

The teaching practices of the participants, in the form of the lessons that they discussed, indicated a very traditional and deferential respect for the value of that scientific knowledge. For example, in discussing the design of secondary science curricula the participants continued to accede to the importance of the traditional disciplines of chemistry, physics and biology, with their requisite reductionist lessons like, parts of the cell, and, parts of the atom. This perspective is consistent with views expressed by Venville et al. (2008) in describing the myopia of science studies as over-valued and discipline-focused. Moreover, the science studies to which several of the participants assigned lesser importance, such as weather, ecology and space studies were seen as less valuable to the academy overall, in part due to what George called their imprecise or fuzzy nature and in part to the teachers' perception that those studies would not be revisited in secondary science.

> "It was a department decision and we looked at the curriculum and space [unit], they [the students] will never see space again [in high school] so don't do the space unit." (Sharon, meeting three)

An explanation for this assignation is offered by Bencze and Hodson (1999) who maintain that the myths surrounding school science teaching include a belief that "science comprises discrete, generic processes and that scientific inquiry is simple and algorithmic" (p.522). For example Sharon explained:

> "That's my comfort level as well... more towards scientific fact, not scientific discovery and how to techniques". Tess added, "We are doing the best with the knowledge that we have now, right? So that's all we can really do, and just hope that we pass on enough scientific literacy so when they [the students] do go to the next level … that they can have an understanding of what they need to understand". (meeting two)

Not every participant's view was equal in this regard; most notably Harvey, who had worked as a research scientist, had a more realistic understanding of how science is enacted, yet even he, as a teacher of senior students, was reluctant to step away from a traditional disciplinary-knowledge-based teaching practice. Harvey articulated his concern over the loss of knowledge:

> "There's the idea that we want to take a more holistic approach and get the kids more involved. It seems to diversify your teaching strategy but ...what's being lost? So maybe knowledge is being lost?" (meeting three)

Lastly, in the scope of this proposition, the participants broached the requisite topic of assessment and evaluation issues associated with EE. Most of them expressed concerns that student learning associated with EE, (for example: interdisciplinary activities, out of classroom learning or student-focused topics) would be problematic in that it would require a different and unfamiliar set of assessment strategies and tools. The participants voiced the belief that the Unit Test remained the single most important method of assessment in secondary science. Lab reports, quizzes and skills demonstrations were also highly valued because they were well-developed and familiar methods of determining content acquisition. Indeed, George's jest *"I was wondering if you are seen recycling 7 times you get a level 4? Will there be a rubric?"* points to an underlying discomfort based on the perceived need to assess and evaluate learning that was not content or skill based. Indeed, teaching and assessing content knowledge alone is seductive because it is a simple transmission of information that upholds the status quo of traditional science education (Barrett & Pedretti, 2006).

The ideas presented in proposition #1 echo the study done by Rico and Shulman (2004) in which they found that the four science teachers with whom they worked had tremendous difficulty (and were unsuccessful) in shifting away from an overarching focus on content knowledge. The second proposition explores the possible reasons for the continued preeminence of content knowledge in science teaching.

2. The culture of secondary science teachers, steeped in the 'tradition of science', is a powerful deterrent to meaningful change in science teaching.

This proposition is based on three issues that surfaced in the data: the reluctance of some of the participants to tamper with what they perceived to be well-developed and long-standing traditions in science teaching, a fear of relinquishing their role as science 'experts', and the pressure that colleagues seemed to exert in order to maintain those traditions.

The suggestion that the enduring traditions in science, tending towards the rational and the logical with the teacher as the gatekeeper of knowledge might be supplanted by issues-based or student-directed pedagogies was disconcerting for some. In the following quote Sharon expresses her concerns related to student/issues-based pedagogies:

> "How do you teach something that you don't know much about?... And is that why I'm not always comfortable with all sorts of issues sometimes... I guess maybe not knowing the solution, ...They're [the students] going to enlighten you...Well there's this insecurity [in talking] about environmental issues. I'm learning as they're learning. And often you're more the expert in the field so to do this stuff with environmental. I don't have that comfort level. That's scary…Would students lose, not necessarily respect, but confidence in a teacher? And if students don't have confidence in you I think I'd feel a little more vulnerable ." (meeting three)

The teachers' efforts to change their practices to include EE were further stymied by their own admitted reluctance to entertain discussions in politics, society or economic consideration, believing those to be outside their purview and that of the traditional realm of high school science (a finding supported by Gayford, 2002). In addition, Harvey suggested that an emphasis on STSE, ethics, or critical thinking could be seen as tantamount to an abandonment of peer culture.

