Australian Journal of Teacher Education

Volume 37 | Issue 10 Article 8

2012

The Tower Builders: A Consideration of STEM, STSE and Ethics in Science Education

Astrid Steele
Nipissing University, North Bay, astrids@nipissingu.ca

Christine R. Brew
Nipissing University, North Bay and La Trobe University, Melbourne, chrisbrew@brbconsulting.ca

Brenda R. Beatty
University of Melbourne, bbeatty@unimelb.edu.au

The Tower Builders: A Consideration of STEM, STSE and Ethics in Science Education

Astrid Steele
Christine R. Brew
Nipissing University, Canada
Brenda R. Beatty
University of Melbourne

Abstract: The call for the integration of ethical considerations in the teaching of science is now firmly on the agenda. Taking as illustrative a science lesson in a pre-service teacher class, the authors consider the roles of STSE (science, technology, society and environment) and the increasingly influential heavily funded STEM (science, technology, engineering and mathematics) education initiatives. The origins and foci of both initiatives are discussed, as are their disparate ontological foundations. The use of Habermas' knowledge theories in conjunction with ethical frameworks is posited as a way of considering both STSE and STEM perspectives and their implications for strengthening science pedagogy.

Introduction

Science Teacher Reflection:

*Every semester I (*Note: Whenever the pronoun 'I' is used, this refers to author 1. Whenever the pronoun 'we' is used, this refers to all three authors) *have pre-service teachers in my science education class build a tower from a piece of card stock and some masking tape. In brief, the scenario is that their airplane has crashed on an island inhabited by a small, friendly, indigenous population and crash survivors need to signal a passing ship for rescue. The students compete to build the tallest, most stable tower as a way of demonstrating and participating in an integrated science, technology, engineering and mathematics activity. It is an engaging problem-solving task that develops an understanding of the structural limits of materials, an understanding of forces acting on structures, and it incorporates elements of teamwork and competition. Once the students are working on their towers, I ask them to discuss in their groups how they would live on the island until their tower is completed and help arrives. Invariably, the students assume that they would use whatever resources are available. I ask, "What impact do you think your stay on the island will be?" They acknowledge some degradation to the flora and fauna but it is a rare group that takes into account the impact on the indigenous population. The tower building exercise provides a starting point for discussions surrounding the place and importance of technology, engineering, and mathematics in the science curriculum and how those endeavors impact societies and environments. The discussions become a gateway into a consideration of the preservice teachers' ethical and moral choices within a broader social context.*

This teaching approach is consistent with recent and urgent calls to broaden the focus of science and technology education as two interrelated subject areas to examine the ethics underpinning them (Hodson, 2003; Jones, McKim & Reiss, 2010; Kim, 2005; Johnson, 2010; UNESCO, 2004). UNESCO (2005) explains:

> ...the study of ethics is important not only for our individual lives but also for developing the insight and competence that human beings as a community need in order to face the challenges of the present and the future in a reasonably successful way. Many of the most important ethical predicaments the world community is facing today arise in connection with science, in scientific research and in the development and applications of new technologies... (p.3)

This direction - to integrate ethics into the study of science - is both controversial and problematic: controversial because many science teachers commonly understand their job as a presentation of facts, compounded by their view of science as value-free (Hodson, 2003); and problematic because many science teachers report being professionally unprepared to integrate ethical considerations in the curriculum and to deal with the controversial classroom discussions (Jones, et al., 2010; UNESCO, 2005). There are issues of will, capability and preparedness here.

Further complications emerge from the contrast in impetus that arises from two current initiatives in science and technology education: STEM (science, technology, engineering and mathematics) which is connected to substantial corporate funding opportunities for schools and universities; and STSE (science, technology, society and environment) which is an Ontario curriculum initiative to deliver a broader, ethics influenced context within which to learn about these disciplines. Both STEM and STSE-based curricula are evident in Ontario and other Canadian provincial education systems as well as various states of the U.S. However, we propose that STEM teaching and learning, while inviting in terms of its apparent interdisciplinary approach, could inadvertently fall far short of its promise to provide ethically grounded answers to pressing global concerns without an ethical framework to guide it. Without the contextualization provided by the STSE framework for instance, our students (and those students they will soon teach) will not learn the lessons that will be needed to live ethically, and by extension, sustainably on the planet. While ethical decision making is not synonymous with sustainability, the tensions among the various ethics related perspectives in sufficiently robust frameworks, can help teachers to surface these considerations and link them to the science itself. It is proposed that ethics become a regular part of the discourse and practice of teaching science and technology. Thus the question that we ask is can the use of such a framework enable educators to embrace the best of both STEM and STSE initiatives in the science classroom?

To this end we first describe STEM and STSE separately in terms of their origins and intentions. We then draw upon both Habermas' (1972) knowledge theory and a range of ethical structures to scaffold a theoretical framework that allow both STEM and STSE to be reviewed through an ethical lens. The tower-building narrative is embedded throughout for the purpose of bringing context to the discussion.

STEM: Building the Tallest, Strongest Tower

During the tower-building activity I am always amazed at how engrossed the students become in creating the tallest, strongest structures. In many ways it seems to be an exercise that mirrors the ways in which society has become riveted by the technologies that are springing up around us; technologies that are dependent on sophisticated understandings and manipulations of

STEM disciplines. In building the tower, simple items like card stock and masking tape are taken to the limits of their structural ability; 'making do' with limited supplies depends on both scientific knowledge and creative energy. There is a strong element of competitive enthusiasm among groups and the opportunity for improvisation and problem-solving appeals to the students. Creativity and competition also resonate with the intentions of the substantial government and industry STEM funding currently being provided to innovative projects in the U.S. and now some Canadian schools and universities.

