Why Do We Teach Science?

A Science Education eBook

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The Art of Teaching Science Weblog

Preface

Why do we teach science? is the first of a series of science education *eBooks* that will be published, and made available on the Art of Teaching Science Website (http://artofteachingscience.org). The eBooks are based on blog posts written over the past seven years, and will include a variety of topics of interest to science teachers, and science education researchers. Future titles include Extreme Earth, Evolution by Design and Science Teaching: Is it Pedagogy or Petrology?

Why do we teach science?

In this first eBook, we explore the question *why do we teach science?* The reasons for teaching science are not as clear as one may think. Much of the reform going on right now does not address the question directly. What one has to do is examine the goals of a particular curriculum or reform report, and then infer what the authors would say if asked, why do we teach science in the first place?

In Part I, we use a model developed by R. Stephen Turner to explore four arguments including the economic argument, the democratic argument, the skills argument, and the cultural argument.

What do we teach?

In part two of the book, we raise the question, *what do we teach?* To answer this question, we suggest two Visions for teaching science, a traditional vision and a humanistic vision. The new Framework for K-12 Science Education is evaluated, and we find that there appears to be a conflict between the desire to standardize the curriculum and foster innovation.

How do we teach science?

In the third part, we explore *how do we teach science?* Insights are drawn from humanistic learning, engineering, native science, and experiential learning to draw a picture for the need to re-think how we teach science.

The series of eBooks will continue to be published, and will be available at the Art of Teaching Science Website. Future titles include Extreme Earth, Evolution by Design and Science Teaching: Is it Pedagogy or Petrology?

About the Author

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Cover: Hummingbird in the Rockies by Jack Hassard using an iPhone camera

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Introduction
Why Do We Teach Science?

There is a new generation of science standards on the way. A committee selected by the National Research Council, with funding from the Carnegie Foundation, has developed the Conceptual Framework for New Science Standards. The Framework will guide the development of new standards, which will be written by Achieve, a non-profit organization established some years ago by the National Governors Association.

The new Framework does not answer the question "Why do we teach science?" but does inform us what students should learn. I have read the report, and there is no discussion of why we teach science. Here is an opening paragraph from the Draft Framework in which what students should learn is explained:

This framework lays out a set of goals for *what students should learn in science and in engineering.* These goals for science and engineering education are informed, first and foremost, by a view of the essential elements of science and engineering that must be conveyed to all students. The first step in identifying these elements must be an exploration of what we perceive science to be, of the distinctions between science and engineering as practices, and of the diversity of practices engaged in by scientists and engineers.

Why do we teach science in the first place? This question is always been important, but much of the reform going on in the US today has not addressed the question directly. What one has to do is examine the goals of a particular curriculum or reform report, and then infer what the authors would say if asked, why do we teach science in first place?

For example, the National Science Board, in its September 2010 report on Preparing the Next Generation of STEM Innovators stated that the development of the Nation's capital through schooling was an essential building block for the future of innovation.

The report's authors outline recommendations in three areas including opportunities for excellence, casting a wide net to attract individuals to science, and create an environment that will foster innovation. The rationale for the NSB report is embodied in these two stated rationales:

- The nation's economic prosperity, security, and quality of life depends on the identification and development of our next generation of STEM (Science, Technology, Engineering, Mathematics) innovators
- Every student in America should be given the opportunity to reach his or her full potential.

In their view the economic prosperity of America, and science for all appear to be rationales for teaching science. As you will see later in this piece, the "economic argument" is only one of several arguments that help us answer the question: Why do we teach science?

In doing research for this piece, I came across R. Steven Turner's paper on science education. Turner, in his keynote speech to the CRYSTAL Atlantique Annual Colloquium, addressed the issue as seen in the title of his talk: Why do we teach science, and why knowing matters. In his address, Turner explored four different arguments that could be used to answer the why question. The arguments are identified as:

- The Economic Argument
- The Democratic Argument
- The Skills Argument
- The Cultural Argument

Why we teach science is embedded in these arguments. Much of Turner's paradigm for looking at why we teach science is based on work by Robin Millar of the University of York, and author of several works on science education. A brief discussion follows for each argument.

Which of these arguments represents why we teach science in your view? Is there one argument that dominates school science today? Is there one or more that dominates the reform agenda of science education?

The Economic Argument

In the pipeline view, students are channeled upward to post-secondary schools to study science, technology and engineering. The goal is produce more scientists and engineers to meet the supply demands in science-related fields. The problem is that crises in manpower shortages have been greatly exaggerated and only 2/3?s of people majoring in science actually take jobs in science. Comparative data used from TIMMS and PISA achievement scores has undermined science teaching and is used in policy debates as if the results are flawless. The argument goes that if we can boost the test scores of 15 old boys and girls, the nation's economy will grow. This results in more of the same curriculum and more time in class. The new national framework for a subsequent set of science standards is a good example of reform rooted in the economic argument. Content of science is emphasized and comparisons with the 1995 science standards show little difference.

The Democratic Argument

In this view we teach science to prepare students to be informed citizens and knowledgeable consumers. The curriculum would be quite different than the economic/standards-based design. It would focus on the technological and real-world applications of science. Science curriculum would focus on what students would need to know to participate in key controversies of the time, global warming, energy, environmental issues, and health. The democratic is another name for the humanistic argument advocated by science educator Glen Aikenhead, especially in his book Science for Everyday Life: Evidence Based Practice. The humanistic argument is the central argument in the STSE movement (science, technology, society, environment).

The STSE movement is not the dominant paradigm used in science curriculum, although one can find "STSE

Standards" in the NSES publication. After examination of the new framework, STSE is still not considered "main stream" by the developers of the NRC New Generation Framework for the Science Standards. Yet the research, as reported by Aikenhead, and others, supports the inclusion of STSE curriculum in school science, and that it does contribute to positive attitudes among students who take science courses.

The Democratic Argument offers a view of the science curriculum that is more student-centered, and related to life-experiences of students within the context of science.

The Skills Argument

The Skills Argument suggests that the mere study of science instills certain transferable skills that are important to students' understanding of science. The skills argument is the process of science argument that is strongly advocated by science education researchers, and by organizations such as the National Science Teachers Association. Indeed, the skills argument claims that students should be involved in hands-on activities, analyze data, and plan open-ended investigations.

The skills argument is the argument that suggests that teachers should use an inquiry-approach to teaching and help students learn how to practice inquiry. Much of science teacher education is oriented around an inquiry-approach to science teaching, and students of science education are steeped in the theories of Piaget, Vygotsky, Dewey, Bruner, and others who advocated this approach.

Indeed, if you peruse the journal Science Education or the Journal of Research in Science Teaching, inquiry appears as a dominant term in any search.

A good discussion of the science as inquiry approach is the testimony that Professor Julie Luft gave to the Commerce, Justice and Science Subcommittee of the U.S. House of Representatives. The inquiry-approach is not without problems. In fact, survey data shows that inquiry teaching is not the dominant pedagogy used in science classrooms.

The lecture/presentation approach is the most frequently used method of teaching science. Inquiry-oriented teaching requires a reorientation to teaching, and one that requires teachers to employ small team learning, as well as encouraging students to explore science and to ask questions.

The Cultural Argument

The cultural argument suggests that the history and philosophy of science should play an integral role in science curriculum. Presently, lip service is played to this approach. Robin Millar argues that we must reduce the amount of content that dominates the science curriculum, and in its place present to students a coherent and cohesive world picture of science that tell students stories of sciences great stories from quarks to super clusters and genes and gerontology. The cultural argument could produce a curriculum that would interest students, and might reduce the general trend which is the more science courses students take, the less they like science.