> "There's a lot of impatience because people want to be told what to do and the second you don't, the second you say, "Well we're going to see what the problem is, I'm going to see how things work" you get crucified for that." (meeting four)

The attitudes that formed the culture of these secondary science teachers seem to be ingrained and resistant to change (although this group had self-selected to participate in a study that clearly was proposing change). It is suggested that one element of enculturation is rooted in the curricula provided to teachers (Barrett & Pedretti, 2006). For example, in Ontario, while classroom teachers might slightly modify the curricula provided, they are expected to adhere primarily to provincial science guidelines and expectations, thus creating an institutionalized and teacher-based practice. Jane provides a further example:

> "When we had the dialysis tubing, it used to be in the grade 10, and I'd make sure I'd add glucose you know, as the things were sitting on the side. Add some stuff to make sure they get the right colors because otherwise when a lab doesn't go right, oh!" (meeting two)

Harvey's comments regarding the lessons used on Shh! Environment Day indicate his belief that only small changes in practice are necessary to embed EE in science curricula.

> *"I think for the most part from what I've heard of our activities [lessons on Shh! Environment Day] I don't think they were something really elaborate and changing everything around, and then the next day you go on back to your normal class. It seemed more like we worked in the context of the curriculum or unit that we were in*

> *and just said, 'This is what I'm going to do,' and then put a little twist on it."* (meeting five)

The project data indicated that it was through their shared experiences and collaborations that the participants found ways to alter their enculturated practice. For example, in a conversation concerning the perceived unassailable necessity for formal lab report assignments after every experiment-based lesson, George ultimately required permission from the other participants in order to effect a change: *" Well after we left last week and other people said, "Oh no, we're not doing those long labs, those big formal labs." All right! I'm not going to either. This is awesome!"(meeting two)*

Hodson and Bencze (1998) suggest that because science teachers' never fully contemplate their own disciplinary balkanization and are thereby passive to, or even thwart, change. The authors further identify two factors that come into play: (1) secondary schools are generally grouped into subject departments but actual teacher work is accomplished in isolation and (2) teachers have been described as leading professionally orphaned lives. Teachers are "isolated from research findings and theoretical debate about key issues in science education" (p. 692), and they are given neither the time, the opportunity, nor the facilitation required to fully contemplate their own enculturation, and the necessity and nature of change (see also Sharpe & Breunig, 2009). Harvey's comment illustrates his frustration with his situation:

> "Just being able to talk to another teacher...how often does that happen? For example, I'm teaching courses with other people like Tess, but we never get a chance to talk. Its not like we don't want to, we just never get the chance." (meeting six)

Fortunately, through readings and discussion prompts provided by the RF, the participants did address some of the issues of professional development and connection that Hodson and Bencze (1998) raise. The subsequent collaborations by the participants resulted in lessons that held ample evidence of emerging teaching strategies associated with EE, and in further discussions the participants all expressed an increased comfort level with the integration of EE in their practice. For example, both Tess and Sharon's lessons occurred outside of the school, George took a narrative-based approach in his science lesson, and Harvey used his water chemistry lab in a local context.

The project data supports the view that change in science teaching is a difficult and complex undertaking that requires patience, a commitment by educators to address issues of enculturation, and acceptance of those changes by colleagues.

3. Textbooks play a central role in shaping secondary science teachers' perceptions of science pedagogy and environmental education.

Each of the participants, during various conversations, admitted to a lack of skills and knowledge in a particular area of science, and their consequent reliance on a textbook as an essential guide in both the organization of a topic or unit, as well as day-to-day lessons. The project data indicates that a heavy reliance on the textbook for content information, activity choice and sequencing occurred not only when a participant was faced with teaching in an area of science with which they were unfamiliar, but also as part of their regular classroom routine when they were comfortable with the subject matter. Participants explained that relying on the textbook made their work simpler, and gave them and their students a point of focus for the lesson (a finding similar to that of Shibley, Dunbar, Mysliwiec and Dunbar (2008). For example, Jane was initially very dependent on her textbook's chapter on ecology because of her weak knowledge base in that area, thus allowing the textbook to become the teacher in the context of requisite content information and relevant activities.