The STEM funding initiative originates from the U.S where there is a perception amongst American policy-makers that they are faced with a grave situation. Machi (2009) in The Report on STEM Education calls it the problem of the "leaky pipeline" and explains:

> In the education pipeline from elementary to graduate education, not enough students are making it to the advanced levels of STEM studies… High school students are not being trained at a high enough level to compete with international students once they reach college. Too few freshmen who declare a STEM major graduate with a degree in STEM… The leaky education pipeline impacts not only STEM industries but America's defense capabilities. (p. 3)

According to the 2009 PISA study (OECD, 2010), U.S. students placed 17th in international science and mathematics assessments, well behind countries like Japan, Shang-Hai, China, Singapore and Korea (Canadian students placed 6th). In 2004, the US Federal Government provided nearly 3 billion dollars in STEM education program funding with two main organizations dedicated to the distribution of three quarters of these funds: The National Science Foundation (NSF) and the National Institutes of Health. Further billions of dollars have been allocated since (Burke & Baker McNeill, 2011), and the America COMPETES Act, signed in January 2011, is intended to reestablish NSF's preeminent role as the lead agency for improving STEM education programs across the country (Holdren, 2011). A noteworthy input from corporate America includes 100 chief executive officers of corporations such as Intel, Xerox, Eastman Kodak and Time Warner, promising significant funding ($5 million in its first year) to an initiative called "Change the Equation".

> STEM is the future. STEM learning is an economic imperative. Experts say that technological innovation accounted for almost half of U.S. economic growth over the past 50 years, and almost all of the 30 fastest-growing occupations in the next decade will require at least some background in STEM. (http://changetheequation.org/why-stem/)

This level of funding is premised on the view that education in science, technology, engineering and mathematics are essential to global competitiveness and the basis of an advanced society which is "a more efficient, effective, safe, and secure world community" (Rockland et al., 2010, p. 62) within which people "live longer and better lives" (Machi, 2009, p. 2).

In his January 2011, State of the Union Address, President Obama of the U.S.A., endorsed this view for the U.S. nation:

> We need to teach our kids that it's not just the winner of the Super Bowl who deserves to be celebrated, but the winner of the science fair … We know what it takes to compete for the jobs and industries of our time. We need to out-innovate, out-educate, and out-build the rest of the world. We have to make America the best place on Earth to do business. (US President Obama's State of the Union Address – 25 January, 2011)

Politically speaking the nation-centered mindset reflected here is perfectly understandable. Arguably however, it is just such fiercely economically driven, nation-centric imperatives that can entirely eclipse more holistic, global considerations. In his critique of the STEM initiatives, Johnson (2010) argues that this direction for future planning is, in part, based on naïve thinking. He proposes that balance is required; science initiatives need to be tempered by consideration of, and integration with, the humanities:

> It is clear that we will need more scientists and technologists. That is the way of the world in the 21st century. … Just as importantly, we need scientists, engineers, and technologists who fill the needs of "the whole national welfare": scientists who strongly wed their expertise and knowledge with knowledge of Humanities, Arts, and Social Sciences (HASS) so that science does not, as Bush warned, attempt "to live by and onto itself alone. (p. 89-90)

Despite the already invested billions of dollars to ensure a steady supply of students progressing through the "STEM pipeline", the students themselves are not co-operating. The President's Council of Advisors on Science and Technology (PCAST) (2010) identified the problem to be the American students' general disinterest and lack of proficiency in STEM studies, which in turn is leading to mediocre test scores in international assessments. The PCAST (2010) notes:

> [T]oo many American students conclude early in their education that STEM subjects are boring, too difficult, or unwelcoming, leaving them ill-prepared to meet the challenges that will face their generation, their country, and the world. (p. 2)

If STEM initiatives are falling short of their goal, what are the implications for curriculum writers and those who implement them, the teachers? In his re-envisioning of a curriculum worth teaching leading to a high school diploma worth having, curriculum authority Grant Wiggins (2011) proposes that the study of "Philosophy, including critical thinking and ethics" is of paramount and strategic importance. Given the recent global financial meltdown he opines, "How unfortunate for us personally, professionally, and socially that all high school and college students are not required to study ethics" (p. 32).

To accomplish a robust, inclusive perspective on science, technology, engineering and mathematics, Johnson (2010) advocates bringing "scientists and technologists together with those in HASS within . . . the realm of ethics: one of the most challenging, but potentially most rewarding for scholars, researchers, developers, and the general public" (p. 90).

On the face of most articulations of the STEM initiative it is hard to find any evidence that ethics is a priority for its funders. Nor is its epistemological or pedagogical rationale clear. Many STEM funded initiatives seem to exist atheoretically. Based on evidence from websites and government agency reports the momentum seems to be clearly political, with strong corporate backing as evidenced by media headlines such as "Bayer's bid for STEM: 'Making Science Make Sense'" (Young & Stewart, 2010), or "IBM CEO ties economic growth to STEM education," (IBM CEO, 2010). Far from being an expression of global social conscience, STEM initiatives in the U.S. are predicated on the preeminence of the global economic and political power struggle (Machi, 2009; Rockland et. al., 2010; Sanders, 2009) founded on a growing realization that Asian countries are "outSTEMming" the U.S (Sanders, 2009).

