Lesson #5: Science – Blessing or Curse or Both or Neither?

<table>
<tr><th colspan="2">Stage 1 – Desired Results</th></tr>
<tr><td colspan="2">Established Goals: GLO A, GLO B
1. Examine mental models about science and its role in decisions about how to TAKE resources, MAKE material goods from those resources and deal with the WASTE.</td></tr>
<tr><td>Understandings:
Students will understand that…
1. SLO A1: There is a difference between science and technology in terms of contexts, goals, methods, products, values
2. SLO A4: Science and technology interact and evolve, often advancing one another</td><td>Essential Questions: SLO A2: Recognize both the power and limitations of science as a way of answering questions about the world and explaining natural phenomenon
SLO A1: Critically distinguish between goals , contexts, values, products, and methods of science and technology</td></tr>
<tr><td>Knowledge:
1. SLO B4: Knowledge of possible science and technology related interests and careers
2. SLO B1: Describe scientific and technological developments and appreciate their impact on individuals, societies, and the environment (locally/globally)(past/present)</td><td>Skills:
SLO A1: Communicate a mental model about the role of science in TAKE-MAKE-WASTE issues</td></tr>
<tr><th colspan="2">Stage 2- Assessment Evidence</th></tr>
<tr><td>Knowledge: Assess the detail the student gained from reading the biography Part A of the handout. This could be included in a rubric that was designed by the teacher and students.</td><td>Skills: SLO B4: Personal consideration of possible science and technology careers could be assessed in Part B of the handout
SLO B1 could be assessed in Part C of the handout. Include parts B and C in the same rubric assessment that involves part A (knowledge component)
Adapt Appendix 9 (p.60) Rubric for Assessment of Class Presentations
Adapt Appendix 9 (p.59) Rubric for Assessment of Student Presentation</td></tr>
<tr><th colspan="2">Materials Required</th></tr>
<tr><td colspan="2">Powerpoint Presentation ““Examining Our Mental Models””
CDs: Ten Summoner’s Tales” If I Ever Lose My Faith”
Eiffel 65 “Silicon Girl”
CD player
Overhead of science cartoon
HANDOUT: Science Cartoon (Bolton, R., Lamphere, E. & Menesini, M. (1979). Action Chemistry. Holt, Rinehart and Winston
HANDOUT: Your career and sustainable development: a scientists for global responsibility briefing. (2003). Kent, UK: Scientists for Global Responsibility (SGR).
HANDOUT: Science: Blessing or Curse (or both or neither)?”</td></tr>
<tr><th colspan="2">Stage 3 – Learning Plan</th></tr>
<tr><td colspan="2">1. Slide 17 - How do “science” and “technology” help or hinder us when we are thinking about the TAKE-MAKE-WASTE of what we consume?
2. Play “If I Ever Lose My Faith” DISCUSS the phrase “You could say I have lost my faith in science and progress” and “Never saw no miracle of science....It has changed from a blessing to a curse”. Encourage students to think of examples when science has been a blessing and when it has been a curse and examples of where it may have started out as a blessing but ended up as a curse. (see extension learning activity below)
Try to establish whether science is a “scapegoat”. That is, science might be asked to solve environmental problems and technology might remediate some environmental issues but there may be unintended consequences that science is then blamed for –feelings of ambivalence toward science/technology (see thesis below)
3. Play “Silicon Girl” DISCUSS the phrase “All that I want is a silicon girl with silicon lips and silicon curls…”</td></tr>
</table>

4. HANDOUT: Science Cartoon (Bolton, R., Lamphere, E. & Menesini, M. (1979). Action Chemistry. Holt, Rinehart and Winston)
5. Answer the following questions about the cartoon caption.
6. Read biography "ethical" scientist
7. Direct students to complete the HANDOUT: "Science: Blessing or Curse (or both or neither)?"
8. Does the analysis of this cartoon affect anything about your organization? Change if necessary.

Homework Learning Activities

Extension Learning Activities

It would be **GRAND** to more deeply develop the last question on the handout My Mental Model to become a research project perhaps with the title "Science Helps and Hinders" as many real-life examples can be found in which some innovation has unintended consequences that are unforeseen or not predicted or simply ignored. Some examples might include
*Three Mile Island
*Chernobyl
*Pesticide Use
*Scientists being paid to keep some findings secret/embellish some findings
*Invasive Species
*classic examples like DDT etc.
(depending on your time available)
The point here is to recognize that science has contributed to many disasters and ethically questionable occurrences (though many factors obviously come into play, not only the science innovation). It is REDUCTIONIST science that is to be questioned – the application of science "in a vacuum" – in a way that is not holistic, not conducive to systems thinking. An exerpt from my thesis is included for your information/interest.