> "I don't have the comfort level there, you know the knowledge, so it's, "Let's open the textbook to page," and I really don't like that. It's not interesting. I don't know how to make it interesting" (Jane, meeting three)

Both Tess and George acknowledged the usefulness of reading and seat work provided by a textbook for the purpose of classroom management. Indeed, George suggested that there are teachers for whom the textbook is their only form of lesson planning, "…*some people just go left to right* [motions turning pages in a book] *day by day*". The overt reliance on the textbook, voiced and demonstrated by almost all of the participants, parallels the findings of Ogan-Bekiroglu (2007) whose research targeted secondary physics teachers, and Tarr, Chlvez, Reys and Reys (2006) who worked with teachers of mathematics; both research groups found that the teachers in their projects relied heavily on their textbooks as curriculum authorities.

There are times when the absence of data is as significant as its presence, a situation which arose when it became apparent that at no point did any of the participants voice any concerns regarding possible disparities between their personal epistemologies, the targeted curriculum and the intent and format of their textbooks. The textbooks were not questioned as authorities on science teaching despite evidence that the textbook can strongly influence the teacher's view of the importance of topics. For example, as she strove to systemize her understanding of studies in ecology and environmental education, Sharon noted that EE topics were placed at the end of each chapter in her textbook, a position which she took to imply that EE was add-on rather than core material. Bart added: "*STSE is last and gets done the way the textbook sets it up, which is the issues stuff is at the end and you do it if you have time, but you do content first*." (meeting three)

The considerable influence of the textbook in a science classroom is troubling for a variety of reasons. Foremost among them is that a publishing house, with both political and economic interests, potentially determines and designs the lessons that students are taught (Kirk, Matthews & Kurtts, 2001). One might ask, since it is in the best interest of the publishing house to turn a profit, what assurance is given that the textbook it produces will incorporate the most current science pedagogies (that might not be accepted or expected), rather than fall back on traditional and ensconced practices. There is no guarantee of the epistemological or theoretical position of the authors of science textbooks, or a statement outlining how they view the nature and history of science, or which pedagogy they advocate for the teaching of science. Thus, I suggest that it is very plausible that, because the participants ceded so much authority to their textbooks, they consequently further diminished their ability to challenge their own practice, and thereby secondary science teacher culture and epistemology.

- How do secondary science teachers perceive EE? How do they understand it?

Although this is the second of the research questions, it will briefly inform the discussion of textbooks, since the data indicated a notable reliance, by the participants, on their classroom textbooks for information and lessons regarding not only the traditional topics of physics, chemistry and biology, but also the topic of environmental studies. The data indicates that based on the positioning of EE within the textbook, the participants generally viewed EE as one of several branches of the study of ecology (itself a positivist undertaking including mathematical formula, graphs and structured labs).

4. Environmental education, beyond the scientific studies of ecology and environmental science, is understood to be a study of nature requiring specialized skills and knowledge and therefore is viewed by science teachers as an add-on to the regular science program.

When asked what an environmentalist looked like, the participants' answers conjured an image of a bearded, tousled 'hippy' chained to a tree. The data further revealed that at the beginning of the project, the participants' understanding of EE was underpinned by a perception that environmental issues are the domain of dissenters and eccentrics who exist on the periphery of social conformity. (Does this piece of data relate to the geographical location of the project in a northern Ontario town whose main industries are directly dependent on harvesting natural resources such as timber and ore?) The initial responses of some of the participants portrayed environmental issues as insurgent, fringe topics, in sharp contrast to the respectable and conventional studies of science. A few participants, notably Harvey, took a more balanced view of EE, positioning it as a way of understanding human impacts on the environment.