The output of science, mathematics and technology graduates in neighboring Canada is being closely monitored by the U.S.A. In their effort to understand and plan for shifts in the demand for highly skilled workers, a report from the U.S. based Population Reference Bureau (Lee & Mossaad, 2010) refers to "the stock of skilled workers in Canada relative to other countries", "the flow of skilled workers into Canada from other countries", and "the production of future workers." (p.1) (emphasis added). Taken from a now *Canadian* nation-centric point of view, the notion of positioning Canadian workers as "stock" to support the U.S. economic and political agenda, may seem stark. And yet both nations' needs are wisely considered alongside the individual worker's point of view. After all, a job is a job. Complex issues beg the need to engage in perspective taking, which is inherent in the exploration of ethics.

While the STEM initiative per se is not a specific education initiative within the Ministry of Education of Ontario (2007), nonetheless science and technology are considered critical curricula foci. The Ministry says:

> Science and technology underpin much of what we take for granted, including clean water, the places in which we live and work, and the ways in which we communicate with others. The impact of science and technology on our lives will continue to grow. (Ministry of Education of Ontario, 2007, p.3)

To date, the STEM acronym has been remarkable by its absence in Canadian education literature, though industry funding in science and technology education has been around for some time (For example, for close to a decade Imperial Oil funded the Centre for Studies in Science, Technology and Mathematics Education at the Ontario Institute for Studies in Education/ University of Toronto). The STEM acronym has begun to surface however; for example, in relation to gender equity in the sciences (Collaborating for Gender Equity, 2009), or as the basis for research grants in Ontario universities (example, Schulich STEM grants at Nipissing University). Youth Science Canada also partnered with Google in January 2011 to launch the internet based Google Science Fair with the goal of becoming the largest global science competition in the world (Youth Science Canada, 2010). It seems inevitable that, like so many initiatives and programs that originate in the U.S.A., STEM initiatives will continue to influence Canadian science education. Notably, in Ontario, Canada, there is also a heightened push for science and technology education; however it is a push with a difference. Science and technology are partnered with both social and environmental concerns. While "social and environmental concerns" are not synonymous with the study of ethics per se, the STSE initiative is STEM with a conscience. Responsibility extends beyond the nationally political and economic and into webs of interconnectedness that can easily go well beyond borders. This is territory very well suited to considerations of ethics especially with the use of robust frameworks to scaffold emerging understandings.

STSE Education: Repercussions of Building the Tower

When my students are asked to consider the repercussions of building the tower on the island on which they have been 'stranded', they are far less eager to pursue that task. Whereas the tower was built with real materials, it is more difficult for students to work in the abstract and 'imagine' what impacts their presence might create. Students require prompting to consider environmental impacts such as food harvesting, shelter building, waste disposal and the introduction of foreign microorganisms. But even more difficult for them is consideration for the indigenous people. Under closer scrutiny, a myriad of environmental and social complexities emerges; for example

- Are the island natives living an ecologically sustainable existence?
- Is the pressure upon the environment that would be applied by the newly arrived humans likely to threaten such sustainability?

- Would the islanders likely become hostile, depending on the actions of the intruders?
- What priority is to be placed upon the would-be survivors' imperative to preserve their own lives?
- What knowledge might the islanders have that could be of assistance?
- What mutual knowledge exchange might inform this situation?
- What cultural differences might play a role?
- How will such cultural differences be explored?
- What communication difficulties could emerge, and correspondingly be overcome?
- How are the competing values and associated ethical perspectives best to be considered?
- What ethics standpoints could inform such considerations?

Symbolically, the tower builder's exercise can be seen as a microcosm of global survival issues. It is not appropriate to imply that science and technology alone can provide answers to pressing global concerns. We argue that science and technology most certainly will not provide such answers without considerations of competing values, and some sort of shared understanding of an holistic inclusive set of ethical standards. However, ethics inquiry itself does not offer a simple solution. Frames of reference in ethics have their own incompatibilities. The complexities abound. However it is just such complexities that need to surface in the context of these studies of science, technology and mathematics, along with explorations of environmental sensitivities and the sustainability of life on this planet.

The STSE curriculum expectations are seen as a means for the transformation of social attitudes and actions by infusing within science curricula elements of: socio-political action, decision-making, interdisciplinarity, uncertainty, multiple solutions and ethics (Pedretti, Bencze, Hewitt, Romkey, & Jivraj, 2008). Kim (2005) points out that science and technology are intertwined with cultural values, but she cautions that although science and technology give the illusion that humans can master the natural world they must approach the science technology duo mindfully. Pedretti and Forbes (2000) identify four cornerstones of STSE education: sustainability issues that address concern for and responsibility towards the environment; an understanding of political decision-making processes; science education as a value laden activity that should therefore have a strong ethical component; and, critical social reconstruction which requires students to recognize the political and social forces that underpin science and technology processes. By way of example, consider this excerpt from the Grade 9 Unit on Earth and Space Science:

> D1.2 assess some of the costs, hazards, and benefits of space exploration (e.g., the expense of developing new technologies, accidents resulting in loss of life, contributions to our knowledge of the universe), taking into account the benefits of technologies that were developed for the space program but that can be used to address environmental and other practical challenges on Earth (e.g., radiation monitors and barriers, sensors to monitor air and water quality, remote sensing technology, fire-resistant materials). (Ministry of Education, 2008, p. 54)