YORK
EINSTEIN KATRINA
SAGAN SCIENTISTS
TEACHING JOHNDEWEY
PEDAGOGY
COSMOS
JOURNAL
NATURE
NCLB
THEORY OZONE CHINA
CHANGE GLOBAL
PROGRESSIVISM
MACINTOSH
PROCESSES TESTING DOVER
GLOBAL-THINKING-PROJECT
EARTHQUAKE STANDARDS PHYSICS
CREATIONISM
STANDARDS PLATE
TEACHING
IMAGINATION
CURRICULUM
CURRICULUM
NASA
SCIENCE
TECTONICS
EDUCATION
INTELLIGENT
INNOVATIVE-THINKING
RESEARCH SCIENCE
CO2
EARTHQUAKES
CONSTRUCTIVISM FOSSILS
CHEMISTRY
HUMANISTIC
EVOLUTION
GLOBAL
TIMES
WIRELESS
CREATIVITY
ARTISTRY
BIOLOGY
CLIMATE
NARST
VYGOTSKY
NEW
PISA
NSF
CHARLESDARWIN
REFORM
CITIZEN
COOPERATIVE-LEARNING
DESIGN
WARMING
GEOLOGY
HIGH-STAKES
CHANGE
CLIMATE
PARADIGM-SHIFT
INTERNET
HAITI
NATICK
WARMING
GEORGIA
INQUIRY
RUSSIA
NSTA

Part 1. Why Do We Teach Science?
1.1. The Economic Argument

In yesterday's blog post, I raised the question: Why do we teach science anyway? Do we teach science to help students become curious and to wonder about the world around them? Do we teach science because various committees and professional societies think that studying science has something special to teach students about the world, and how to solve problems in the world? Do we teach science because our nation's economic prosperity depends upon innovation and discoveries made in science and to maintain a supply of scientists and engineers?

In that post I identified four arguments, each of which will form the content of this and three subsequent posts in the next week. When we explore the answer to the question–Why do we teach science? –The answer will depend upon the argument we are using to support our answer. The four arguments are as follows:

1. The Economic Argument
2. The Democratic Argument
3. The Skills Argument
4. The Cultural Argument

The Role of the Federal Government

The economic argument is by far the dominant reason why we teach science, especially in the more advanced and prosperous countries. For science research and science education, the work of Vannevar Bush took center stage prior-to and after WWII. He headed the Department of Scientific Research and Development during WWII, and was for a time, head of the Manhattan Project, which developed the Atomic bomb. Bush advanced the role of government in research and development; he was responsible for the creation of the National Science Foundation (1950). He became NSF's first director. But as importantly as these roles, he wrote a report to the President (Truman) in July 1945 entitled *Science, The Endless Frontier*. This report was written to answer a set of questions posed by President Roosevelt. Following are the questions Roosevelt proposed:

1. What can be done, consistent with military security, and with the prior approval of the military authorities, to make known to the world as soon as possible the contributions, which have been made during our war effort to scientific knowledge?
2. With particular reference to the war of science against disease, what can be done now to organize a program for continuing in the future the work which has been done in medicine and related sciences?
3. What can the Government do now and in the future to aid research activities by public and private organizations?
4. Can an effective program be proposed for discovering and developing scientific talent in American youth so that the continuing future of scientific research in this country may be assured on a level comparable to what has been done during the war?

Bush's report became an important document in shaping America's conception of science, especially in the role that government should take in advancing scientific research and development. New discoveries, and progress in technological innovation would be key to national security and defense. The report called for support in the form of scholarships in science and engineering enabling a wide scope of students to work towards a Ph.D.

The National Science Foundation

The economic and security reality of science was readily seen in the aftermath of WWII, and as a result science education was seen as taking a new role in the developing a pipeline of science and engineering talent. In 1950, the National Science Foundation (NSF) was created and headed by Bush, and soon after science education researchers began to write and critique the present science curriculum.

It was evident the curriculum needed to change, and NSF took the lead in impacting secondary science education by creating at MIT the Physical Science Study Committee which ended up producing one of the most important high school science curriculum projects, the PSSC—a new high school physics course. The PSSC course advanced the knowledge of science in physics by creating a laboratory-oriented program—a text, a laboratory manual, and a set of corresponding lab materials were developed for teachers to use to involve students in inquiry learning.

The NSF also decided that high school mathematics and science teachers needed advanced training in science, and so they created the Summer Institute concept, and thousands of teachers participated in these 6- or 8-week summer programs.

In 1957 things really changed. The Soviets launched the first satellite (Sputnik I), and this event began a period of reform efforts in science and technology education in America characterized as "crises" and in some cases "hysteria" that America was falling behind in science and technology, and that efforts needed to be taken at a National level to resolve the crisis.

Pipeline ideology emerged after WWII in that the government felt that there was a manpower shortage in science and engineering, and that the school science curriculum was outdated, and that teachers needed more training in science, mathematics and technology. This ideology has characterized the way the Federal Government, and State Departments of Education have approached reform and change in science education over the past 60 years.

The Economic Argument

The Economic argument for why we teach science is rooted in the nation's perception of how it compares to other nations in science, technology and engineering. The Sputnik Era naturally focused in on the hysteria that America was way behind in the "Race to Space" and that the Soviet System of science and mathematics education must be superior to science and mathematics in the USA.

The Race to Space led to enormous appropriations to the National Science Foundation to develop "new curricula" in science and mathematics, K-12. It also led to proliferation of Summer Institutes for science and math teachers, and Academic Year Institutes for science and math teachers to were paid to leave their teaching position and pursue a full year of coursework in science and mathematics. Thousands of science and mathematics teachers participated in these summer and year-long institutes, all supported by the NSF.

Millions of dollars were spent on developing new curricula in science, starting with the PSSC course leading to long line of "alphabet soup" science courses in chemistry, biology, earth science, and elementary science. The courses emphasized a laboratory approach (inquiry-approach) and conceptual approach to science, and there was great excitement within the science and science education communities. Although these programs advocated an inquiry and hands-on approach to teaching, the survey data on the nature of classroom behavior in science classes revealed the lecture/demonstration approach based on traditional science textbooks was the dominant player, even with the infusion of millions of dollars into science education reform.

America did "win" the space race to the moon, but critics soon began to emerge and to claim that America would be at risk if education in the nation did not improve and change.

In 1983, the U.S. Department of Education released the report, A Nation at Risk. The report began with these two paragraphs that left an indelible image in the minds of politicians and reformers:

Our Nation is at risk. Our once unchallenged preeminence in commerce, industry, science, and competitors throughout the world are overtaking technological innovation.

This report is concerned with only one of the many causes and dimensions of the problem, but it is the one that undergirds American prosperity, security, and civility. We report to the American people that while we can take justifiable pride in what our schools and colleges have historically accomplished and contributed to the United States and the well-being of its people, the educational foundations of our society are presently being eroded by a rising tide of mediocrity that threatens our very future as a Nation and a people. What was unimaginable a generation ago has begun to occur–others are matching and surpassing our educational attainments.

The "rising tide of mediocrity" was the phrase that called into question the way science (and other subjects) was being taught, and whether teachers had the competency to teach science and mathematics in a way that would result in America's students and future workers could compete against citizens from other nations.

Jane Butler Kahle, a prominent science education researcher, characterized this period of reform as "courses and competency" and it led to a new set of requirements for students to graduate from high school, and encouraged states to require more science and mathematics courses for all students. Sights were set on moving American students to the head of the class in comparisons with students in other countries. In an influential report, Educating Americans for the 21st Century, the authors stated the basic objective for American education:

to provide all the nation's youth with a level of education in mathematics, science, and technology, as measured by achievement scores and participation levels, that is not only the highest quality attained anywhere in the world, but also reflects the particular and peculiar needs of our nation.

Here is the first pronouncement that student achievement scores will be used in comparisons with other nations to measure the effectiveness of American science education, but it clearly implies a national view that the needs of our nation must be at the forefront of education.

Student achievement, as measured by bubble tests, is now the fundamental way to measure the effectiveness of schools, systems and individual teachers, and the strength of this argument had its roots in the 1980s and 1990s with this Federal report.

Science for All

In 1985, the American Association for the Advancement of Science (AAAS) created Project 2061 (the date when Halley's comet returns), a massive science education improvement project focusing on scientific literacy. Its first publication was an outline of the goals of science education and was published under the title Science for All Americans (Oxford, 1989). As a long-term project for improving science, mathematics, and technology education, Project 2061 is still an active player in the current reform efforts in the nation.

Project 2061 led the way, and was the foundation upon which the National Science Education Standards (NSES) were developed in 1996. The Standards in science had a profound impact on school science, and led to the development of some new textbooks, but perhaps more importantly the Standards became the benchmark upon which various states developed their own standards.

The economic viability of the nation has been relentlessly defined by politicians and educators, but especially U.S. governors, and corporate bodies that have used their vast resources to invest in a number of "innovations" including the creation of private charter schools that have been able to get state funding, the establishment of Common Core Standards in Math and Reading (Language Arts). These standards were written by Achieve, an organization established by the National Governors Association. All but two states have adopted the Common Core Standards. The Common Core Standards speak to the economic argument in that these backers and developers of the Standards were concerned that some states did not have "rigorous" content and achievement standards, and that a single set ought to be developed, and all students should be held to this one set.