Exerpts from

Science Content Through Sustainability Contexts: A Systems Thinking Approach for Learning Resources in Secondary Level Education

(Maxwell, 2009, p.71-79).

Rethinking the Science-Sustainability Relationship

I acknowledge that it is through scientific endeavour that has often been conducted in a traditionally reductionist manner that we have come to understand the nature of natural systems. I agree with the "rock-solid realization that modern science has brought us startling benefits – and will no doubt continue to do so" (Porritt, 2000, p. 10). My critique begins with the insufficiencies of studying natural systems (or even physical systems as I will discuss later) through purely quantitative means.

Indicators within the MA (2005) demonstrate that repeatedly, natural systems are shown to be more unpredictable than quantifiable science can handle. The limits of strictly "quantifiable" analyses are perhaps most pronounced when studying natural systems. Goodwin (2000) states, "we have reached the limits on the use of scientific knowledge for the control of nature through predictive technology… Furthermore, attempts to manipulate them for our advantage result in problems: pollution, erosion, environmental disease, stress and ill-health in individuals, communities and organizations, economic instability and insecurity….The control paradigm of science arises from a separation of the controller from the controlled, of subject from object, of human being from nature. This developed out of the Cartesian separation of mind from matter. However, the restoration of qualities as objectively-observable aspects of the world requires that we rethink our definition of matter" (p 33).

I suggest that the contribution of quantifiable aspects directed at control and prediction of natural systems is one, but only one, important aspect of the "holistic" science needed to address sustainability issues effectively. Reliance on strictly the quantifiable and predictable has resulted in understandings of natural systems that are not fully informed as they do not take into account the dynamics of the entire system as a whole. This reductionist approach has contributed to the current state of unsustainability as it has rendered science ill-equipped to deal with the complexity that is inherent in natural systems.

In rethinking the science-sustainability relationship, the first challenge then will be to simultaneously value the role of quantifiable science while expanding science to include analysis of the emergent properties of the whole system under study. This does not alter the essential properties of science though it does demand systems thinking (Senge, 1990).

The science-sustainability relationship is fundamentally altered when one views natural systems from a systems thinking perspective. Firstly, there is a rejection of a narrow or reductionist approach to scientific endeavor that precludes the importance of the qualitative analysis of a natural system as a whole. Secondly, there is no need to abandon quantitative analysis. Instead, systems thinking would necessitate quantitative analysis on the grounds that a complete picture cannot be described without it. Quantifiable science offers quantified results of empirical data collection. As a tool for examining one aspect of reality – that which can be quantified – reductionist science has served phenomenally well. Abandoning quantifiable aspects of science would be a great disservice to humankind, and my research is not meant to underestimate its contribution.

As Goodwin (2000) describes: “Western science has been phenomenally successful in its goal of unlocking nature’s secrets…The diversity of aspects of the natural world that fall under the spell of numbers and mathematics is astonishing, ranging from light and magnetism and chemical reactions to the laws of biological inheritance” (¶30).

Reductionist Thinking – A Long Tradition

Reductionist thinking includes the notions that systems can be fragmented, compartmentalized, and understood. Furthermore, once put back together, the whole is no more than the sum of its parts. Therefore, analysis of the parts is all that is necessary to understand the whole.

While a deep discussion of the evolution of physics from Cartesian/Newtonian physics to modern physics is beyond the scope of this research, that transition demonstrates a fundamental shift toward systems thinking that needs to be awakened in the field of science and in science education. While the former is likely inevitably occurring -I cannot comment - the latter, I contend, lags behind.

As an example, it was once thought that subatomic particles were “things” made up of discretely identifiable parts such as the proton, electron and neutron. However, modern physics posits that matter does not exist with certainty at definite places. Instead it shows ‘tendencies to exist’ and there is no certainty that any atomic events will or won’t occur with certainty at definite times in definite ways (Capra, 1982). Clerk Maxwell and Michael Faraday are partially credited with dethroning Newtonian mechanics through electromagnetism by replacing the idea of a force with a force field that has its own reality and can be studied without any reference to material bodies (Capra, 1982). Subatomic particles are more about interconnections between things that being things themselves (Capra, 1982). Dealing with interconnections rather than discrete entities is how modern physics reveals the basic oneness of the universe. It shows that one decomposes the world into independent units, we are distancing ourselves from what nature shows us. Nature shows a web of relations between various parts of a unified whole rather than an accumulation of independent units (Capra, 1982).