> "When I go in the classroom and talk about environmental stuff I almost think of us as on the outside looking in ...when we teach about natural cycles and we teach about natural systems I always feel like we are not really a part of that, the only part that we seem to play in that is when we disrupt those natural cycles. So it's almost a negative. Its a negative role that we play in that system and that's why maybe people feel like they are being preached to when we talk about it." (Harvey, meeting three)

Notwithstanding, environmental education, within the context of existing secondary science curricula, was initially perceived by the participants as comprising a largely theoretical study involving trophic levels, food webs, and population changes, as examples. It is evident that the participants adopted a certain perspective of EE that parallels the naturalist or conservationist current or conception of environment described by Sauvé (2005). The fifteen currents put forward by Sauvé have evolved over the last century. Those embraced by the educational community have become predictably institutionalized in the form of, for example, studies in ecology and environmental science, outdoor and experiential education centres, and adventure education programs. During the first two meetings the participants described their experiences with environmental studies as safely neutral and knowledge-based, taking place almost entirely within the confines of their classrooms. Any active or hands-on environmental education that may have taken place beyond the classroom (and its textbook), was seen as requiring unique skills and knowledge, as evidenced by Jane's repeated assertions that she was not knowledgeable enough to teach EE, and Sharon and Tess' recounting of student management issues out of doors. The project participants spoke of EE as part nature study, part conservation study, part recycling program, and part adventure education. They identified only a few of the many ways in which EE can be understood (refer to Sauvé, 2005 paper outlining the currents of EE).

Environmental studies lessons undertaken in the form of a field trip, or given over to experts at various centres or organizations, were considered by the participants as add-ons to their science programs. While experts in field centers and guests in the classroom are not unreasonable approaches to teaching environmental studies (indeed there are highly knowledgeable and qualified individuals who can provide specialized EE programming) by laying the teaching of environmental studies in the hands of experts, teachers may further distance the science curriculum from EE, rather than moving towards an integration of the two. Certainly, the project described in this study situated EE as separate from science, therefore requiring a conscious effort of integration.

Towards the end of the project, after working collaboratively within an action research framework to understand EE, and embed it in their science practice, most participants' perceptions of EE had evolved considerably. To varying degrees, each of the participants had moved from the rather narrow view of EE as either an outdoor field excursion or an environmental science lesson, begun to view EE as a natural component of multiple topics and lessons within science. They saw EE not as a distinct topic of the science curricula, but rather an enrichment of a science teacher's practice.

In one instance Sharon described environmental education as a way of thinking about teaching, and in another instance both Bart and Jane stated that they were beginning to see the possibility of environmental connections in almost all of the lessons that they were teaching. Both Sharon and Jane found ways to embrace portions of EE in their science practice and these are further discussed in Proposition Six. The next proposition identifies elements of EE that remained problematic for the participants.

5. Secondary science teachers do not feel comfortable addressing contemporary EE in terms of the political, economic and social ramifications inherent in environmental issues.

A contemporary form of EE links environmental science studies to political, social, economic and/or technological issues. In other words, through STSE, science informed by EE should be grounded in relevant local and/or global contexts. Yet the teachers in the project expressed ongoing reluctance to address pressing social, political and economic concerns that are linked to environmental issues. They cited a number of reasons for their reluctance. First and foremost, almost all of the participants argued that they were not trained in the humanities, and thus, might neither understand nor have the strategies required to adequately address social, political or economic issues with their students. Sharon was very emphatic in her pronouncement that she had no political acumen, that she felt entirely unable to tackle such topics with her students, and that her lack of knowledge would weaken her position as a teacher. Secondly, the participants in the study recognized that issues pertaining to environment, society, politics, and so forth have few straightforward solutions, are open to multiple interpretations and provide little in the way of resolution. They were uncomfortable with such a blatant disabuse of the infallibility of scientific endeavours, preferring to view science as an effort to uncover answers moreso than to think critically about the social, political or possibly ethical issues that arise from such an undertaking. The data reveals a belief by most of the participants that social, political, economic, and even ethical issues should largely be the concerns of teachers in the arts and humanities. The requirement to emphasize STSE was seen by the participants as new territory, and for most of them, it represented a discomfiting evolution of their practice. This is not surprising given the following example of an STSE question from the Grade 12 Earth and Space Science course: *What are the effects on local economies of oil extraction in Alberta, transportation by pipeline through the Prairies, and refinement in Ontario? How does the economic benefit of manufacturing items using a mineral resource compare to the economic benefits for the communities that mine the resource? What is the impact on the economy of local Aboriginal communities of diamond mining on their lands?* (Ministry of Educatoin of Ontario, 2008b, p. 144). Indeed, the participants felt that such a series of questions demanded far more expertise than their science training and knowledge provided, leaving them inadequately prepared to tackle such issues with their students.