To get the country out of the Great Recession, the U.S. Government established the American Recovery and Reinvestment Act (2009). This $700 billion program provided about $100 billion for the U.S. Department of Education. Setting aside part of the money, the Secretary of Education, created the Race to the Top Fund, which would enable the states to compete against each other to obtain part of the $4.5 billion Race to the Top Funds. As part of the criteria for submitting a proposal (each state had to present a single proposal) each state had to adopt the Common Core Standards. In the first round, only two states were funded. Six months later, an additional 9 states were funded receiving grants from $200 million to more than $500 million.

The economy, according to the developers of these present reform efforts, depends upon the "rigor" and quality of education in our schools. Most of the reform effort supports charter schools, the use of high-risk tests to not only measure student learning, but to measure teacher effectiveness. Using the "value-added" concept, the reformers have put into place assessment techniques that will hold schools and teachers accountable for student learning.

Why do we teach science?

We teach science in the schools to help the nation produce enough scientists and engineers who will work in science and engineering careers, produce innovation, and wealth.

1.2. The Democratic Argument

There are at least two interpretations that emerge when we explore why we teach science from a democratic argument. The first interpretation is that we should be teaching science to help students become informed citizens in an increasingly technocratic and scientific world, and provide them with the tools to intelligently discuss, vote on, and make decisions about "modern life, politics and society." (Turner, p. 10.)

But we also interpret the democratic argument in the context of democratic schools–that is schools in which students and teachers participate equally in shared decision-making on matters related to the organization of school, the curriculum and related matters.

Students as Informed Citizens

In am going to focus on the first argument here, namely that school science should be in service of helping students become informed citizens. In science education, there is an interesting history of curriculum projects and efforts at the school level aimed at a science education that are context-based. (See Judith Bennett for synthesis of the research on context-based science) Helping students become informed students is also the subject of Science-Technology-Society Environment (STSE), environmental education, social responsibility, public understanding of science, humanistic science, and citizen science.

In the democratic paradigm of science education, contexts and applications are the starting places for learning about science, which is in contrast to the traditional approach to science teaching, which chiefly attends to the structure of the disciplines of science, and its subject matter knowledge in curriculum design. This is clearly a very different approach than is used in the design and construction of the science standards. The 1996 National Science Education Standards (NSES) and the Conceptual Framework for a New Generation of Science Standards **start** with the key concepts or core ideas in the disciplines of science: earth science, life science, and physical science (engineering and technology were added as a fourth area in 2010 Conceptual Framework). If you want to find examples of STS or Context-based science standards, you have to mine the standards to find instances of STS.

The democratic argument creates a curriculum that potentially is more interesting to students. In fact, in a synthesis of research on S-T-S Context-based science programs, Judith Miller and colleagues reported that:

detailed research evidence from 17 experimental studies undertaken in eight different countries on the effects of context-based and STS approaches, drawing on the findings of two systematic reviews of the research literature. The review findings indicate that context-based/STS approaches result in improvement in attitudes to science and that the understanding of scientific ideas developed is comparable to that of conventional approaches.

The Rose Project

This is an important finding. In a very large study involving more than 40 countries, researchers of the Rose Project (The Relevance of Science Education) surveyed the attitudes of thousands of 15-year old students to find out the status of science education. Under the direction of Svein Sjøberg, & Camilla Schreiner (University of Oslo), the Rose Project seeks to address:

mainly the affective dimensions of how young learners relate to S&T. The purpose of ROSE is to gather and analyze information from learners about several factors that have a bearing on their attitudes to S&T and their motivation to learn S&T. Examples are: A variety of S&T-related out-of-school experiences, interests in learning different S&T topics in different contexts, prior experiences with and views on school science, views and attitudes to science and scientists in society, future hopes, priorities and aspirations as well as young peoples' feeling of empowerment with regards to environmental challenges, etc.

The findings in the ROSE study are important to the democratic argument because the researchers sought to find out about students attitudes about the science curriculum and science in their lives and society. As the researchers claim, developing a positive attitude about science is an important goal of science teaching, and it would appear important to know what attitudes students hold. Most large-scale assessments of students focus on the "knowledge" students have as reported by TIMSS and PISA. ROSE researchers point out that

It is a worrying observation that in many countries where students are on top of the international TIMSS and PISA score tables, they tend to score very low on interest for science and attitudes to science. These negative attitudes may be long lasting and in effect rather harmful to how people later in life relate to science and technology as citizens.

Designing a science curriculum around STSE not only will further the democratic argument, but it might contribute to more positive attitudes of students about science. In Bennett's research, it was found that in context-based science programs, students achieved at the same content levels as students in more traditional science courses. We could argue that context-based program might serve not only the students, but contribute to an improvement of science teaching in general.

Moving ahead with a context-based or STSE approach to science curriculum is not without problems. Are there significant context-based themes that could be used with young students, say in grades K- 4? Is this approach more applicable to students in middle and high school? There is also the problem with teacher education. Some researchers suggest that teachers are more reluctant to move away from the content of their discipline, and entertain social and contextual issues as a basis for curriculum.

But there are many examples of context-based science programs that are successful with students and teachers. ChemCom (Chemistry in the Community) is one example—a high school chemistry course that is context based, SEPUP (Science Education for Public Understanding), Project Learning Tree, and Project Wild, just to name a few.

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Students need to see relevance and connection between their lived-experiences and the science content (or any content for that matter) that they learn in school science. The democratic argument for why we teach science appears to foster these connections.

1.3. The Skills Argument

In the last two posts, the economic and democratic arguments have been discussed, respectively. We now turn to a third argument, the "skills argument." According to R. Stephen Turner, the "skills argument" is second to the economic argument as to why we teach science.

According to Turner, the skills argument provides the rationale that the study of science results in the development of certain "transferable skills" that are important to an informed citizenry. For science teachers the skills argument is associated with pedagogies that include hands-on activities, involve students in analyzing and interpreting data, and also in designing and conducting open-ended investigations. If you were to interview science teacher educators at university levels, you would find not only agreement on these pedagogies, but that their science teacher education programs include these approaches.

Is this Inquiry-Based Learning?

Many science educators would argue that the term "skills" as used here ought be called "inquiry-based learning." Both "skills" and "inquiry" will generate thousands of hits if you search the two main journals in science education, the journal Science Education, and The Journal of Research in Science Teaching (JRST). For instance searching the term "inquiry" generated 1709 hits in Science Education, and 1422 hits in JRST; the term "skills" generated 2723 hits in Science Education, and 1780 hits in JRST. Furthermore, you will find the term "inquiry" used in many textbooks in science written for teachers and teacher educators.

Inquiry was also an important concept in the National Science Education Standards (1996). In 2000, the NRC published Inquiry and the National Science Education Standards, a 200-page document that defines inquiry teaching, and provides evidence that inquiry is a viable teaching strategy.

In 2010, the National Association for Research in Science Teaching (NARST) published its first virtual journal, Research Informing Practice, and the focus was on scientific inquiry. Ten research articles were published in this journal, all with a focus on inquiry science teaching. And in 2010, the most accessed article in the Journal of Research in Science Teaching was "Inquiry-based science instruction: What is it and does it matter—Results from a research synthesis years 1984 – 2002.

Many science teachers would claim that we teach science to help students develop the skills associated with scientific inquiry (observation, measurement, analyzing data, predicting, making hypotheses, testing theories, designing investigations). Even textbooks have integrated some aspects of inquiry by including "laboratory" and hands-on activities within the texts that students should perform.

Learning Theory

The skills or inquiry-based argument for teaching science is also connected with learning theories that have been an integral part of the science teaching community. Science education has been influenced by the learning theories of John Dewey, Jerome Bruner, Jean Piaget, Ernst Glasersfeld, and Lev Vygotsky.

In each of these theorists' works, inquiry takes a prominent role in attempting to explain human learning. For example, social constructivism, which has emerged from the works of these theorists, has many of the elements of inquiry-based learning.

For many science teachers, the theory of social constructivism paints a picture in which students make meaning of the world—in short, students construct meaning. Inquiry learning fosters such a notion because it draws on the theory of constructivism. In this view, knowledge is not like a brick—it can't be passed on directly to a student—but it is more like a building, which is built up indirectly, through experience and interaction.

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The skills argument is more than simply teaching transferable skills, but goes to the heart of science, and that is the notion of inquiry-based learning. For many science teachers, science is synonymous with inquiry, and it ought to be a focal point of the science curriculum. It ought to be the reason we teach science.

Coming next will a discussion of the cultural argument for teaching science.

