“Utility of Science in A Globally Unsustainable Society”

Abstract

A central “risk factor” (Rutter, 1987) for secondary level learners drives this research: the perceived irrelevance of scientific endeavour to the pursuit of sustainability. The intent of this study is to employ an educator survey, the Natural Step Framework for Sustainability (Robert, 2000) and Senge’s Systems Thinking (Senge, 1990) to develop, implement and assess the impact of an interdisciplinary sustainability-based educator resource for use in senior years level sciences/ mathematics classrooms in Manitoba. The particular applicability of systems thinking in science education to achieve that end will be explored (Capra 1982; Porritt 2000). Bronfenbrenner’s dynamic systems model (1979) is the foundation for understanding and measuring the “development-in-context” that is potentially achieved upon implementation of the resource and the increase in “resiliency” (Rutter, 1987) will be measured.

This paper will first establish a theoretical basis for development of the educator resource and then clarify the central risk factor so that it can be used to guide the subsequent implementation and evaluation of the educator resource. It should be noted that the educator resource is in development stage and thus implementation and evaluation of the educator resource is projection only.
Need for the Research

The interconnected web of unsustainable practices the planet is experiencing is as ubiquitous as the daily news. Recognition of the importance and urgency of ensuring movement toward more sustainable living is becoming increasingly commonplace. Recognition of the pivotal role of education, and the particular applicability and necessity of science education in this movement is evidenced in statements from the UNDESD (United Nations Decade for Education for Sustainable Development), the OECD (Organisation for Economic Co-operation and Development), and the AAAS (American Association for the Advancement of Science).

The AAAS is an international non-profit organization dedicated to advancing science around the world by serving as an educator, leader, spokesperson and professional association. It released the document titled Science for All Americans as part of Project 2061. It argues that,

“Science, energetically pursued, can provide humanity with the knowledge of the biophysical environment and of social behavior needed to develop effective solutions to its global and local problems; without that knowledge, progress toward a safe world will be unnecessarily handicapped.” (Science for All Americans, 1990)

This highlights the notion that science is an essential tool in the quest for a “safe” world. Resolving issues of peace are central to develop sustainability. Peace and security are identified in the Millennium Ecosystem Assessment (MEA) as one of the essential
elements of human health and well-being on the path to sustainability (Milennium Ecosystem Assessment, 2005). This document further details the utility of science in saying that America’s ability to

“...create a truly just society, to sustain its economic vitality, and to remain secure in a world torn by hostilities depends more than ever on the character and quality of the education that the nation provides for all of its children.” (Science for All Americans, 1990)

While this document self-proclaims to fulfill “...immediate national interests of the United States...” there is also acknowledgement that

“... The most serious problems that humans now face are global: unchecked population growth in many parts of the world, acid rain, the shrinking of tropical rain forests and other great sources of species diversity, the pollution of the environment, disease, social strife, the extreme inequities in the distribution of the earth's wealth, the huge investment of human intellect and scarce resources in preparing for and conducting war, the ominous shadow of nuclear holocaust—the list is long, and it is alarming.” (Science for All Americans, 1990)

The concern and clear direction is not unique to the AAAS. The UNDESD also emphasizes the challenge that lies ahead for science education in particular saying,

“Promoting the goals of a transition to sustainability is a major challenge for science and technology” (UNDESD, 2005).

Having established that Science and Mathematics are necessary tools in working toward sustainability, the reversal of the notion that students generally do not perceive this genre of academia as pertinent is clearly an urgent, worthy goal.
Context

Using Bronfenbrenner’s dynamic systems model, the focal point is the learner and the “development-in-context” that the learner experiences through exposure to the educator resource. It is pivotal to describe the development of the learner as part of an ecological environment defined by Bronfenbrenner (1979) as “…a set of nested structures, each inside the next, like a set of Russian dolls” (Bronfenbrenner, 1979). The innermost level is the microsystem, followed by the mesosystem, exosystem and macrosystem. Each successively nested system is inextricably connected to all other systems.

This research is situated in the “macrosystem” defined by Bronfenbrenner as the “...consistencies, in the form and content of lower-order systems (micro-, meso-, and exo-) that exist or could exist at the level of the subculture of the culture as a whole, along with any belief systems or ideology underlying such consistencies” (Bronfenbrenner, 1979) Since the macrosystem includes three lower-order systems (micro-, meso-, and exo-) an explanation of the scope of each is necessary here.