Further, the participants predicted that most of their students viewed science as a content-oriented discipline and that those students preferred the safe neutrality of content over the difficult and messy treatment of issues (a sentiment also proffered by Breunig, 2005). However, the data collected during classroom visits and subsequent discussions demonstrates that the students' responses to the EE embedded science lessons were very favourable. For example, Jane recounted that a group of her students enthusiastically stayed after class to complete their assignment and Bart expressed surprise that his students were thoroughly engaged in their internet research instead of furtively playing internet games. The students' responses may indeed indicate that rather than a simple desire for discrete facts, their learning is an act of knowledge construction directly related to their experience and context (which may well have social, economic or political elements).

- In what ways will EE challenge the classroom practice of secondary science teachers?

6. Embedded environmental education offers secondary science teachers the opportunities to broaden their repertoire of teaching strategies, which provides the possibility to make small but significant incremental changes in epistemology and in practice.

The response of the project participants, when presented with teaching methods most often associated with EE (Smyth, 2006) (for example: interdisciplinary, locally relevant, student-based), was an agreement that those were the hallmarks of what they considered to be masterful and desirable pedagogies. However, they also discussed the difficulties of implementing those pedagogies, given the curricular and cultural expectations within which they worked. Some of those difficulties have been discussed in previous sections of this paper. Despite the realization that embedding EE in their science practice might present difficulties, nevertheless the participants took on that task with enthusiasm and perseverance. The results were encouraging and point to the need for continued collaboration that inspires incremental change, both in epistemology and in practice.

Sharon shared her thoughts on the pedagogies associated with EE:

> "It's like EE is not about the environment. EE is a way of thinking about teaching. It's about teaching style." and later added: "I think sometimes its a way of thinking too. Since we've started this whole project there's been an awareness, you start thinking about it [teaching science] differently." (meeting four)

Towards the end of the project both Bart and Jane expressed their continued desire to integrate EE into their lessons. Bart commented:

> "I'm actually looking forward to teaching the 3E [science] next semester. Never taught it before. I have nothing in terms of resources, so its going to be interesting after doing this [project], its going to kind of change my philosophy going into the course, you know integrating stuff into it... just the idea of every day how can I make them think about the impact of environment. I'm looking forward to seeing how it works out." (meeting six)

After Shh! Environment Day, Jane articulated her new perspective as well:

> "I thought I'm going to teach the hormones this way [issues-based] instead. It was good because in the articles the kids learned what estrogen does...instead of us doing it [as a note], so I thought, "This is great". It opened my eyes. We can teach things in completely different ways, I can teach it through an environmental [perspective]". (meeting six)

Indeed, perhaps it is the slow accumulation of small changes, brought about by the inclusion of EE and its pedagogies, which eventually result in a refreshed and altered secondary science practice that is more student-centered, requires critical thinking and is problem or issues-based.

Implications

The propositions presented above provide some insight into the work of teachers as they embed EE within their secondary science programs. In the case of this study, the participants knew that their action research would challenge their views of how they taught science. In fact, the participants grappled throughout the project with the myriad of impediments. Some have been discussed here and include: the scientific knowledge base that is deemed necessary for students, the approval of colleagues, issues of assessment and evaluation, and the influence of textbooks. Certainly other factors, such as student attitudes, administrative support, interdisciplinary strategies and the strenuous requirements of teacher work, also surfaced in the data to a lesser degree. Stevenson (2007) supports this list with several school-related factors that he suggests will continue to shape science pedagogy at the secondary level: (a) the problems with classroom management that result in more highly structured teaching approaches and focus on content learning; (b) the necessity of evaluation and grading of students that is far more easily managed with content knowledge and cookbook activities, and; (c) science itself is considered an objective inquiry and thus the teaching (and evaluation of learning) of science has remained objective.