1.4. The Cultural Argument

In four of the last five posts, I've explored the question, *why do we teach science* from four points of view. Using a template by R. Stephen Turner I've presented the arguments for teaching science from economic, democratic, and skills points of view. In this post, I want to use the cultural argument as the answer to why do we teach science anyway?

Turner introduced the cultural argument this way:

Science is, beyond dispute, one of the great intellectual enterprises of modern, especially western, civilization. The vision of nature embodied in modern science defines the universe for us, informs our vision of our human essence, and speaks to the hopes and fears of our world. Science plays a roll for us today somewhat like the great mythologies of the civilizations of the past: it provides the great narrative of truth, meaning, and essence that we live by. The proper goal of school science, according to the cultural argument, is to bring students to understand that great story and the enterprise behind it, so that they might not remain ignorant and alienated strangers to modern, scientific culture.

As such, Turner refers to Robin Millar's plan in which he suggests that:

we must re-conceptualize the science curriculum as the opportunity to tell science's great stories about nature, the universe, and our bodies. We must present students with coherent and cohesive world-pictures, tell them stories that transmit science's great visions – its great contemporary visions – of the world as narrative accounts, from quarks to superclusters and genes to gerontology.

According to Turner, Millar advocates "jettisoning" much of the content that is defined in the current textbooks, and standards in science.

Humanistic Argument?

We might look at the Turner/Millar cultural argument as the humanistic science argument advocated by science educators such as Aikenhead, Bryce, and many others. Aikenhead has outlined the research and made suggestions for humanistic science curriculum in his book, Science Education for Everyday Life. As Aikenhead points out, the present day science curriculum is out of date (educationally), but not politically.

The new generation of science standards which will be written next year will reinforce the out dated science curriculum—one that dots on the canons of science in biology, chemistry, physics and earth science. This curriculum, unfortunately, has not worked for the majority of students in school, and it does not prepare the "pipeline" students who will pursue careers in science and engineering any better.

Bryce, in a research paper published in Cultural Studies in Science Education, Bryce makes the claim that resistance to more humanistic forms of science education is an endemic and persistent feature of university scientists as well as school science teachers." Although Bryce did not discuss it, the 1996 National Science Education Standards, and the Conceptual Framework for a New Science Standards reinforce the claim, as each document focuses in on the canonical discipline of science.

Bryce's article:

is about the relationships between the science that science teachers teach and the science that science educators write about. It is also therefore about how classroom practitioners and science education researchers view each other, a relationship which is normally seen one way; that is, through researchers' views of science teachers. I will argue that more consideration needs to be given to how practitioners stand in relation to what many consider they ought to be doing; to their view of things; to why (ironically) many teachers are not well disposed to teaching science for everyday life, instead preferring to teach science with an orientation rather more internal to the subject itself, suffused with its own 'tribal' identities.

The cultural argument of science curriculum would ask curriculum designers and teachers to consider the history and philosophy of science, and try and bring to students experiences in which they learn how science discoveries are made, to focus on the struggle that people working on a particular problem had, and what these problems were.

Resistance to Change

There is a great deal of resistance in moving away from the traditional way in which science is taught in school science, and at the university. Bryce helps us understand this when he makes this remark:

The impediments are well understood and range from the demonstrated lack of teacher confidence in pedagogies involving more open- ended activities and discussion of ethical and social issues arising from new biotechnologies; through the pressures from assessment which remains stubbornly focused upon canonical content; to the models of science which teachers work with, their ideologies and philosophies—notably steeped in positivism and realism.

Why do we teach science?

The cultural argument represents a humanistic approach to science curriculum. Although it is not the dominant approach used in school science, there is a rich body of research to support the movement to bring a cultural approach to the table.

Bryce, T. (2010). Sardonic science? The resistance to more humanistic forms of science education *Cultural Studies of Science Education, 5* (3), 591-612 DOI: 10.1007/s11422-010-9266-6

1.5. Voices From The Classroom

Up to this point we've explored the question "Why do we teach science, anyway?" Using a paradigm from Canadian and U.K. educators, I explored the question from four vantage point or argument: Economic, Democratic, Skills, and Culture.

Now let's turn our attention to what science teachers have to say about why they teach science. What do these science teacher voices tell us why they teach science?

> My students are not passive learners of science, they ARE scientists. They embrace the idea that they are empowered to own their learning. In addition to creating a love of learning within my students, I am intentional about equipping students with wonder, teamwork strategies, and problem-solving skills for jobs that may not exist yet. Kareen Borders, Lakebay, WA

> One of my goals is that students see physics everywhere through activities and projects. Students are surprised that they are encouraged to play with toys in a physics class. Sometimes students build things like windmills and motors; sometimes they dissect things like disposable cameras. Sandee Coats-Haan, Liberty Township, OH

Opening doors, allows any student with a desire to enroll in my classes. High standards, yes, but I try and inspire students through my willingness to spend evenings and weekends tutoring them. I strive to make science relevant. For example, environmental students participated in service learning activities such as habitat reconstruction. Marian DeWane, Boise, ID

As a scientist and educator, this voice from the classroom continually investigates ways to refine her classroom practices in order to excite and engage students in scientific inquiry. She has become an inspiring role model for both staff and students for her persistent quest for improvement and her student-centered teaching. As a master teacher, she has facilitated support classes for more than 300 first-year teachers. Jessica Gogerty, Des Moines, IA

Passion for Learning

The statements shown above are made by four different science teachers, each of whom was selected as one of the 103 Presidential Awards for Excellence Teachers in Mathematics and Science Teaching.

In each of the comments made above, the voice of the teacher when thinking about why they teach science has to do with *inspiring and encouraging a love* of learning science.

These teachers bring their passion into the classroom and work with their students to encourage inquiry, project work, and innovative thinking. In each of these cases, teachers are very involved in projects not only with their own students but also with their colleagues. Many of these science educators teach other science teachers to help them bring this same king of enthusiasm to teaching science.

No mention is made that they teach science to keep America competitive with other countries. No mention is made that the nation's economy is dependent upon science and engineering, the reason to teach science is produce more scientists and engineers.

Why do we teach science?

No, these teachers see a more powerful role for science in our schools, and that is "in equipping students with wonder, teamwork strategies, and problem-solving skills for jobs that may not exist yet."

Part 2. What Do We Teach?
2.1. Two Visions of Science Teaching

I have been reading and have referenced on this weblog the October 2009 special issue of the Journal of Research in Science Teaching (JRST) on the topic/theme "Scientific Literacy and Contexts in PISA Science." The articles in the special issue provide a broad view of international testing as conceived in PISA, as well as the TIMSS.

One of the articles (by Sadler and Zeidler), which was focused on PISA and Socioscientific Discourse, used the term progressive science education as a way to describe a vision of science education that includes public understanding of science, humanistic science education, context-based science teaching, S-T-S, and socioscientific issues. As pointed out by the authors, George DeBoer used the term progressive science education in 1991.

Two Visions of Science Literacy

In a paper written by Douglas A. Roberts (Scientific Literacy/Science Literacy) that appeared in the 2007 Handbook of Research on Science Education, the author introduced two visions to explore the notions of scientific and science literacy, namely Vision I and II.

Vision I. In Roberts view, Vision I gives meaning to scientific literacy by "looking inward at the canon of orthodox natural science, that is, the products and processes of science itself." As Roberts states, this approach envisions *literacy (or, perhaps, thorough knowledgeability) within science*. He goes on to point out that the Benchmarks for Science Literacy by the AAAS approximates his view of Vision I.

I would add that the National Science Education Standards (NCES) imparts Vision I as well. And the new Science Standards, which will be published next year, will also reflect Vision I.

In the JRST special issue on PISA Science, some of the authors suggest that most of the documents produced in the past 20 years under the "standards movement era" tend to support Vision I. Indeed, we could also suggest that most state-standards are written as Vision I science literacy. At the U.S. national level, the NAEP assessments focus on Vision I. At the international assessment level, we might identify TIMSS as a Vision I marker.

Vision II. To Roberts, there is a contrasting and quite different vision of science, Vision II, which gets its meaning from "the character of situations with a scientific component, situations that students are likely to encounter as citizens."

Roberts defines this vision as *literacy (again, read thorough knowledgeability) about science-related situations*. In my view, a very good description and discussion of Vision II is by Glen Aikenhead in his book, Science for Everyday Life.

We might think of Vision I as traditional science education and Vision II as progressive science education.