Definition of micro, meso, exo systems

The microsystem is the ecology of the individual learner, focussing on the personal attributes that influence an individual’s interaction with science and mathematics. Examples of factors considered in this system are student’s perceptions of and attitudes towards these subjects, their own science-mathematics learning efficacy and their sense of ‘belonging’ as learners in the domains of science and mathematics. The starting point of this research is thus the identification of the risk and protective factors in learners, which will be discussed in detail.
The mesosystem examines the impact of the proximal relationships in the ecology of the individual: teachers, family, and peers. This focuses on science and mathematics learning in the classroom and how social factors such as teachers, family and peers influence science and mathematics learning and success. For this research, the identification of risk and protective factors for educators delivering science curricula is pertinent and will be ascertained through use of an educator survey.

The exosystem examines science learning in the context of the community and investigates how the local community can work collaboratively to enhance the science and mathematics success of the individual student. Facets of this will be sure to play a role in the educator responses on the survey. The Natural Step Framework has particular application in this system as it provides a framework for collaboration.

Finally, the macrosystem considers the interplay between the global society and science/mathematics success. The development and implementation of an educator resource is framed as such and so will involve interaction of senior level students in the learning of science as it is applicable to global sustainability. Such contextualized interaction aims to increase the utility of science in the minds of the learners by minimizing their risk factors and maximizing their protective factors.

Reductionist Science in the Macrosystem and Utility of Science

Within a Bronfenbrenner dynamic systems approach, the relationship between science and society has been summarized well by Porritt when referring to comments made by Sir
Michael Attiyah, President of the Royal Society in November, 1995. When speaking of the first atom bomb destroying Hiroshima, Attiyah argued that,

“No other single event has so profoundly affected the relationship between science and society....The most immediate effect was to highlight the moral dilemma of scientists...this anti-science feeling has grown alarmingly, with environmental worries taking over from nuclear weapons as the driving force” (Porritt, 2000).

If environmental worries are indeed the driving force of the “anti-science” feeling he identifies, the moral dilemma of scientists must be addressed by this research. The nature of this moral dilemma is difficult to define. Is it a dilemma between scientific endeavour and its indiscriminate application regardless of context or consequence? This research suggests that it is a dilemma between present reductionist science and the need for systems thinking. Within systems thinking, the application of scientific endeavour considers the entire system and all systems it lies within, and thus, context and consequence cannot be ignored.

Reductionist science has limited learners to think and study in terms of minute parts of the universe without thought as to how the parts integrate to form a functioning whole. This is demonstrated well by Capra in describing the study of biology. He claims that,

“Carried away by the successes of the reductionist method, most notable recently in the field of genetic engineering, they [biologists] tend to believe that it is the only valid approach, and they have organized biological research accordingly...Biological phenomena that cannot be explained in reductionist terms are deemed unworthy of scientific investigation...As distinguished biologist and human ecologist Rene Dubos has pointed out, they usually feel most at ease when the thing they are studying is no longer living” (Capra, 1982).
It is by no leap of the imagination that one can connect this notion to the separation from context that must be experienced by secondary students when studying science. This in turn has lead to a sense of irrelevance toward scientific endeavor. As learners may not innately think in reductionist terms, reductionist science imposes an unnatural mode of thinking upon learners. With the context removed, the individual parts seem irrelevant. This research seeks to re-contextualize science in terms of sustainability.

Paradigm Shift- Reductionist Thinking to Systems Thinking

Having made the argument to shift away from reductionist science, a case is now made to move toward systems thinking. Bronfenbrenner’s description of a “transforming experiment” is applicable in this regard because it involves “…the systematic alteration and restructuring of existing ecological systems in ways that challenge the forms of social organization, belief systems, and lifestyles prevailing in a particular culture or subculture. (Bronfenbrenner, 1979). Essentially, this research does aim to systematically restructure the experience of the learner in a way that challenges the prevailing notion that science is irrelevant to sustainability in the global society. To accomplish this, the educator resource will incorporate principles of systems thinking in place of reductionist thinking so prevalent in present educator resources.

Systems thinking begins with a true reflection rather than try to “…reassemble fragments of a broken mirror to see a true reflection” (Senge, 1990). This research posits that if reductionist science results in the perception that scientific endeavour is irrelevant to sustainability issues, then it is in itself a risk factor identified at a macrosystem level. The
protective factor is then deemed to be the promotion of systems thinking, and the educator resource to be developed will place priority on systems thinking.