The teaching and learning expectations specified above go well beyond basic facts about space science, and beyond the fundamental skills of research and the drive to be nationally economically competitive. Students are asked to consider and critique the use of funds for space technologies; an undertaking that both mirrors and develops their skills as informed democratic citizens and provides the opportunity to wrestle with ethical decision making. While the term 'STSE expectations' is unique to the Ontario science curriculum, expectations with the same intent are explicit in the science curricula of many other Canadian provinces (for example, British Columbia Ministry of Education, 2005; Alberta Learning, 2009; Saskatchewan Ministry of Education, 2009; Arizona Department of Education, 2005; Newfoundland and Labrador Department of Education, n.d.); and States of the U.S.A. (Arizona Department of Education, 2005; The State Education Department, The University of the State of New York, 2010).

However, teaching through an STSE lens is proving to be problematic for many science educators for a range of complex reasons: 1) It can challenge a teacher's sense of identity and socio-cultural beliefs and through this their pedagogical practices (Kim, 2005); 2) STSE takes science teaching and learning off the familiar and well-beaten track of memorizing content knowledge and following recipe laboratory activities, into the realms of social, environmental and ethical issues and actions (Steele, 2011); 3) Even when teachers express confidence and motivation regarding the teaching of STSE, the hegemony they confront in schools often presents barriers to its implementation (Pedretti et al., 2008).

We propose that STEM funding and STSE-like curriculum standards are the products of contrasting world views, and have at their core differing ethics and differing future expectations. With phrases like: production of a stock of skilled workers (Lee & Mossaad, 2010), matters of national security, or maintaining position of world superpower (Machi, 2009), the language of STEM education connotes studies based on competition, military power and a national 'manifest destiny'. In contrast, the language describing STSE education is rife with references to democratic citizens, responsible and wise choices, and global citizenship (Council of Ministers, 1997; Hart, 2007; Hodson, 2003). STSE education is often critical of globalization, consumerism, and the commodification of both human and environmental resources (Steele, 2011). Is the STEM versus STSE contrast an irreconcilable difference or are there encouraging signs on the horizon? Could the science funding that emanates from the US take ethics into consideration?

It is true that the National Science Foundation's (NSF) program Ethics Education in Science and Engineering (EESE) has provided around 11 million dollars since 2006 to research to improve ethics education in all fields of science and engineering. This might have been taken as an encouraging sign. Indeed, a further 1.5 million dollars has also been granted to set up an Ethics in Science, Mathematics, and Engineering Online Resource Center. This Centre's *stated* purpose is to develop, compile, and maintains resources related to ethics in science, mathematics, and engineering (National Science Foundation, 2011). However, this funding is most closely linked to a specific change in grant requirements that requires researchers to provide ethics training for their graduate students, which is not going to have any influence upon science teaching and learning at the high school level or policy making at a national and international level.

In the political climate of available funding for STEM initiatives at the school level, a theoretical pathway is needed to work effectively across these seemingly incompatible perspectives. We turn to Habermas' theory of knowledge, as described by Crotty (2010) and Edgar (2006), in an effort to frame and accommodate these initiatives under one philosophical umbrella.

Habermas' Theoretical Framework

Considerations of epistemological perspectives about the nature of knowledge and its creation can be informed by Habermas' work, which is considered by many a source of wise counsel regarding human knowledge structures. He posited that knowledge is bound by what is most important or most 'interesting' to humans (Habermas, 1972) and offered three interests that are key to how human's construct reality: 1) in order to survive and thrive, humans have developed a body of knowledge (science and technology) that allows them to predict and manipulate their physical environments; 2) to build relationships and cultures, humans have developed a body of knowledge (language, cultural symbols, and social structures) that allows them to communicate; and 3) in order to critique their actions, to recognize the need for and effect emancipatory actions, humans have developed the body of knowledge (self-reflection, ethics) that informs human responsibility (Crotty, 2010).

Crotty (2010) proposes that the first two bodies of knowledge, science/technology and communicative interests find their focus in the present and the past and that the third body of knowledge, the capacity for self-reflection and critique of the present is the gateway to the future. "It is precisely by imagining a future and taking steps to achieve the imagined future that humans can break out of the cultural system into which they have been socialized" (p. 635).

In our view, the construction of the tower per se, as an example of a STEM activity, fulfills the criteria for Habermas' first body of interest-bound knowledge: the scientific and technical need to control and manipulate the physical environment in the pursuit of surviving and thriving. And during the tower building, the ability to communicate amongst each other is crucial to the success of the enterprise, thereby drawing upon Habermas' second knowledge-interest. Both knowledge interests enable the castaways to stay alive and perhaps meet with immediate success. Viewed in the light of Habermas' framework, and Crotty's (2010) commentary on it, STEM funded initiatives are still largely concerned with the profit-making and environment manipulating power of innovation in the present along with the insistence that a strong STEM education is the key to a brighter future for one nation's cultural and economic advantage. Here, the pursuit of these first two knowledge interests remains free from accountability to all possible consequences beyond its nation's borders. Habermas' third knowledge interest, which involves future focus through critical inquiry, brings in ethical considerations as people come to see whose interests are being served and what the implications are for the future of related decisions. This offers important challenges to the would-be 'brightness of the future': what future and bright for whom?