However, the changes to science education policy in Ontario mandate the embedding of EE in secondary curriculum, particularly through the STSE expectations. While the participants in this study were strongly supported by the RF and by the collaborative efforts of their action research project, their colleagues throughout the rest of the province may not enjoy that level of support. This research study confirms the view that teachers of secondary science face unique barriers to changing their practice to accommodate environmental education. Unlike their elementary counterparts, they teach in discrete and often disconnected disciplines, and often in professional isolation. This combination makes interdisciplinary, contextual, student-centered pedagogies difficult to enact (Stevenson, 2007; Venville et al., 2008).

The ensuing questions, then, become: (1) How can secondary science teachers be aided and supported in deepening their understanding of the importance of EE within the science curricula and, (2) How can secondary science teachers be supported in their efforts to transform the theory of embedding EE in science, into practical and workable curricula?

In order for secondary science teachers to fully embrace an integration of EE and science, and to experience and create a transformative experience for their students, they must have available to them a powerful structure for professional development. The facilitated action research model used in this project proved to be suitable in this study because a facilitator provided opportunities to question science teaching epistemologies and practices, to collaboratively design and implement changes in teaching practice and to critically review the success of those changes. Inherent as well in the action research model, is the element of extended time; a definite requirement when it is expected that change will be gradual and possibly cautious.

In addition to a professional development model, teachers must have a source of support to bolster the confidence required to resist the conventions of history and peers, and to embark on a critique of their practice. While administrative and financial support is certainly requisite for teacher professional development, it is the sanction and encouragement of colleagues which will allow secondary science teachers to entertain changes in their enculturated practices.

Lastly, as evidenced in the project, secondary science teachers need a measure of leadership to focus their professional development efforts. That leadership may come from within, if the participants in a collaborative professional development endeavour have a clear goal in mind. However, in the case of this research study, it was the guidance of the RF that provided focus for the group. As Bart pointed out: "*We were able to get so much done in six weeks because we had a facilitator and we had a direction right from the get go.*"

This paper began with the image of a confluence of two magnificent rivers that provided a metaphor for the convergence of the traditions of secondary science and environmental education. The waters do not merge immediately; their mingling currents require time and space as they flow over the riverbed, which itself is constantly in silent, deep motion. That is the nature of rivers, and in many respects it is the nature of environmental and science education.

References

Barrett, S. E., & Pedretti, E. (2006). Contrasting orientations: STSE for social reconstruction or social reproduction. *School and Science Mathematics*, *106*(5), 237-247.

Bencze, L. (2001). Empowering students via authentic science: Changing views about practical work through action research. In D. Hodson, L. Bencze, L. Elshof, E. Pedretti & J.Nyhof Young (Authors), *Changing science education through action research: Some experiences from the field* (pp. 113-141). Ontario Institute for Studies in Education at the University of Toronto, Toronto, ON: Imperial Oil Centre for Studies in Science, Mathematics and Technology Education.

Bencze, L., & Hodson, D. (1999). Changing practice by changing practice: Toward more authentic science and science curriculum development. *Journal of Research in Science Teaching, 36*(5), 521-539.

Bowers C. A. (2002). Toward an ecojustice pedagogy. *Environmental Education Research, 8*(1), 21-34.

Breunig, M. C. (2005). Turning experiential education and critical pedagogy theory into praxis. *Journal of Experiential Education, 28*(2), 106-122.

Capobianco, B. M., Lincoln, S., Canuel-Browne, D., & Trimarchi, R. (2006). Examining the experiences of three generations of teacher researchers through collaborative science teacher inquiry. *Teacher Education Quarterly, 33*(3), 61-78.

Chapman, R.L. (2007). How to think about environmental studies. *Journal of Philosophy of Education, 41*(1), 59-74.

Clandinin, D. J. & Connelly, F. M. (1992). Teacher as curriculum maker. In P. Jackson (Ed.) *Handbook of research on curriculum: A project of the American Educational Research Association* (pp. 363-401). New York, NY: Macmillan Publishing Company.

Connelly, F. M., & Clandinin, D. J. (1990). Stories of experience and narrative inquiry. *Educational Researcher*, *19*(4), pp. 2-14.

Creswell, J. W. (2009). *Research design: Qualitative, quantitative and mixed methods approaches.* Thousand Oaks, CA: Sage.

Denzin, N. K., & Lincoln, Y. S. (2000). The discipline and practice of qualitative research. In N. Denzin and Y. Lincoln (Eds.), *Handbook of qualitative research* (2nd ed., pp. 1-28). Thousand Oaks, CA: Sage.