There is some suggestion in the JRST issue that PISA 2006 aligns very closely with the Vision II view of science literacy described by Roberts. The editors of this special issue suggested this view, but Sadler and Zeidler wrote that they have serious concerns about the extent to which PISA supports progressive science education. Can progressive science education, or Vision II science literacy be "measured" by the use of a standardized assessment such as PISA?

The answer to this question is probably not. As much as the authors of PISA would like us to believe that the test measures contextualized and controversial topics, others argue that the items are really decontextualized. I found the items on PISA to be quite complicated, and required a lot of reading, and in some cases, what the students were asked to read had little or nothing to do with the questions that were asked.

Svein Sjoberg wrote an evaluation (see PISA and "Real Life Challenges: Mission Impossible) of the PISA assessment program. He suggests that, although PISA claims to test "real-life skills and competencies in authentic contexts," such a goal is impossible in a traditional testing environment as described in the PISA documentation.

Progressive science education (humanistic science education) will require a different form of assessment, and one that will rely on the observations, and active assessment of learning in the context of classrooms by science teachers and researchers. The most effective form of classroom assessments that contribute to our understanding of student learning, and indeed help students improve in their learning are formative assessments, not summative assessments in the form of PISA, or TIMSS.

Yet, in the USA, where science education has actually made a great deal of progress (see Lowell & Salzman), the winds of change are aimed at further standardizing teaching by the "common standards movement." This will be followed by the development of "common tests" which will be used to compare and contrast schools, school districts, states, and individuals, including teachers and principals.

2.2. Framework For K-12 Science Education

According to the report published by The National Academies Press, The Framework for K-12 Science Education outlines a broad set of expectations for students in science and engineering in grades K-12. These expectations will inform the development of new standards for K-12 science education and, subsequently, revisions to curriculum, instruction, assessment, and professional development for educators.

The book identifies three dimensions that convey the disciplinary core ideas and practices around which science and engineering education in these grades should be built. These three dimensions are crosscutting concepts, scientific and engineering practices, and cores ideas.

The overarching goal is for all high school graduates to have sufficient knowledge of science and engineering to engage in public discussions on science-related issues; be careful consumers of scientific and technological information; and have the skills to enter the careers of their choice.

What you will see are three ideas that form the foundation for the K-12 Science Education Framework.

- **Idea 1: Crosscutting Concepts**. These will be familiar to you. They are what science educators call the "processes of science," such as cause and effect, scale, energy and matter, etc.
- **Idea 2: Scientific and Engineering Practices**. Again, these will be familiar to you. They reflect the kinds of teaching strategies that inquiry oriented teachers use including asking questions, helping students develop and use models, doing science investigations, analyzing and interpreting data, and others. In short, these can be added to the crosscutting ideas to form two sets of science processes.
- **Idea 3: Core Ideas**: We have a new core idea added to the science curriculum, and that is engineering, technology and the applications of science. Added to physical science, life science, earth & space science, we have the content framework in four ideas.

You can download and read the book from the National Academies Press.

2.3. Attributes of the Framework

According to the committee that drafted and wrote the final edition of the Framework for K-12 Science Education, American science education needs a complete overhaul, currently lacks vision, and does not prepare students for a scientifically and technologically-based society.

Helen Quinn, Chair of the National Research Council's Conceptual Framework for K – 12 Science Education Committee had this to say about the state of science education in the USA:

Currently, science education in the U.S. lacks a common vision of what students should know and be able to do by the end of high school, curricula too often emphasize breadth over depth, and students are rarely given the opportunity to experience how science is actually done.

Truth be told, this same argument was set forth in the late 1980s when the AAAS created Project 2061, Benchmarks for Science Literacy, which led to the creation of the National Science Education Standards (NSES). And these standards have become the benchmark for the state departments of education to develop their own standards in science.

The Framework for K-12 Science Education: Practices, Crosscutting Concepts and Core Ideas, according to the NRC committee, provides a blueprint for K-12 science education, and will lead to the development of a new set of science education standards.

Attributes of the Framework

What are some of the attributes of this new framework? Here are just 5 attributes, and of course I could identify many more. But I hope this will get you started exploring this new document.

1. Dimensions. It's a book length report, spanning 280 pages. It contains 13 chapters, divided into three sections: Section I: A Vision for K-12 Science Education; Part II: Dimensions of the Framework; Part III: Realizing the Vision. You can download a PDF file of the entire book for free here.

2. Vision for K-12 Science Education. According to the report, "The framework is designed to help realize a vision for education in the sciences and engineering in which students, over multiple years of school, actively engage in science and engineering practices and apply crosscutting concepts to deepen their understanding of the core ideas in these fields."

Two reasons are given for writing a new Framework. The first is that it's been 15 years since we wrote the last set of standards (NSES). The second is that science education community has the opportunity to use the momentum of Common State Core Standards movement. In fact, the Framework will be used by Achieve, Inc., to write the new science standards. Achieve wrote the reading/language art and math Common Core State Standards.

The vision is stated in terms of "by the end of the 12th grade, students should have gained sufficient knowledge of the practices, crosscutting ideas and core ideas to be able to." This is language similar to the way in which standards are presented in the NSES, and in most state science standards.

The vision of the new Framework, according to the Committee, is based on the earlier documents including the NSES 1996 standards, AAAS Benchmarks, the Science Framework for the NAEP, and Science College Board Standards for College Success.

3. Practices. This is the first of three major dimensions of the Framework (the other two follow in items 4 and 5 below). The Committee chose the term "practices" (as in scientific and engineering practices) to get us away from the notion that there is one scientific method. The Committee believes that students should learn how scientists and engineers do their work, and thus should be involved in the practices of science and engineering. You will find the "practices" very familiar because they are a list of science processes that emerged decades ago with the science reform era of the 1960s. The committee identified these as scientific and engineering practices that students should learn:

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics, information and computer technology, and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)

7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

There is also a lengthy discussion of how science and engineering differ, as well as how the "practices" of science and engineering are different from each other.

4. Crosscutting Concepts. The committee defines "crosscutting concepts" as concepts that bridge disciplinary boundaries, having explanatory value throughout much of science and engineering. Examples of crosscutting concepts will be very familiar to you. Some include patterns, cause and effect, and stability and change. As stated in the report, the committee acknowledged that crosscutting ideas were no different than earlier reports' usage of terms like unifying concepts or common themes. Each crosscutting concept is explained in detail, and you can read about them in the report here. The complete list of crosscutting concepts include:

- Patterns
- Cause and effect
- Scale, proportion, and quantity
- Systems and system models
- Energy and matter
- Structure and function
- Stability and change

5. Core Ideas. Now we are getting to the heart of the Framework, the *core ideas*. The Committee wanted to focus on a limited number of ideas and the Framework organizes the science & engineering curriculum into four core areas with just a few core ideas identified in each area: Physical Science, Earth and Space Science (which the committee thinks is a new area of the science curriculum!), Life Science, and Engineering, Technology and Applications of Science (ETAS).

ETAS is an area new to the science standards, although some of you might argue that STS, and Context-Based Teaching explored some of the ideas in this part of the Framework. Unfortunately, there is little integration of ideas, that is to say, wouldn't have been possible to integrate ETAS into each of the three content areas of Physical, Life and Earth/Space science?

Within each area, the Committee, through the work of separate design teams for each content area, identified just a few core ideas—three or four core ideas that the committee felt underscored the essence of that particular content area.

The report identifies the core ideas as shown in example taken from the Physical Science content area:

CORE IDEA PS1: MATTER AND ITS INTERACTIONS
How can one explain the structure, properties, and interactions of matter?

The first Core Idea in the physical sciences is "matter and its interactions" followed by a core question. Interestingly, the committee identified two fundamental questions for the physical sciences which included: questions—"What is everything made of?" and "Why do things happen?"

The committee then identifies "*grade band* "endpoints for each content area at these grade level points: grade 2, grade 5, grade 8, and grade 12. These are quite specific paragraphs of what students should know about the core idea at these points along the students' school experience.

Each of the content areas of Life science, Earth/Space science, Engineering is detailed in the same manner as the physical sciences.

I've identified for you only 5 attributes of the new Framework. There are many more, but I hope that these help you explore the Framework, from the standpoint of its strengths and weaknesses.

2.4. Questions about the Framework

The standards devote insufficient attention to the need for an interdisciplinary curriculum, and represent a contracted view of the "common core" that disregards the role of schools in preparing students for citizenship. William G. Wraga, Professor, University of Georgia as quoted in Education Week

You probably know that the National Research Council has published A Framework for K-12 Science Education: Practices, Cross-Cutting Ideas and Core Ideas. The Committee on a Conceptual Framework issued the report for K-12 Science Education Standards.