Systems thinking is described as “…a discipline for seeing wholes. It is a framework for seeing interrelationships rather than things, for seeing patterns of change rather than static ‘snapshots’” (Senge, 1990). For example, learners will focus on interrelationships between facets of climate change rather than simply an emaciated polar boy as the poster-child of climate change. Patterns of change will be explored rather than sterile “snapshots” of one scientific principle unrelated to the others and even more unrelated to other disciplines.

**Systems Thinking and Interdisciplinary Implementation of the Educator Resource**

It follows logically that systems thinking in its purest form would require science curricula to be covered in concert with other subject areas, taking a holistic approach across all subjects. Indeed this is the definition of interdisciplinary learning. (Manitoba Education and Training, 1998). The UNDESD advocates for interdisciplinary learning and teaching, stating that,

“*Housing natural and social and human sciences under one roof, UNESCO promotes multidisciplinary and interdisciplinary approaches to the wise use of natural resources and to the improved understanding of human–environment relationship*” (UNDESD, 2005).
The barriers to true interdisciplinary learning at the secondary level has been well documented by Summers (2005) and is beyond the scope of this paper. Though limiting, the parameters for implementation of the educator resources described herein need to be realistic and will likely occur in one of the courses which allows interdisciplinary delivery of content such as Current Topics 30S or Interdisciplinary Science 40S.

**Systems Thinking and The Natural Step Framework**

Since global sustainability will provide the context for the delivery of Manitoba science/mathematics curricular outcomes within these courses, the necessity of a very all-encompassing yet science-oriented framework is obvious. The capacity of the Natural Step Framework to serve as such is described now. Its non-prescriptive nature does not sacrifice strict adherence to four scientifically based “system conditions” (Appendix One) (Robert, 2000). The Natural Step is self-described as

“...part of an international non-profit research, education and advisory organization that uses a science-based, systems framework to help organizations, individuals and communities take meaningful steps toward sustainability. The mission of The Natural Step is to act as a catalyst to bring about systemic change, by making fundamental principles of sustainability easier to understand and effective sustainability initiatives easier to implement” (The Natural Step, 2006).

The Natural Step has “…worked to accelerate global sustainability by guiding companies, communities, and governments onto ecologically, socially, and economically sustainable paths.” It provides a decision-making model that can be applied many times in order to move toward sustainability.
The applicability of the Natural Step Framework to Manitoba curriculum can be made in that it is an applicable decision-making tool that demands adherence to four scientifically derived system conditions. It is within these system conditions that specific connection can be made to several curricular outcomes. Specific discussion of the curricular outcomes to be made are beyond the scope of this paper, but one example is presented here for clarity.

System condition 2 of the Natural Step Framework states that in order to move toward sustainability, we must “Eliminate our contribution to systematic increases in concentrations of substances produced by society” (Robert, 2002). This refers to persistent and unnatural compounds that have likely been synthesized by humans. One can link this easily to the Organic Chemistry component of the Chemistry 30S curriculum.

Having established a theoretical basis for development of the resource, the remainder of this paper clarifies the central risk factor so that it can be used to guide the subsequent implementation and evaluation of the educator resource.

**Identification of Risk Factors**

Microsystem: Learners Risk Factors

Clarifying the central “risk factor” for secondary level students -the perceived irrelevance of scientific endeavour as it applies to sustainability issues- is pertinent here. The foundation of my study is the recognition that student success is a function of "risk factors" which have a negative influence, and "protective factors" which have a positive influence. The combined effect of these factors is "resiliency" (Rutter, 1987) so that the aim of my study is to increase resiliency of learners by minimizing risk factors and optimizing protective factors. My research also recognizes Bronfenbrenner’s dynamic systems model
that what matters for student development is the students’ perceptions of their experiences rather than the objective reality of those experiences (Bronfenbrenner, 1979).

The OECD (Organisation for Economic Co-operation and Development) released a report titled “Declining Interest in Science and Technology Studies Among Young People: Trends, Factors and Actions” (OECD, 2005). In describing the trend of decreasing enrolment, it identified that

“Canada does rank towards the bottom of OECD countries in the proportion of students who do choose to study S&T (science and technology). The aggregate country data used in this study also hides disturbing trends in Canada that suggest certain Science and Technology fields are currently, or will soon, suffer from declining enrolment” (OECD, 2005).

A deeper examination of the reasons for decreased enrollment reveals that level of difficulty, negative perception of science careers and lifestyles, and lack of relevance of science to current “cutting edge science” play a role (OECD, 2005).