Dillon, J. T. (2002). Editorial-perspectives on environmental education-related research in science education. *International Journal of Science Education 24*(11), 1111-1117.

Eisner, E. W. (1991). *The enlightened eye: Qualitative inquiry and the enhancement of educational practice.* New York: Macmillan.

Gayford, C. (2002). Controversial environmental issues: A case study for the professional development of science teachers. *International Journal of Science Education, 24*, 1191-1200.

Glesne, C., & Peshkin, A. (1992). *Becoming qualitative researchers: An introduction.* New York, NY: Longman.

Gough, G. (2002). Mutualism: A different agenda for environmental and science education. *International Journal of Science Education, 24*(11), 1201-1215.

Greunewald, D. A. (2005). More than one profound truth: Making sense of divergent criticalities. *Educational Studies (American Educational Studies Association), 37*(2), 206-215.

Greunewald, D. A. (2004). A Foucauldian analysis of environmental education: Toward the socioecological challenge of the earth charter. *Curriculum Inquiry, 34*(1), 71-104.

Gruenewald, D. A., & Manteaw, B. O. (2007). Oil and water still: How No Child Left Behind limits and distorts environmental education in US schools. *Environmental Education Research, 13*(2),171-188.

Hart, P. (2007). Environmental education. In S.K. Abell & N.G. Lederman (Eds.), *Handbook of research in science education* (pp. 689-728). Lawrence Erlbaum Pub.

Hart, P. (2003). *Teachers' thinking in environmental education: Consciousness and responsibility.* New York: Peter Lang.

Hodson, D. (2003). Time for action: Science education for an alternative future. *International Journal of Science Education, 25*, 645 - 670.

Hodson, D. (2001). Science curriculum development: Lessons from the past. In D. Hodson, L. Bencze, L. Elshof, E. Pedretti & J. Nyhof Young (Authors), *Changing science education through action research: Some experiences from the field* (pp. 25-43). Ontario Institute for Studies in Education at the University of Toronto, Toronto, ON: Imperial Oil Centre for Studies in Science, Mathematics and Technology Education.

Hodson, D., & Bencze, L. (1998). Becoming critical about practical work: Changing views and hanging practice through action research. *International Journal of Science Education*, *20*(6), 683-694

Hungerford, H. R., Peyton, R., & Wilke, R. (1980). Goals for curriculum development in environmental education. *Journal of Environmental Education*, *11*(3), 42-47.

Jensen, B. B., & Schnack, K. (2006). The action competence approach in environmental education. *Environmental Education Research, 12*(3), 471- 486.

Jickling, B. (2001). Environmental thought, the language of sustainability and digital watches. *Environmental Education Research*, *7*(2), 167-180.

Kirk, M., Matthews, C.E., & Kurtts, S. (2001). The trouble with textbooks. *The Science Teacher, 68*(9), 42-45.

Ministry of Education of Ontario. (2008a). Science: The Ontario curriculum grade 9 and 10 revised. Toronto, Ontario: Queen‟s Printer for Ontario.

Ministry of Education of Ontario. (2008b). Science: The Ontario curriculum grade 11 and 12 revised. Toronto, Ontario: Queen‟s Printer for Ontario.

Ministry of Education of Ontario. (1999). *Science: The Ontario curriculum grade 9 and 10*. Toronto, Ontario: Queen’s Printer for Ontario.

Mulholland, J., & Wallace, J. (2003). Strength, sharing and service: Restorying and the legitimation of research texts. *British Educational Research Journal, 29*(1), 5-23.

Ogan-Bekiroglu, F. (2007). To what degree do the currently used physics textbooks meet the expectations? *Journal of Science Teacher Education, 18*(4), 599-628.

Ontario Curriculum Council. (2007). *Shaping our schools, shaping our future: Environmental education in Ontario schools.* Toronto, Ontario: Queen’s Printer for Ontario.

Orr, D.W. (1992). *Ecological literacy: Education and the transition to a postmodern world.* Albany, NY: State University of New York Press.