Habermas' second knowledge-interest recognizes and describes cultures and enables communication. If explored purposefully, it can act as a vehicle to engage with the third knowledge-interest: the ability and desire to engage in the future by being critical of the present (Crotty, 2010). It is at this juncture that the tower-building students are encouraged to come to terms with and articulate their understandings of the impact of their presence upon the natural and social aspects of the environment. In contrast to a narrowly defined notion of STEM, STSE grounded pursuits of science and technology find a foothold in both the second knowledge interest that rests on communication, and the third knowledge interest that examines the social and environmental implications associated with the ethics of human agency. Balancing science and technology with social and environmental concerns addresses present and future sustainability, and positions as foundational the imperative to act morally, wisely and pragmatically from an ethically conscious perspective.

The Ethics of Tower Building

To build their towers tall and strong the students realize after some discussion, that their needs might not be met without degrading the environment and depending on the level of sensitivity to their intrusions, potentially impacting the sustainability of the island's ecosystem. Students rarely factor in a consideration of the island's ecosystem or the indigenous group as they propose appropriating the island's resources to maximize their chances of survival. While pursuing their survival is part of the project, it can be argued that, in the true spirit of colonialism, the students see themselves as entitled to lay claim to the island resources and to use them as they see fit. During one of the tower building sessions a student of indigenous descent expressed indignation at the tendency of the larger group in the class to have overlooked the rights of the people who inhabited the imaginary island. It reminded her of the historical colonialism that had impacted her personal story. This led to disquiet within the group. When encouraged to become more inclusive in their considerations they become torn between a focus on the physical science and technology that could ensure their rescue, and the potentially emerging social and environmental issues that could be precipitated by their presence. At this point, the students' conversations turn to ethical considerations, which are largely confounded by a lack of background knowledge with which to engage meaningfully on the matter.

Generally, there is a strong belief that science and technology lie at the heart of progress and their adoption is believed to be able to deliver a higher more desirable 'standard of living'. On more than one occasion during the tower building activity, students have made the case that the indigenous group has a right to better medicine and better technology and it is the responsibility of the castaways to provide this knowledge. Revisiting the personal experiences of colonialism a First Nations student responded to her peers, "Why do you think we would need or want those things? Why do you think we weren't happy just the way we were?" Clearly identifying with the island's indigenous people, she has asked a very important question by highlighting the potentially erroneous assumption that the native islanders do not possess sufficient or even superior medical and technological knowledge.

The students struggle with the recognition that they have assumed their rights to the island resources, without recognizing that this might interfere with the rights of those who called the island home, not to mention their potential impact upon the flora and fauna's sustainability. Some of their revelations challenge their self-concept of being people of good character and this can lead to discomfort and defensive posturing. Situations such as these might be called teachable moments, but they require an ability by the students and the teacher to stay present to the emotional discomfort (Boler, 1999), the courage to 'see' things differently (Greene, 1988) and the courage to move towards the emotional 'danger' (Maurer, 1996). We propose that to support teachers in this endeavor we need to provide theoretical scaffolding to support and promote these difficult conversations in the science classroom. Jones, McKim and Reiss (2010) in their recently edited volume have begun this process by providing teachers with an accessible summary of some of the major ethical frameworks and then linking them to classroom practice. They propose that students need to be exposed to a range of ethical frameworks in order to both understand and develop their own. Here we draw on their work and expand on the kinds of discussion questions one can associate with the ethical frameworks they explore.

Approaching the Discipline of Ethics

"Ethics is a branch of knowledge just as other intellectual disciplines, such as science, mathematics and history" (Reiss, 2010, p.7). When one tries to justify a moral position one does so whether knowingly or not, by drawing on positions that can be explored through the lens of an ethical framework. One's ethical perspective may be sketchy, not entirely coherent, explicit or even known to oneself meta-cognitively. Moreover, as educators we need to understand our own ethical perspectives, and locate these within a workable framework. We need to be knowledgeable about alternative ethical frameworks in order to support our students in developing theirs. While not exhaustive, for the purposes of this discussion we draw on three main ethical frameworks as outlined by Jones et al. (2010), ones that are easily distinguished and useful in the education field: Consequentialism, Deontology and Virtues. We acknowledge that there are others in the study of ethics such as natural law, ethic of care etc.

Consequentialism

The ethical framework called Consequentialism would ground discourse in a science and technology classroom by asking questions like the following:

- Who or what is affected by this issue?
- What are the benefits involved?
- What are the harms for those involved?
- Are some consequences greater or lesser than others?
- If one is harmed and another benefits, how do you decide who or what matters most?(McKim, 2010, p. 31).

And we might add:

- Can we know all of the consequences of actions with respect to the issue of focus?
- Is there a legitimate time-frame within which to consider the consequences of our actions?
- What should you do to be sure your actions are based on a full consideration of the consequences?

Consequentialism as a basis for decision-making takes into account the human responses to the ramifications of a decision taken, in effect weighing them upon an imaginary balance. "Those consequences that promote human, and other than human, welfare more are ethically preferable to those that do not maximize welfare" (Crotty, 2010, p. 637). The tower building activity offers the opportunity to examine the basis of Consequentialism. For example, when students ignore the impact on the indigenous group these kinds of questions provide a structure to elicit a recognition that this has happened and how colonizing attitudes enabled their choices without the teacher having to state this directly. These questions also encourage them to consider the island from the perspective of the 'other'. Pre-service teachers and people generally like to consider themselves as essentially "good" people. When students realize that their behavior on the island could be characterized as disrespectful, uncaring, and/or unfair to the indigenous group, as well as thoughtlessly exploitive of the natural environment, they are taken aback. These issues of social sustainability and equity lead to the second ethical framework.