Sources of Perception of Irrelevance

According to the OECD report, declining enrollments are “...very often attributed to the uninteresting and difficult content of science courses” (OECD, 2005). One can seek depth to the two descriptors “uninteresting” and “difficult”. The question arises as to whether the content itself is “uninteresting and difficult” or whether the delivery of that content is the source of these undesirable modifiers.
Irrelevance caused by “Uninteresting” Science

In addressing “uninteresting”, the AAAS publication Science for All Americans suggests that,

“Science is more than a body of knowledge and a way of accumulating and validating that knowledge. It is also a social activity that incorporates certain human values. Holding curiosity, creativity, imagination, and beauty in high esteem is certainly not confined to science, mathematics, and engineering—any more than skepticism and a distaste for dogmatism are. However, they are all highly characteristic of the scientific endeavor. In learning science, students should encounter such values as part of their experience, not as empty claims” (Science for All Americans, 1990).

Curiosity, creativity, imagination, and beauty are provided in the context of natural systems in this research. Few can dispute the intrinsic value of natural systems to evoke all four of these ‘values’. Content and delivery that value curiosity, creativity, imagination and beauty would not likely be described as “uninteresting” by learners. Further to the reference to the “human” essence of these values, the impetus for humanization of science is perhaps long overdue. Porritt maintains that,

“It’s so much easier to remain embunkered in the value-free, uncomplicated rational world that reductionist science offers...than it is to venture out into the contested territory of ‘holistic science’ or ‘civic science’ or ‘precautionary science’...”

(Porritt, 2000).
Again, the call for systems thinking seems evident. Upon giving up reductionist science, one can,

“..build ‘learning organizations’, organizations where people continually expand their capacity to create results they truly desire, where new and expansive patterns of thinking are nurtured, where collective aspiration is set free, and where people are continually learning how to learn together.” (Senge, 1990)

Yet it is a shift of paradigmal proportion much like the one witnessed by the discipline of physics. Deep discussion of the evolution of physics from Cartesian/Newtonian physics to modern physics is beyond the scope of this research. That evolution, however, demonstrates a fundamental shift in thinking that needs to be re-injected into science education – that of systems thinking. Simply put, it was once thought that subatomic particles were “things” made up of discretely identifiable parts such as the proton, electron, neutron, and so on. Indeed, this is how educators teach these concepts to children today. However, modern physics posits that “…matter does not exist with certainty at definite places, but rather shows ‘tendencies to exist’ and atomic events do not occur with certainty at definite times in definite ways, but rather show ‘tendencies to occur’” (Capra, 1982).

This idea is consistent with and advocates for systems thinking in that,

“Subatomic particles…are not “things” but are interconnections between ‘things’ and these ‘things’ in turn are interconnections between other ‘things’, and so on. You always deal with interconnections. This is how modern physics reveals the basic oneness of the universe. It shows that we cannot decompose the world into independently existing smallest units. As we penetrate into matter, nature does not show us any isolated building blocks, but rather appears as a …web of relations between the various parts of a unified whole” (Capra, 1982).
Indeed this was a paradigm shift for physicists and similar stories can be told of other disciplines. The matter is that for most scientific fields, systems thinking may seem “unscientific” when indeed the opposite may be true. Capra advocates that

“Scientists will not need to be reluctant to adopt a holistic framework, as they often are today, for fear of being unscientific. Modern physics can show them that such a framework is not only scientific but is in agreement with the most advanced scientific theories of physical reality” (Capra, 1982).

Scientific endeavor is perhaps better off if it searches for unifying concepts rather than miniscule bits of information. Perhaps only then can humans come full circle from complexity to simplicity.

Irrelevance Caused by “Complexity” of Science

The “difficulty” or complexity alluded to earlier perpetrates the perception of irrelevance of scientific endeavor. In addressing the “difficult” aspect of science learning identified in the OECD report, one can look again to systems thinking.

“All, systems thinking is needed more than ever because we are being overwhelmed with complexity...All around us are examples of ‘systemic breakdowns’...problems that have no simple local cause...” (Senge, 1990).

The effects of complexity are described as follows:

“Complexity can easily undermine confidence and responsibility – as in the frequent refrain, ‘It’s all too complex for me,’ or ‘There’s nothing I can do. It’s the system.’ Systems thinking is the antidote to this sense of helplessness that we may feel as we enter the ‘age of interdependence’” (Senge, 1990).
Robert also speaks of complexity in saying that “…we seek knowledge but we drown in information” (The Natural Step, 2006). Reducing complexity is another argument in support of the use of the Natural Step as a framework. It clarifies the important conditions under which sustainability can occur and limits it to four system conditions derived from natural systems themselves. It also provides a simple four-step process (The Natural Step, 2006) to facilitate learner’s quest to move toward sustainability.