As Dr. Wraga wrote, the standards, especially the Common Core Standards, lack any attention to interdisciplinary curriculum and it is his judgment that this has resulted from the "discipline myopia" that characterizes the Standards (in any field of study).

Some Questions

How does the Framework for K-12 Science Education fare? There are several criticisms that I identify here, and ask you to think about your own professional work, and what you think of these criticisms.

1. Composition of Committee and Design Teams. You will probably agree that a committee that is going to create a framework for K-12 science educations ought to be comprised of a mix of individuals from academia, research organizations and K-12 schools. An examination of the report shows that there were 19 individuals on the Conceptual Committee, and 19 people on the four design teams. There were no K-12 educators on the Conceptual Committee. There were two persons listed of the 19 design team members who worked in either a state department of education or a school district. But there were no science teachers listed in the report. This is a serious problem in my opinion because it sends the message that K-12 science educators are either not capable or not interested in serving on such boards, and committees.

2. Discipline Myopia. Using Dr. Wraga's terminology, you can see that I am extending this criticism to the Framework for K-12 Science Education. The Framework promotes four disciplinary content areas, Life science, Earth/Space Science, Physical Science, and Engineering and Technology. As a result, the curriculum that is implied from the Framework is overly discipline oriented, and except for the addition of the area entitled Engineering and Technology, is no different than the 1996 National Science Education Standards. Even in elementary and middle school, there is little attempt of interrelate the content of science. Interdisciplinary science is not a structure in the Framework.

3. Student as Outsider. This might seem overly critical, but the Framework is written from the standpoint of the discipline of science, and very little attention is placed on students, their communities, and environment. The emphasis is on established or canonical science rather than establishing contexts for learning. Much of the work in environmental education, STS, science and social issues is put on the periphery of the Framework.

4. What about the Content? One reader had this to say about the content in the life science section of the Framework: *"That section is certainly improved, but still reads as if written by individuals with only a superficial background in biology. In the evolution section, natural selection is still ill defined and treated as the only mechanism for change. In the information processing section, animals are apparently the only organisms that can sense and respond to their environment.*" Although Dr. Fugate is questioning the nature of the content, because there were no science teachers on any of the panels, we can question the relevancy as it relates to K – 12 students. Or at least we can raise questions.

5. Pipeline Mentality. The Framework underscores the domination of curriculum by a pipeline mentality, and disregards the more important notion of preparing citizens to live in a changing world. Very few students will go on to careers in science or engineering, and as you read this report, you'd think that this is still the major goal for teaching science in our schools.

2.5. Conflict Between Standardization and Innovation

Is there a conflict between the drive to standardize the curriculum, and the claim that innovation is needed now, more than ever? Let's take a look.

There was a government report on Science, Technology, Engineering, and Mathematics (STEM) education released over the past few days. The report, combined with the National Research Council's project, which has developed a Conceptual Framework for a New Generation of Science Standards, set the tone for STEM education over the next few years.

STEM Innovators

The National Science Board issued a report today entitled Preparing the Next Generation of STEM Innovators:
Identifying and Developing Our Nation's Human Capital. The NSB committee uses as a rationale for fostering the development of STEM innovators Vannevar Bush's Science–An Endless Frontier, a report on science and technology education presented in 1944 to President Roosevelt. It was an important report, and the NSB committee felt it was relevant in their present report to the nation.

According to the NSB report,

STEM "innovators" are defined as those individuals who have developed the expertise to become leading professionals and the creators of significant breakthroughs in scientific and technological understanding. To this end, this report addresses talent identification and development of children and young adults, and provides recommendations that should ultimately enhance the innovation capacity of our Nation.

According to the committee, three "keystone" recommendations have been made to enhance the development of STEM innovators. They are:

1. Provide opportunities for excellence by offering coordinated, proactive, sustained formal and informal interventions to develop their abilities.
2. Cast a wide net to identify all types of talents and to nurture potential in all demographics of students.
3. Foster a supportive ecosystem that nurtures and celebrates excellence and innovative thinking.

This gifted and talented report recommends pedagogy in which:

…all students, including the most talented, should have the opportunity to experience inquiry-based learning, peer collaboration, open-ended, real-world problem solving, hands-on training, and interactions with practicing scientists, engineers and other experts. Currently, many of the opportunities for these activities materialize in the form of informal, out-of-school enrichment activities (e.g., summer camps, competitions, science museum visits, Math Circles), rather than as an integrated ingredient of a STEM curriculum. Out-of-school enrichment is extremely valuable, particularly to inspire interest in STEM, but insufficient by itself. Students spend the vast majority of their time in the regular, formal classroom. Formal and informal education is mutually reinforcing and is most effective when synchronized.

Is there a disconnect?

There is a disconnect here between wanting on the one-hand an innovative science curriculum, but on the other hand, a growing insistence at the Federal, State and Corporate levels to have a single set of standards that all schools would subscribe to. This unfortunately defines the present culture of school reform. Top-down mandates developed by organizations and individuals with little or no accountability undermine real innovation and reform at the school district and school level. Real innovation and change takes place at the community level—with groups of teachers collaborating with local universities and agencies—to create new curricula and innovative teaching methods.

This tension between innovation, inquiry, problem-based learning and national and state standards and high-stakes testing is an issue that teachers have had to deal with it seems for the foreseeable future. Teachers are quite able to make the decisions about what is best for their own students.

Part 3. How Do We Teach Science?
3.1. A Humanistic Learning Paradigm

Education is facing issues that will provide opportunities for really changing the way we think about teaching and learning over the next decade. It will require, however, that educators and the public to use research for decision-making, and develop programs that promote learning for the diversity of students that attend our schools. We need leaders who are steeped in educational research, and realize that our schools need reform more than ever. We need leaders who are not directed by political winds, and corporate approaches to privatize schooling.

Vision I (Paradigm A)

In my own view, we need to recognize that the traditional paradigm (Paradigm A in the chart–which is Vision I as outlined earlier in this eBook) has not worked for most of the students who attend schools, not only in the USA, but also in most countries around the world. Unfortunately, when educational leaders talk about reform in schooling, they restrain themselves by basing their thinking on this old paradigm, one that is based on a corporate model, and uses test scores as the measure of student learning.

The tests that are used reduce learning to rote, and evaluate not only a student's progress in a period of a few hours, but also use these results as a way to assess teachers' performance. In neither case should we be satisfied. There are much better ways to find out how students are doing, and far more valid ways to assess teachers' performance other than basing it on student achievement.

Vision II (Paradigm B)

We need leaders at the national, state and local levels (in each country) who embrace a humanistic approach to teaching and learning, and an educational system that is based on research.

For example, in the chart below, the humanistic paradigm is by its nature innovative and flexible. It does not believe in a one-size-fits-all approach to teaching. Instead, learning is constructivist in nature, and students need to be helped to develop their ideas in environments that foster a social constructivist approach.

In this approach learning is seen as a social process, and much of the work of students should be done in the context of groups—especially problem solving groups, and the problems should be based on lived experiences of students, and be as authentic as possible.

A humanistic paradigm values interdependence, and creates environments in which students have a right-to-choose not only some aspects of content, but also the design of methodologies for learning.

The chart below compares and contrasts Vision I and Vision, or Paradigm A and Paradigm B, respectively. Note the key words within each framework.

Science Teaching Paradigm A—Traditional Approach	Science Teaching Paradigm B—Humanistic Approach
• Traditional, mechanized thinking • Individualistic–although students may at times work together in groups, interdependence typically is not a goal. • Dependence–teacher-directed instructional model establishes a dependent social system. • Hierarchical—choice-made-for-you. Rarely do students choose content or methodology for their investigations • Emphasis on literacy: knowing facts, skills, concepts • Emphasis on content; acquiring the right body of knowledge • Learning encourages recall, and is analytical and linear	• Innovative, flexible thinking • Cooperative–students work collaboratively in small teams to think and take action together • Interdependence–a synergic system is established in groups within a classroom, and within global communities of practice. • Right-to-choose—students are involved in choice-making including problem and topic selection, as well as solutions; reflects the action processes of grassroots organizations • A new literacy insofar as “knowledge” relates to human needs, the needs of the environment and the social needs of the earth’s population and other living species • Emphasis on anticipation and participation; on inquiry, learning how to learn, and how to ask questions • Learning encourages creative thinking, and is holistic and intuitive

The humanistic paradigm would view standards in a different way. Instead of simply being an outline of the content of the science discipline, content would be seen as knowledge as it relates to human needs, the needs of environment, and the social needs of the earth’s population and living species.