Virtues Ethics

Virtues Ethics is strongly associated with the recent focus on character education in schools. Drawing on descriptions of this framework from Crotty (2010) and Reiss (2010) we propose that Virtues ethics would ground discourse in a science and technology classroom by asking questions like the following:

- How would you define a person of good character?
- What would a person of good character do in this situation?
- What characteristics or qualities would we want a person to manifest in this situation?

And we might also consider:

- How might a person of good character make questionable ethical decisions in this situation?
- Who decides what are the ideal qualities of a person with good character in this situation?
- What would you do in this situation?

The Virtues framework proposes that a good person would exhibit "core principles relating to virtues such as honesty, justice, fairness, care, empathy, integrity, courage, respect and responsibility" and that these "should guide conduct and interpersonal relations" (Campbell, 2006, p.32). But Virtues ethics can be complex: Campbell (2003) in An Ethical Teacher, asks the question, "Would you treat a student in a manner that embarrassed or belittled them?" Our initial response to the question would be a resounding "No! We should not create situations in which our students feel bad about themselves. We prize the virtues of respect, caring and empathy and work hard to embed them in our classroom teaching". Yet if we value pedagogies that challenge students to think and discuss, we must realize that in creating the opportunity for a candid learning discourse, we need to be prepared for the discomfiture of our students and ourselves in order to harvest the pedagogical opportunities this same discomfort presents (Boler, 1999). The students struggle with the recognition that they have assumed their rights to the island resources, without recognizing that this might interfere with the rights of those who called the island home. A focus on rights and obligations is the basis of the third ethical framework.

Deontology

We propose that Deontology would ground discourse in a science and technology classroom by asking questions like the following:

- Is there some science that should never be undertaken because it is intrinsically wrong? (i.e. Is there some knowledge that we should never know?)
- Is there a right or wrong way to proceed in this situation?
- Is this the right time to proceed in a scientific investigation?
- What are the right reasons for proceeding with this investigation?
- In the conducting of the science, are any One's rights transgressed? *(Capitalization of 'One' indicates the rights of the other than human)*
- Will the new science and technologies lead to greater resource equity, (i.e. will the resources be shared fairly?)
- How shall we decide what is fair?
- Who is obligated to ensure that the rights of those affected are maintained? (i.e. Are scientists responsible?)

Deontology is commonly contrasted with Consequentialism and focuses on ethical principles that are "concerned with rights and obligations of various kinds" (Reiss, 2010, p.11). The two key elements of a Deontological ethical framework are informed autonomy and justice. The framework can be viewed as multi-dimensional, "that one is not only doing the right thing, but doing it in the right way, at the right time and for the right reasons" (Covaleskie, 2005, p.134). Using the new-born baby as an example, Reiss (2010) proposes that the baby has no duties but certainly has rights. It therefore follows that "if A has a right, there is a B who has a duty to ensure A's rights are met" (p.12).

By working through sets of questions from different ethical frameworks that are relevant to the context, we propose this will assist the students in not only better understanding their own ethical frameworks but will also assist them in navigating the dissonance that can arise between juxtaposed values. For example, do immediate human needs take priority over our long-term responsibility to environment and sustainability? Such dissonance can lead to emotional discomfort, often traceable to challenges to self-concept, and can signal the need to question their worldview.

Finding Meaning

Today we are confronted with the inconvenient truth (Gore, 2006) that partly as a result of rampant scientific and technological development unchecked by social and environmental priorities, we are on a trajectory towards unimaginable losses, if not outright extinction, of many parts of our biosphere, including ourselves. Infused with a focus on the future and implications for sustainability of all life on the planet, science and technology may indeed hold some of the answers to these pressing planetary problems, depending on the ways that science, technology, engineering and mathematics knowledges are implemented locally, nationally and globally. Thus, the development of sensitivities to these more robust integrative perspectives needs to be taught in schools (Council of Ministers of Education, Canada, 1997; Hodson, 2003; Pedretti, 2005)

As educators, it is important to become cognizant of the values and world views that inform STEM driven initiatives and to balance these with equal attention to social and environmental concerns. Direct experiences with the interconnectedness of the natural world can help to support the development of predispositions to resist the 'partitioning off of parts' that allows self-serving/other-depleting decision-making to continue to flourish. Certainly, an understanding of the connections between human societies and the natural environments that sustain them has become a focal point for various eco-philosophies that describe the need for transformatory experiences. Among these schools of thought are the following: deep ecology, a term coined by Arne Naess, which mourns the estrangement of humans from their natural roots and seeks to reestablish the connection (Naess, 1989); transpersonal ecology which encourages a self-concept that includes a strong sense of the natural world (Fox, 1990); and eco-feminism, which stresses the embodied recognition of interconnectedness amongst all living beings (Diamond & Orenstein, 1990). The theorized philosophies and values that connect individuals and societies to their natural environments need to find explicit expression everywhere, especially in classrooms. Which brings us back to our original question: Can a common theoretical framework enable educators to embrace the best of both STEM and STSE initiatives in the science classroom?