With Einstein’s tangible recognitions of this in our century, the ideas of evolution, change, growth, and development arose and it would dominate the nineteenth century and all future scientific thinking (Capra, 1982).

Public Rejection of Reductionist Thinking

The public has begun to recognize the limitations of reductionist thinking. Science can indeed be seen to play a pivotal role in initiating and perpetuating events that negatively affect human well-being on a massive scale. A pivotal historical event was detailed in the final address of Sir Michael Attiyah, President of the Royal Society in November of 1995 to highlight a moral dimension to this anti-science sentiment. In reference to the first atom bomb destroying Hiroshima, “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, p.19). The belief in “the benign influence of science” that prevailed after World War II began eroding following events such as the Vietnam War, the Three Mile Island nuclear accident, and the outbreak of bovine spongiform encephalopathy (BSE) (Porritt, 2000, p.11). Yet these events seem to be only precursors to a downward spiral of anti-science sentiment from which we have not yet escaped. To fuel the public distrust more recently, add genetically modified foods, chlorofluorocarbons, persistent pesticides and endocrine disrupting chemicals to the list of sustainability issues that science has been held accountable for by many. Such events and “developments” and “revolutions” perpetrate a “deep unease about the wisdom of looking to science as the ultimate arbiter of authority in modern society” (Porritt, 2000, p. 10).

Science today is in a precarious position - simultaneously perceived as a scapegoat for the world’s ill and as its solution to those ills. The risk mechanisms that consequently evolve are deeply rooted historically and philosophically.

Capra (1982) specifies clearly a moral dimension in saying that science is getting ‘carried away’. In an editorial in the *Daily Mail* commenting on a human genetics breakthrough**: “**This uneasiness is not hard to understand. It is not simply the feeling that science is advancing at a pace that leaves most of us in a state of almost total incomprehension. In this century, that feeling has long been familiar. No, it is something older and more basic, something that previous generations would have unhesitatingly and unselfconsciously identified as the fear that scientists are ‘playing God’. Though we would welcome the advertised benefits of these breakthroughs, we cannot help suspecting that such work is driven by a blinkered arrogance that will inevitably lead to calamity” (Porritt, 2000, p.12). Presented this way, this sentiment might be a demand for a cessation of seemingly indiscriminate and ethically void study and application of science, regardless of context or consequence.

Porritt’s (2000) description of the astonishment that the public displays “at the easy ability of so many scientists to remain indifferent to the fact that the planet seems to be disappearing down the evolutionary plughole as they pursue increasingly specialized areas of knowledge of decreasing value to society at large” (p.10) is really a critique of the failure, in the public’s eye, of science approaches that rely strictly on the quantifiable aspects of reality for the purpose of control and prediction.

Thus, while the public has recognized value to the “quantifiable aspects” of science and the resulting fruits, it has also acknowledged the limits to reductionist approaches in science. Especially in the area of sustainability issues, there is a need for an expansion of the type of thinking in scientific endeavor which includes examination of entire natural systems as more than merely the sum of their parts. Such analysis requires more than quantitative analysis that has been the dominant mode of thinking since Descartes. The challenge for science is in redefining itself in terms of wholes with parts rather than parts only.

The shift from reductionist to systems thinking in the field of science will not be a simple or quick one. As Porritt (2000) argues, “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’” (p.33). This is also a major challenge for my research and I do not purport to ensure an instant shift of paradigmatic proportion. A phenomenon so tacit and ubiquitous is not easily shifted. Nevertheless, even one further demonstration of the value of systems thinking shifts us closer to the use of science to address sustainability issues in meaningful and lasting ways. In addition, Senge proposes that humans are more naturally suited to systems thinking (Senge, 1990) and so I have optimism that students can be guided by their natural ways of thinking if we allow it.

Shifts Toward Systems Thinking in the Field of Science

If the reader accepts that the shift toward systems thinking is thus becoming increasingly necessary in the field on scientific endeavour, then the question of exactly how this paradigm shift will occur is next. Goodwin (2003) describes four awakenings in science that have undeniably begun this paradigmatic shift.

Four Awakenings in Science

The first awakening followed Einstein's discovery of relativity early in the twentieth century which was a way to describe the relationships between different observers in a world where communication is not instantaneous but is limited by the velocity of light: “There is no absolute frame of reference, no preferred perspective that gives one observer authority over another in observing natural processes. Each observer is free to choose whatever frame of reference is most convenient and elegant for describing whatever is being observed, and consistency with other observers' chosen reference frames depends upon relations defined by a mathematical transformation” (Goodwin, 2003**,** ¶unknown).