**Mesosystem and Exosystem: Educators Risk and Protective Factors**

Educators are the vector of the learner’s experiences. As such, the risk and protective factors that affect teachers’ abilities to employ sustainability contexts in their teaching is necessarily the beginning focal point. A teacher survey is currently being conducted in two urban and two rural school divisions with the goal of identifying risk and protective factors that influence teacher’s abilities to integrate a sustainability context into present curricula delivery. This survey data will be used to develop the educator resource. Early results are supportive of both the need for the resource and the viewpoint that sustainability can be integrated into curriculum.

Preliminary results reveal that the risk factor that most influences educators’ abilities to integrate sustainability into their courses is “…lack of time to adapt sustainability issues from a source to ‘work in a classroom’ and secondly ‘…to meet science outcomes’”. This can be interpreted as a current lack of resources that pursue science outcomes in a sustainability context. Alternately, it could be interpreted to mean that educators are generally overworked. Either or yet alternate interpretations identify a need for the development of educator resources.
Even more intriguing is the most frequently identified protective factor. This factor was cited as having the least influence teacher’s ability to integrate sustainability into their courses and was worded as follows: “Sustainability issues should be taught separately from science”. This demonstrates that the educators surveyed did indeed believe that sustainability is an applicable context for the teaching of science at the secondary level.

The limitations of such preliminary results warrants discussion. It should be noted that these results are very preliminary in that the sample size was only fifteen.

**Implementation and Evaluation of the Resource**

Identification of risk factors and establishment of a baseline of learner’s perceived utility of science in a sustainability context will be the goals of pre-testing learners. A survey and face-to-face interviews will be used. Risk factors will be collated and categorized so that changes in risk factors can be tracked during implementation. Each student’s data will be summarized by graphically representing their perceptions on a continuum of perceived utility of scientific endeavour. Individual interviews of key participants who lie at various places on this continuum will be conducted to determine in more detail the sources of perceptions of irrelevance of scientific endeavor.

During implementation of the resource in (a) classroom(s), the educator employing the resource will be requested to complete a template describing pedagogical strengths and weaknesses of the resource. Tape-recordings of the classes to capture anecdotal situations involving expressions of utility of science will be conducted.
Post-testing of students carries the goal of measuring the impact of the resource as identified by change from pre-test results. A survey and face-to-face interviews will be used. Finally, a semi-structured writing activity will be used to debrief the experience.

Potential for province-wide implementation

Though this educator resource will be piloted in a limited number of classrooms, Manitoba Education, Citizenship, and Youth (MECY) has acknowledged alignment between the goals of the research and its own. Science, technology, society and environment (STSE) connections will be made in the resource, aligning it with the Pan Canadian Science Framework. As such, support in terms of dissemination of the resource through MECY provincial workshops and the Manitoba Education, Citizenship and Youth website have been offered.

Conclusions

Systems thinking as described by Senge maintains that “…small, well-focused actions can sometimes produce significant, enduring improvements, if they’re in the right place. Systems thinkers refer to this as ‘leverage’” (Senge, 1990) It is hoped that this research is in itself, or leads to leverage large enough to influence the learner at the heart of the microsystem so that they have the willingness, desire, technical knowledge and creativity to move structures, activities, and organizations toward sustainability. As the city planners, legislators, visionaries, and scientists of the near future, youth are an effective vehicle for this movement. It is investment in their education that can ensure they are agents of change toward a sustainable future.
Bibliography


Appendix One

The four system conditions are:

1. Eliminate our contribution to systematic increases in concentrations of substances from the Earth’s crust.
2. Eliminate our contribution to systematic increases in concentrations of substances produced by society persistent and unnatural compounds.
3. Eliminate our contribution to the systematic physical degradation of nature through over-harvesting, introductions and other forms of modification.
4. Contribute as much as we can to the meeting of human needs in our society and worldwide, over and above all the substitution and dematerialization measures taken in meeting the first three objectives. This means using all of our resources efficiently, fairly and responsibly so that the needs of all people on whom we have an impact, and the future needs of people who are not yet born, stand the best chance of being met. (Robert, 2002)