By facing head on what Tan (2009) calls the 'collateral damage' of a high standard of living, we can, in re-examining the 'STEM-without-limits' road that we are on, begin to see possibilities in the road not yet taken, the road that has limits, the road into the future, from which we can backward-map to the present. STEM disciplines provide an important canon of knowledge and skills but STEM without ethical grounding, remains self-serving and hegemonic. STSE re-balancing, informed by the framework of Habermas' second and third knowledge-interests, can encourage self-critique and more globally suitable choices. We propose that the third knowledge interest be considered first. All decision making concerning the manipulation of the physical environment needs to be future-focused and critically examined for consequences, values, and ethics. Essentially a synthesis between Habermas' three knowledge interests and the various ethical frameworks is a challenge worthy of our focus.

When the tower-building class is over, students often stop to chat on their way out the door. The lesson has been fun, they comment, but more importantly it has been thought provoking. There are no simple instructions for how to teach science well; no easy recipe for preparing our students with high levels of knowledge and skills and the ability to make informed and wise decisions. When we take up the challenge of an ethics-infused science pedagogy, we must be prepared to embrace a "pedagogy of discomfort", which is "both an invitation to inquiry as well as a call to action" (Boler, 1999, p.176).

Responsible tower-building is a lot harder than it looks.

References

ABC News. (2011). State of the Union 2011: President Obama's full speech. Retrieved June 30, 2011 from http://abcnews.go.com/Politics/State_of_the_Union/state-of-the-union-2011-full-transcript/story?id=12759395&page=4.

Alberta Learning (2009). Science Grades 7-8, http://education.alberta.ca/media/654829/sci7to9.pdf.

Arizona Department of Education (2005). The Science Standard Articulated by Grade Level. http://www.azed.gov/standards-practices/files/2011/09/sciencegrade8.pdf.

Boler, M. (1999). Feeling Power: Emotions and Education. NY: Routledge.

Burke, L.M., & Baker McNeill, J. (2011). "Educate to Innovate". How the Obama Plan for STEM Education Falls Short. Backgrounder. 2504, 1-8.

Campbell, E. (2006). Ethical Knowledge in Teaching: A Moral Imperative of Professionalism. Education Canada. 46(4), 32-35.

Campbell, E. (2003). An Ethical Teacher. UK: Open University Press.

Change the Equation. (2011). Retrieved June 30, 2011, from http://www.changetheequation.org/why/why-stem/.

CNN Politics. (2010, September). Obama announces new education initiative led by corporate CEOs. CNN Wire Staff. [electronic version]. Retrieved June 30, 2011 from http://www.cnn.com/2010/POLITICS/09/15/obama.education.initiative/index.html.

Collaborating for gender equity in STEM. (2009). NSTA (National Science Teachers Association) Reports. 21(4), 26.

Council of Ministers of Education, Canada (1997). Common framework of science learning outcomes. Toronto, ON: CMEC Secretariat.

Covaleskie, J. F. (2005). Ethical Teacher s: Ethical People. Philosophy of Education Yearbook, 34-136.

Crotty, R. (2010). Values education as an ethical dilemma about sociability. In T. Lovat, R. Toomey, N. Clement (Eds.), International Research Handbook on Values Education and Student Well-Being (pp. 631-644). New York, NY: Springer Science and Business Media.

Diamond, I., & Orenstein, G. F. (Eds.). (1990). San Francisco, CA: Sierra Club Books.

Edgar, A. (2006). Habermas: The Key Concepts. New York, NY: Routledge.

Fox, W. (1990). *Toward a Transpersonal Ecology: Developing New Foundations for Environmentalism*. Boston and London: Shambhala Publications.