Beyond this notion that all perspectives are dependent on the observers’ frame of reference, the second awakening involved quantum mechanics which revealed a holistic physical reality. That is: “The quantum realm is governed by principles of intimate entanglement and co-ordination between its components, a non-local connectedness resulting in holistic, correlated order that extends over time and space, while what is observed depends also on what the observer chooses to look at” (Goodwin, 2003**,** ¶unknown).

Both of these awakenings demand a shift toward a view of natural systems as complex systems comprised of individual elements. The shift involves accepting that one is unable to predict the coherent behaviour of the entire system despite being able to understand the behaviour of all the elements in isolation and having a perfectly clear understanding of their individual rules of interaction (Goodwin, 2003¶unknown).

The third transforming development was the realization in the 1970s that “the laws governing the motion of the planets and the dynamics of the weather include the possibility of what is called deterministic chaos, which means that their behaviour cannot be predicted accurately beyond a limited period of time” (Goodwin, 2003, ¶unknown). This was due to a property known as sensitivity to initial conditions. The first person to understand this was the great French mathematician/physicist Henri Poincaré, but it was Edward Lorenz who made this property clear through his computer simulations at Massachusetts Institute of Technology (MIT) in the 1960s and 1970s (Goodwin, 2003, ¶unknown).

In the 1980s and 1990s, the emergence of complexity theory provided the most recent awakening. The patterns that emerged in computers simulating complex systems, “which include flocks of birds, social insects such as ants and termites, evolving ecosystems, and the dynamic patterns described in Lovelock's Gaia hypothesis, reveal that the Earth is like a living organism; the patterns are often unexpected but can be understood after one sees their behaviour. However, the slightest change in the properties of the components or their rules of interaction can produce quite unpredicted behaviour. These unexpected phenomena are known as emergent properties of complex systems.

They give us insights into the natural creativity of the world, and urge caution in how we interact with it" (Goodwin, 2003, ¶unknown).
Goodwin (2000) clarifies: "Here the problem is to understand how unexpected properties arise from the interactions of the component elements of a complex system, which can be physical, chemical, biological or social. These are called emergent properties, because the system as a whole displays behaviour that is unpredictable from an observation of the interactions of its component parts" (¶31). As a practical example: "colonies of social insects such as bees, wasps, termites and ants achieve remarkable feats of organization and co-ordinated action that go so far beyond the capacities of the individuals that the colony is often described as a superorganism, an emergent whole with properties of its own. Termites construct their beautifully intricate colonial dwellings through processes that look anything but organized. Yet out of the activities of termite construction gangs that form and disperse in apparently chaotic patterns, there emerge coherently structured apartments, complete with air conditioning, that accommodate thousands of inhabitants" (Goodwin, 2000, ¶31).

Science Cartoon

Copyright not obtained

Cartoon titled “AH.HA!”

Source: Bolton, R., Lamphere, E., & Menesini, M. (1979). *Action Chemistry*. New York: Holt, Rinehart and Winston, p. 325.

Bolton, R., Lamphere, E. & Menesini, M. (1979). Action Chemistry. Holt, Rinehart and Winston.

1. Look at the person who is in the “supervisory position”.
   a) Why would he be saying “Ah ha!”?
   b) What does he show us about his “mental model” about how “stuff” is made?
   c) Do you think this has ever happened in “real life” to any supervisors?

2. Look at the scientist.
   a) How would you describe the look on his face?
   b) What does he show us about his “mental model” about how things are made?
   c) Do you think this has ever happened in “real life” to any scientists?

3. If the whole world decided that there were to be no more synthetic fibers, what would change for
   a) scientists?
   b) consumers?
   c) sheep?
   d) Others involved?

Science: Blessing or Curse?
(or both or neither?)

Read your biography. Your biography has several things in common with everyone else's biography. In each biography, the person is

*involved in a career in the area of science/technology
*has an "issue" that causes some level of discomfort with their career/position
*takes action to solve the issue (individual level, society level)

A. Research the following from your biography.

1. Education the person obtains:

2. Details about the career

3. Issue that caused them to become uncomfortable with their career/position:

4. What action the person took to "solve" the issue (individual level, society level)

B. Reflect on your personal opinion:

1. What would you do if you were this person?

2. Do you see yourself going into a career in science/ technology? Why/why not?

Communicate your opinion about science:

1. Do you think science is a blessing, a curse, both or neither? Explain. Use real life examples (historical events, experiences, stories, -other than the biography) in which science has been a blessing/curse to support your opinion.