Embracing this paradigm, which is also as old as the traditional paradigm, would require courage on the part of educational leaders. Yet, there is evidence to support a movement toward the humanistic model, and I’ll explore some of this evidence in future posts.

3.2. Engineering As A Way To Humanize Science Teaching

In earlier posts I have talked about the humanistic science paradigm of learning, and have indicated that this paradigm has the potential of increasing the interest that students have in science, as well as helping students comprehend and understand science. In one post I made this point:

What has emerged in science education is a major trend that is a departure from the traditional view of curriculum. Instead of starting with science concepts (as the Standards do), the starting points for teaching are contexts and applications for the teaching of scientific ideas. The traditional approach to science teaching attends chiefly to the structure of the discipline of science and its subject matter. We might call it scientist-centered.

This alternative trend gives priority to a student-centered point of view, and to citizens as consumers of science and technology in their everyday lives. Some have called this the science-technology-society (STS) approach; others, including Judith Bennett have used the concept context-based to describe this trend. Glen Aikenhead describes this approach to science education as the humanistic perspective. We might call it humanistic science education.

The evidence to support a humanistic science education is very powerful. Aikenhead's book, *Science Education for Everyday Life*, provides an "evidence-based practice" approach to humanistic science. For example, in a synthesis of studies of humanistic science, Aikenhead reports that students are motivated to high levels if the science content being learned is associated with social or cultural relevance. Although this approach led to greater complexity, student motivation led to greater science understanding.

Engineering in Science Teaching

Two days ago, I received an email from Dr. Bill Hammack, professor of Chemical and Biomolecular Engineering at the University of Illinois. The email that I received linked me to one of his sites entitled Engineerguy.com. In this very rich website, Dr. Hammack explores ways that the engineering profession might reach out to the public to help citizens become more aware of how engineering concepts are a part of their everyday life. He goes on to explore how that might be done, and how new media might aid in this endeavor.

For science teachers, Dr. Hammack's ideas provide many examples of context-based, and humanistic science. In one paper on his website, entitled *Three Fundamental Questions to Ask About Scientific Outreach*, Dr. Hammack makes the case for engineers and scientists to work with the public to help them understand scientific endeavors. In my own view, Dr. Hammack is describing the role of the science teacher in civic life. It is the science teacher that tethers between the worlds of science & engineering, and world of adolescents. Dr. Hammack has devoted his professional life to helping the public understand engineering by using a variety of public outreach media: radio, video, and public speaking. At his website you can access archives of his radio shows, his videos, and papers that he has presented to various organizations.

The examples that you will find on his engineerguy.com website are good examples of context-based teaching. For example, he directed me to this video, which you can see below.

[Link to embedded object]
The video shows how we can use a context-based approach to humanize science and engineering. This video is one of many videos that will be a great resource for science teachers.

I recommend you visit his site, and explore the radio shows, videos, and papers that should help you understand more fully how we can make science teaching more relevant to our students.

3.3. Native Science As A Way To Humanize Science Teaching

The Art of Teaching Science weblog and book has, as its underlying philosophy, a humanistic paradigm promoting an active and lived learning experience for classroom learning. I have been traveling in the West recently, and was fortunate to visit the *Museum of Indian Arts and Culture* in Santa Fe, New Mexico. There in the museum bookstore I found a copy of Gregory Cajete's *Native Science: Natural Laws of Interdependence*.

My own view is that Native science, as explored and presented by Dr. Cajete, is a paradigm that offers science educators a robust, and experiential way to engage their students in the learning and exploration of science. In this eBook, I have described this as the humanistic science paradigm. It's the ideas in Native science that I wish to talk briefly about here, and suggest that Cajete's ideas should be a part of the movement recently to develop a new generation of science standards.

Native Science

According to Cajete:

> *Native science is a metaphor for a wide range of tribal processes of perceiving, thinking, acting and 'coming to know' that have evolved through human experience with the natural world.*

He emphasizes the notion that Native science is based on using the entire body of our senses in direct participation with the world. It is this notion of direct participation that fundamental to a humanistic paradigm, and as Cajete points out, forms the foundation of the Native science paradigm.

Native science is holistic. Although Cajete points out that Native science includes such areas as astronomy, farming, plant domestication, plant medicine, animal husbandry, hunting, fishing, metallurgy, and geology, Native science goes further and extends these fields by including spirituality, community, creativity, and technologies that sustain and support environments of human life.

Dr. Cajete also observes that both scientists and non-scientists question whether there is such a thing as Indigenous science. Many argue that science is really a Western idea, and that Indigenous science knowledge is really not science. But, there are many that argue that Native science is indeed science. Cajete informs us that Native science cannot be isolated from culture, and that when one is speaking about Indigenous or Native science, "one is really talking about the entire edifice of Indigenous knowledge.

According to Cajete, Native science is very much like the Western science that is called environmental science or ecology. He points out that Native people don't have words for environmental science or ecology, they understand the relationship that profoundly connect them to the natural world—which is indeed the purview of environmental science and ecology.

3.4. Three Ways to Interest Students in Science

Stephen Hornstra Landgraaf, of The Netherlands suggested in a comment on this blog about the purpose of science teaching. He said:

> *Perhaps the fundamental goal of science education should be finding ways to interest students in science.*

In this era of standards-based education we leave most students outside of science, and do little to bring them in to see a connection between their own lives and the joy of science.

Yet even in these high-stakes testing times, there are some powerful ways in which science educators are interesting students, young and old, alike. Here are three:

Thinking Big

This is all about asking "big" questions, much the way that Carl Sagan did. Of course it is more than that. Thinking Big in science teaching means we bring students in contact with interesting questions, ones that continue to pique our curiosity, and ones that are sure to interest students. Where did we come from? Are we alone in the Universe? How big is the Universe? Are we the only planet with living things?

A really good example of "thinking big" was NASA's announcement last fall of The Carl Sagan Exoplanet Fellowship. Then follow this link to NASA's Planet Quest (Exoplanet Exploration) Website, and explore how NASA is trying to answer the question, Are we alone? It's fascinating, and would capture student's imagination. You might also visit the Carl Sagan portal for other interesting ideas.

Thinking Informally—Science museums

One of my favorite theorists in education is John Dewey. Dewey wrote lots of books on education, and advocated a humanistic approach to teaching, and specifically believed that "non-school learning" could provide the kind of energy that learning in school would require to engage and interest students. Science museums are a kind of informal learning environment that typically engages students of all ages.

Yesterday I visited the Tellus Museum of Science, located in Northwest Georgia, a new museum full of fascinating science wonders including an extensive mineral gallery, dinosaurs and more than 40 pre-history animals in the Fossil Gallery, a fossil dig, and gem panning, history of flight from the Wright brothers to the American and Russian space programs.

The visit to Tellus reminded me of all of the museums that I've visited in Atlanta, Barcelona, Boston, New York, Chicago, Denver, Detroit, Prague, San Francisco, Seattle, Washington, Vancouver, London, Moscow and St. Peterburg. In fact, some years ago I was in St. Petersburg, Russia with 100 American and Russian middle and high school students and their teachers as part of the Global Thinking Project, and we were brought to the Zoological Museum of the Zoological Institute of the Russian Academy of Sciences. It was there we viewed the famous display of the Wooly Mammoth.

Museums play an important role in science education, and have to near the top of list of ways to interest kids and adults in science. Here informal learning is emphasized over formal, classroom-like instruction. Visitors are encouraged to "touch" and "play" with exhibits.

Reconnecting with Nature: The National Park Syndrome

Although Yellowstone Park was established in 1872, the U.S. Congress established the National Park Service in 1916 protecting the 35 national parks that existed at that time. Now there are 391 units in National Park Service including parks, national monuments, seashore sites, battlefields and other recreational and cultural sites. If you add to this the number of state parks that there are in the U.S. you have an enormous resource available for another type of informal learning that emphasizes the outdoors, and cultural experiences.

I am not sure if there really is a "National Park Syndrome," but what I mean is that we should work to reconnect students to nature. My own National Park Syndrome was created by my many trips to the Rocky Mountain National Park, both personal, and professional (teaching graduate courses on environmental education).

And indeed the Children & Nature Network is dedicated to this, and supports a movement to reconnect "children and nature." The goal here is to give students opportunities to experience nature directly. C&NN is a great resource for science teachers, and provides a convenient way to connect with other educators who are developing strategies in the service of nature for children and youth.