Gore, A. (2006). An inconvenient truth: The planetary emergency of global warming and what we can do about it. NY: Rodale.
Greene, M. (1988). The Dialectic of Freedom. NY: Teachers College Press.
Habermas, J. (1972). Knowledge and human interests. (J. Shapiro, Trans). London: Heinemann.
Hart, P. (2007). Environmental education. In S.K. Abell & N.G. Lederman (Eds.), Handbook of research in science education (pp. 689-728). Lawrence Erlbaum Publishers.
Hodson, D. (2003). Time for action: Science education for an alternative future. International Journal of Science Education, 25, 645 - 670.
Holdren, J. P. (2011). America COMPETES Act keeps America's leadership on target. The Whitehouse Blog. Retrieved June 30, 2011from http://www.whitehouse.gov/blog/2011/01/06/america-competes-act-keeps-americasleadership- target.
Johnson, R.R. (2010). Balancing Acts: A case for Confronting the Tyranny of STEM. Programmatic Perspectives, 2(1): 86–92.
Jones, A., McKim, A., & Reiss, M. (Eds.) (2010). Ethics in the science and technology classroom: A new approach to teaching and learning. Rotterdam/Boston/Taipei: Sense Publishers.
Kaufman, G. (1992). SHAME: The power of caring. Rochester, Vermont: Schenkman Books.
Kim, M. (2005). Ethics of pedagogy in world-becoming: Contemplations on scientific literacyfor citizenship. Delta Kappa Gamma Bulletin 71(3) 52-58.
Lee, M., & Mossaad, N. (2010). Canada STEM workers data sources. Population Reference Bureau, [electronic version]. www.prb.org/pdf10/canada-stem.pdf.
Lewis, M. (1995). Shame: The exposed self. NY: The Free Press.
Machi, E. (2009). Improving U.S. competitiveness: With K-12 STEM education and training.The Heritage Foundation. Washington, DC.
Margolis, D.R. (1998). The fabric of self: A theory of ethics and emotions. New Haven: Yale.
Maurer, R. (1996). Beyond the wall of resistance. Austin, Texas: Bard Books.
McKim, A. (2010). Bioethics Education. In A. Jones, A. McKim, & M. Reiss (Eds.), Ethics in the science and technology classroom: A new approach to teaching and learning (pp. 19-36). Rotterdam/Boston/Taipei: Sense Publishers.
Ministry of Education, British Columbia (2005). Science K to 7: Integrated Resource package. http://www.bced.gov.bc.ca/irp/pdfs/sciences/2005scik7.pdf.
Ministry of Education of Ontario. (2008). Science: The Ontario curriculum grade 9 and 10 revised. Toronto, Ontario: Queen□s Printer for Ontario.
Ministry of Education of Ontario. (2007). Science: The Ontario curriculum grades 1-8 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.
Naess, A. (1989). *Ecology Community and Lifestyle*, (trans) David Rothenberg, CUP, Cambridge.
National Science Foundation. (2011). Ethics Education in Science and Engineering. Retrieved June 30, 2011 from http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=13338,; and http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503490&org=SBE.
Newfoundland and Labrador Department of Education (n.d.). Intermediate Science Curriculum Guide: Grade 7. http://www.ed.gov.nl.ca/edu/k12/curriculum/guides/science/index.html#intermediate.
OECD (2010), PISA 2009 results: Executive summary. Retrieved on February 19, 2011 from www.oecd.org/edu/pisa/2009.

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

Pedretti, E. (2005). STSE education; Principles and practices. In Alsop, S., Bencze, L., & Pedretti, E. (Eds.), Analysing exemplary science teaching: Theoretical lenses and a spectrum of possibilities for practice (pp. 116-126). New York: Open University Press.

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 Education, 17, 941-960.

Pedretti, E. G., Forbes, J. (2000). STSE education: From curriculum rhetoric to classroom reality. Orbit, 31(3), p. 39.

President's Council of Advisors on Science and Technology (PCAST). (2010). Report to the President. Prepare and inspire: K-12 education in science, technology, engineering, and math (STEM) for America's future. Retrieved September 13, 2012 from http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-stemed-report.pdf

Reiss, M. (2010). Ethical Thinking. In A. Jones, A. McKim, & M. Reiss (Eds.), (pp. 7-18). Ethics in the Science and Technology Classroom: A New Approach to Teaching and Learning. Rotterdam/Boston/Taipei: Sense Publishers.

Rockland, R., Bloom, D.S., Carpinelli, J., Burr-Alexander, L., Hirsch, L. S., & Kimmel, H. (2010). Advancing the "E" in K-12 STEM education. The Journal of Technology Studies, 36(1), 53-64.

Sanders, M. (2009). STEM, STEM education, STEMania. The Technology Teacher, 68(4), 20-26.

Saskatchewan Ministry of Education (2009). Curriculum Science 8, https://www.edonline.sk.ca/bbcswebdav/library/curricula/English/Science/science_8_2009.pdf.

Scheff, T.J., & Retzinger, S. M. (2000, October). Shame as the master emotion of everyday life. Retrieved June 28, 2011, from sell.hil.no/nndr2005/symbol.doc.

Singer, P., & Hauser, M. (2006). Godless Morality. Project syndicate. http:/ www.projectsyndicate. org/commentary/hausersinger1/English

Sommerville, M. (April, 2011). What Does Doing Ethics Mean? The Conference. http://theconference.ca/what-does-doing-ethics-mean.

Steele, A. (2011). Beyond Contradiction: Exploring the work of secondary science teachers as they embed environmental education in curricula. *International Journal of Environmental and Science Education. 6*(1): p 1-22.

Tan, M. (2009). Science teacher activism: The case of environmental education. Journal for Activist Science and Technology Education, 1(1), p. 32-43.

The State Education Department, The University of the State of New York (2010). Intermediate Level Science: Core Curriculum, Grades 5-8, http://www.p12.nysed.gov/ciai/mst/sci/documents/intersci.pdf

UNESCO. (2005). Scientism: A weed well fertilized in the garden of science education? Connect: UNESCO International Science, Technology and Environmental Education Newsletter. 30(3-4), 2-5.

UNESCO. (2004). Ethics of science and technology. Connect: UNESCO International Science, Technology and Environmental Education Newsletter. 29(3-4), 2-4.

Wiggins, G. (2011). A Diploma Worth Having. Educational Leadership, March, 28-33.

WRALtechwire (2010, December 13). IBM CEO ties economic growth to STEM education. WRALtechwire. http://wraltechwire.com/business/tech_wire/biotech/blogpost/8766999/.

Young, B., & Stewart, P. (2010, December 24). Bayer□s bid for STEM: „Making science make sense□. WRALtechwire. Retrieved February 19, 2011 from http://wraltechwire.com/business/tech_wire/news/blogpost/8823420/.

Youth Science Canada Welcomes New Google Science Fair. (2010, December 1). Youth Science Canada. Retrieved February 19, 2011 from http://www.ysf.ca/News_Releases/news12011001.aspx.