Pedretti, E. (2001). The road less travelled: Implementing STS education through action research. In D. Hodson, L. Bencze, L. Elshof, E. Pedretti & J. Nyhof Young (Authors), *Changing science education through action research: Some experiences from the field.* (pp. 65-87). Ontario Institute for Studies in Education at the University of Toronto, Toronto, Pedretti, E. G., Bencze, L., Hewitt, J., Romkey, L., & Jivraj, A. (2008). Promoting issues-based STSE perspectives in science teacher education: Problems of identity and Ideology. *Science and Educa*tion, *17*, 941-960.

Rico, S. A., & Shulman, J. H. (2004). Invertebrates and organ systems: Science instruction and 'Fostering a Community of Learners'. *Journal of Curriculum Studies, 36*(2), 159-181.

Robottom, I., & Sauvé, L. (2003). Reflecting on participatory research in environmental education: Some issues for methodology. *Canadian Journal of Environmental Education, 8*, 111-128.

Sauvé, L. (2005). Currents in environmental education: Mapping a complex and evolving pedagogical field. *Canadian Journal of Environmental Education*, *10*, 11-37.

Sauvé, L. (1996). Environmental education and sustainable development: A further appraisal. *Canadian Journal of Environmental Education, 1,* 7-34.

Sharpe, E., & Breunig, M. (2009). Sustaining environmental pedagogy in times of educational conservatism: A case study of integrated curriculum programs. *Environmental Education Research, 15*(3), 299-313.

Shibley, I., Dunbar, M. E., Mysliwiec, T. H., & Dunbar, D. A. (2008). Using science popularizations to promote learner-centered teaching: Alternatives to the traditional textbook. *Journal of College Science Teaching, 38*(2), 55-58.

Smith, G. A., & Wheeler, D. R. (1999). Introduction: Re-engaging culture and ecology. In G. A. Smith & D. R. Wiliams (Eds.), *Ecological education in action; On weaving education, culture, and the environment* (pp. 1-18). New York, NY: State University of New York Press.

Smyth, J.C. (2006). Environment and education: A view of a changing scene. *Environmental Education Research, 12*(3), 247-264.

Stevenson, R. B. (2007). Schooling and environmental education: Contradictions in purpose and practice. *Environmental Education Research, 13*(2), 139-153.

Tarr, J. E., Chlvez, O., Reys, R. E., & Reys, B. J. (2006). From the written to the enacted curricula: The intermediary role of middle school mathematics teachers in shaping students' opportunity to learn. *School Science and Mathematics, 106*(4), 191-201.

Venville, G., Sheffield, R., Rennie, L. J., & Wallace, J. (2008). The writing on the wall: Classroom context, curriculum implementation, and student learning integrated, community-based science projects. *Journal of Research in Science Teaching, 45*(8), 857-880.

Wallace, J., & Louden, W. (2000). Stories and science. In *Teacher's learning: Stories of science education* (pp. 3-15). Dortrecht, The Netherlands: Kluwer.

Wals, A. E. J., & Alblas, A. H. (1997). School-based research and development of environmental education: A case study. *Environmental Education Research, 3*(3), 253 - 267.

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Çelişkinin ötesinde: çevre eğitimini müfredatın içine alan öğretmenlerin çalışmalarını keşfetme

Çağdaş çevre eğitimine göre geleneksel lise fen eğitimi belirgin farklı pedagojileri kullanır, bu nedenle öğretmenler için çevre eğitimini lise fen müfredatının içine alma hem epistemolojik hem de pratik zorluklar sunar. Bu etnografik çalışma altı lise fen öğretmeninin (Nothern Ontaria, Kanada) bir proje kapsamında çevre eğitimini fen derlerine entegresini incelemektedir. Beş aylık kurs boyunca öğretmenler proje ile ilgili görüşlerini ve profesyonel gelişimlerini incelediler ve tartıştılar. Sonuçlar kesin olarak lise öğretmenlerinin çevre eğitimine ilişkin çalışması ile ilgili altı önermenin çalışmanın olası etkisine yönelik bir tartışma için bir taban oluşturduğunu gösterdi. Olası etkiler özellikle çevre eğitiminin fen çalışmalarının içinde verilmesi zorunlu Ontario, Kanada'da ki liseler için önemlidir.

Anahtar kelimeler: kültürlenmiş pratik, çevre eğitimi, fen öğretmenleri, fen kitapları, eylem araştırması, STSE, çevre eğitimi entegrasyonu