Connecting our students to nature does not have to involve traveling to a park. Simply going outside one's school will bring you and your students in contact with nature.

In my own experience as college teacher, I taught in the center of Atlanta's urban environment. The urban environment was rich with experiences for my students. We were able to study the geology of building stones, that not only included rocks from various parts of the world, but also many of the sedimentary building stones included fossils. We did scavenger hunts looking for change, living things, biodegradable substances, various types of rocks and minerals, plants, animals, mineral processes, evidence of physical and chemical weathering, and other phenomena. We even looked for stalagmites and stalactites that formed when water trickled through cracks and fissures in the underground parking garage.

From the vantage point of central Atlanta, our students were engaged in environmental studies, including the investigation of ground-level ozone (Project Ozone). We did this every summer, and students not only monitored ozone in central Atlanta, but also from the vantage point of their homes. This provided us with a rich data base all around the Metro-Atlanta area. Project Ozone was one of the projects that we developed as part of the Global Thinking Project. Using very simple monitoring equipment, students from many parts of the world were able to monitor the air outside their school, and use our online database to share and investigate the problem of ground-level ozone.

There are many ways to interest students in science. These are simply three that I have found to be very effective with students of all ages. I'll continue to talk about this and come back to it from time to time.

3.5. Experiential Science Education

Experiential education is not a new idea, and it certainly is not a new construct for science teachers, especially those teachers that involve their students in inquiry and problem-based learning. However, experiential education is not at the top of the "to-do" list in the minds of many leaders and advocates for the No Child Left Behind approach to education. It may be that change is coming, and experiential education might be returned at the real core of teaching.

Experiential Learning

Experiential education as I think about it represents a paradigm of learning that is in stark contrast to the kind of education experiences that most students "experience" in school. As I've discussed before, experiential education is a humanistic approach to science teaching, and has been well documented in the literature of science education. Glen Aikenhead's book, *Science Education for Everyday Life* describes the humanistic science experience, and provides the research base for experiential science education, which in my view is the real core of teaching.

The real core of teaching is providing environments, formal or informal, in which students can experience their education—whereby students can inquire into, discuss, become involved in moral and socially relevant issues, and perhaps make real change in themselves, and their community. This is the kind of education that allows students to ask questions such as: "Why should I learn this?" "How is this experience relevant to me and my fellow citizens?" and "How will this experience contribute to my and others growth?"

You can probably discuss and describe teachers in your own education, or colleagues with whom you have worked that were experiential science educators. I have had the privilege to know many, and have worked alongside others who embodied the spirit that underscores an experiential educator. I received an email from one of my colleagues who I consider one of the most outstanding experiential science teachers that I have known.

The Royal Classroom

It was note a from Ken Royal, who is now Senior Editor at Scholastic, and you can read his interviews, tech how-to's, and opinions at the Royal Treatment blog, which is now part of Scholastic. I first met Ken in the mid-1990s when he was teaching science at Whisconier Middle School, Brookfield, Connecticut. At the time I was conducting national seminars for the Bureau of Education and Research, and I met Ken at one of my seminars in Hartford.

At Ken's invitation, I visited his school and classroom, and actually presented a seminar at his school for science teachers in his district. His classroom was a model for the experiential science approach, and he was also a pioneer in the use of technology as a tool to enhance student learning in science. His students were involved in global conversations and research with students in at least three continents, and his students were posting results of their research using digital cameras and text at a time when the Web was in its infancy.

His classroom was an environment where students were involved in active inquiry, and with the rapid development of technology in the 1990s, Ken was one of the leaders pioneering ways that this technology could be harnessed to help students get excited about science. He later became technology coordinator for the Brookfield School District, and then started writing as a freelancer about technology, and making presentations around the country. Scholastic saw one of his presentations, and hired him as senior editor in the area of technology and teaching.

Experiential educators are out there making learning interesting and fun, and returning the core of teaching to experiential knowing. Ken Royal is one of those educators.

Resources

Association for Experiential Education–nonprofit, professional membership association dedicated to experiential education and the students, educators and practitioners who utilize its philosophy

Beyond Learning By Doing: Theoretical Currents in Experiential Education by Jay W. Roberts, Routledge, 2011

National Society for Experiential Education–Founded in 1971, NSEE also serves as a national resource center for the development and improvement of experiential education programs nationwide.

Minnesota State University Master's Degree in Experiential Education–there are others, but this is the oldest degree program in experiential education.

Experiential Education–an article from Wikipedia

David Kolb's Experiential Learning Model–Article related to Kolb's four-element model of experiential learning

3.6. Should science teaching be political? A Humanistic Question

Yesterday, I wrote about how science teacher education needs to embrace a humanistic perspective, and work with teachers at their highest level. Today there is a dismissive language that runs across the political spectrum condemning public schools, and teachers. This is fairly well documented in Diane Ravitch's recent book, *The Death and Life or the Great American School System: How Testing and Choice Are Undermining Education*. Throughout my writing on this blog I have advocated a humanistic perspective, and the need to embrace a humanistic view in teaching and learning. About a year ago I wrote a post that seems apropos today. Here it is as published last year:

I could have titled this "Is science teaching political? A Humanistic Question." In an article recently published in Science Education, Wildson L.P. dos Santos, of the Instituto de Quimica, Universidade de Brasilia, describes a rationale for advancing a new idea in humanistic science education developed from a Paulo Freire perspective. It relates to many discussions about humanistic science education that have been posted on this weblog, and I want to talk about the implications of dos Santos' research.

Freirean Humanistic Science Education

Firstly, this is an important contribution to the field of science teaching, and to those science teachers who advocate a humanistic science education paradigm. Dos Santos bases his research on the perspective of teaching advanced by Paulo Freire, an early advocate of humanistic ideas in education. Freire's, *The Pedagogy of the Oppressed*, describes the pedagogy that forms the foundation of dos Santos' analyses of humanistic science education. The core of Dos Santos' ideas are reflected in this passage from the abstract of his paper:

From Freirean educational principles, the idea unfolds that a *Freirean humanistic science education* perspective is a *political commitment* to sociopolitical action, considering conditions of oppression in society. Although some humanistic science education approaches to school science have incorporated a sociopolitical perspective, it is showed that not all of them necessarily focus on the political purpose of transforming oppressive conditions in society as stressed by Paulo Freire.

From this Freirean humanistic perspective, an approach to science education is then highlighted, which implies the introduction of socially relevant themes and socioscientific issues, the establishment of a dialogical process in classrooms, and the development of sociopolitical action.

Call to Action

Dos Santos' paper is a call to action for science educators—teachers, professors of science education, and developers of science curriculum—to rethink how STS (science, technology & society) and STL (scientific and technological literacy) might be used to advance humanistic science ideas.

In the view developed by dos Santos, we are challenged not to be neutral politically, and at the same time not to impose our own values. This has always been a serious issue for science teachers who supported an STS approach to teaching.

The very fact of involving students in science-related issues begs the question, why this issue? Is it important to the teacher? Or is it an issue that students should deal with? What will it teach the students? In whose interest is studying this issue?

According to dos Santos, *teaching is directive and political in itself*, and teachers who choose to bring STS in the classroom will have to reveal their own views, but at the same time must enable every student to express his or her ideas, and indeed to develop and take action on their own choices. dos Santos puts it this way:

> *The challenge of humanistic education is therefore not to give the answer but to prepare students to reflect on, and select their own destiny. The role of the teacher is not to reveal the reality to their students but to help them discover the reality for themselves; not to impose their values or to give their solutions to SSI, but to help students understand the different values and alternatives available so they can select their own.*

A humanistic science education approach to teaching would involve students in debates about the issues they are exploring, and to go deeper into the implications of the issues they are studying to incorporate the contradictions related to the issues around the world. As stated by Dos Santos:

> If the course is for students who have a good social condition, the prompt could lead to a comparison of their situation to that of students in contrasting contexts in their country or in another country they relate to—for instance, a country that was colonized in the past by their own country; or a country from which their own country imports food. The role of the teacher is to facilitate this debate, to ponder students' opinions as well as his own, but never to impose it.

Wildson dos Santos presents intriguing ideas for us as science teachers not only to ponder, but also to consider how we might incorporate his ideas into our own practice. These pedagogical ideas bring us into unsafe territory, but in fact it might be the territory that would attract many of our students. What do you think?

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Omne tulit punctum qui miscuit utile dulci — Horace