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Environmental Science for All? Considering Environmental Science for Inclusion in the High School Core Curriculum

A compelling argument is made for incorporating environmental science into the high school core curriculum to improve students' perceptions of science while preparing them both for the use of science in their lives and for postsecondary education.

Introduction

With the dramatic growth of environmental science as an elective in high schools over the last decade, educators have the opportunity to realistically consider the possibility of incorporating environmental science into the core high school curriculum. Environmental science has several characteristics that make it a candidate for the core curriculum. It is: important for students and society; representative of contemporary science; an opportunity for students to experience an applied science; a particularly engaging context for learning fundamental science. In this paper, I consider the possibility of a reform with the goal of achieving widespread adoption of environmental science as a required subject for high school by: arguing for the value of environmental science, examining the rationale for the status quo, exploring what a high school core curriculum that includes environmental science might look like, and considering which of the elements that would be required to implement this reform are in place. I conclude that many of the elements to support broad adoption of this reform are in place, but several are not, so additional groundwork would need to be laid before a large-scale reform effort targeted at integrating environmental science into the core high school curriculum could be successful.

An Opportunity

In recent years, environmental science has gained an increasingly prominent place in the high school curriculum. Data gathered by Horizon Research, Inc. as part of the National Survey in Mathematics and Science Education show that between 1993 and 2000 the percentage of high schools teaching environmental science increased from 24% to 39% (Smith *et al.*, 2002). In fact, as of 2000, the number of schools offering environmental science exceeded the number offering Earth science (34%).

Through informal data gathering, I have begun to put together a picture of how this growth in environmental science teaching has taken place. In conversations with numerous teachers and administrators from around the U.S., I have heard a variety of stories about why and how schools have made the decision to begin offering environmental science. The most common story is that a specific teacher or teachers lobbied in favor of offering environmental science and volunteered to teach it. Teachers cite their own interest in the subject or their belief in the importance of environmental science for their students as the reasons for taking that initiative. These teachers frequently report that they are able to successfully engage students in environmental science classes that have not engaged or been successful in prior high school science courses. A second—but less common-ly told—story is of schools and districts that have introduced environmental science as a top-down initiative under the leadership of an administrator. In these cases, a commitment to the importance of environmental science on the part of the initiator is often the reason, but other reported reasons are: to serve as a ninth grade introductory science in the role that general science has often played in the past; or simply to offer an additional elective to students. On a few occasions, I have heard that unsolicited student demand played an important role in the initial decision to offer environmental science. The fact that the College Board introduced an Advanced Placement (AP®) exam for environmental science in the late 1990's also appears to have played an important role in the decision of schools to offer environmental science. Schools have introduced environmental science as an advanced placement course because they have found that there is a population of students qualified to take AP science that would prefer to take environmental science over a second year of biology, chemistry, or physics. However, the existence of the AP exam in environmental science appears to have contributed to the growth of environmental science courses at all levels. The College Board's endorsement of environmental science as an undergraduate subject deserving of AP credit has provided the subject with a credibility that it may have lacked previously. Teachers report that administrators are more receptive to the idea of environmental science at other levels as a result of its acceptance as an AP course.

A Proposal

The fact that environmental science has expanded beyond the niche of specialty electives presents educators with the opportunity to seriously consider the question of what role environmental science can and should play in American high schools in the future. The growth of environmental science teaching in high schools to date appears to be largely in the form of added electives, not in the form of integration into the core curriculum. In this essay, I consider the possibility of incorporating environmental science into the course of study for all high school students. In short, I argue that environmental science should be an expected course for all high school students.

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There are several reasons why we might integrate environmental science into the core curriculum, which I elaborate below. While I do believe American schools should implement this change, I am making this proposal in part because I believe there is value simply in the act of considering it. A broad and open discussion about the role of environmental science in the core curriculum will lead to a frank re-assessment of the rationale behind our high school science curriculum, a process that happens far too rarely in our system.

Why include environmental science in the core curriculum?

Here are four reasons why I believe environmental science should be a component of the curriculum for all high school students. Environmental science education is:

- Important for students and society;
- Representative of contemporary science in ways that the disciplinary courses that currently comprise the core curriculum are not;
- An opportunity for students to experience an applied science;
- A particularly engaging context for learning fundamental science.

In a position statement adopted by its Board of Directors in 2003, the National Science Teachers Association summed up these reasons in the following way (National Science Teachers Association (NSTA), 2003):

> NSTA strongly supports environmental education as a way to instill environmental literacy in our nation's pre-K-16 students. It should be a part of the school curriculum because student knowledge of environmental concepts establishes a foundation for their future understandings and actions as citizens. Central to environmental literacy is the ability of students to master critical-thinking skills that will prepare them to evaluate issues and make informed decisions regarding stewardship of the planet. The environment also offers a relevant context for the learning and integration of core content knowledge, making it an essential component of a comprehensive science education program.

I elaborate on these reasons below.

Importance for Students and Society

Environmental science is unique among the widely taught high school courses in its direct applicability to students' lives and its value for society. The current generation of K-12 students face a future in which responding to the tension between human resource use and natural systems will become increasingly urgent. In coming decades, governments and individuals will confront the reality that the growing human population and its increasing demands for resources will stress the Earth's limited supplies of fossil fuels, freshwater, and arable land. At the same time, if exploitation of natural resources continues at its current pace, the current generation of school age children will experience unparalleled degradation of the natural environment and loss of biodiversity. While there are innumerable ways that these future citizens and their society may decide to respond to these challenges, we have an obligation to prepare them to make those decisions. One step in that direction is to provide all high school students with a sound understanding of how environmental systems function and how human activities depend upon and impact those systems.

An Interdisciplinary and Unresolved Contemporary Science

Environmental science provides an opportunity for students to gain a more rounded understanding of contemporary science because it has two features that are absent from the current high school curriculum. Environmental science is interdisciplinary and presents science that is unresolved, even at the introductory level.

Unlike the dominant high school courses of biology, chemistry, and physics, environmental science is interdisciplinary. The study of environmental science provides students with the opportunity to see how fundamental physical, chemical, geological, biological, and social processes interact to shape the environments that we inhabit. Environmental science courses provide students with the opportunity to both apply the disciplinary science that they have learned previously to understand their world and to extend their understanding of disciplinary science. In this way, environmental science draws on prior disciplinary learning and motivates disciplinary learning within the environmental context. For example, a typical high school environmental science course might incorporate the study of the physics of electricity generation, the chemistry of water pollution, the biology of ecosystem inter-dependencies, the geology of erosion and deposition, and the social dynamics of human resource consumption. Because of its relevance to social issues, environmental science also provides the opportunity for students to experience the connections between science and social studies.

In addition to being interdisciplinary, environmental science can provide an opportunity for students even at the introductory level to learn about unresolved science. Many of the key environmental challenges of our time are creating demand for scientific knowledge that exceeds current human understanding. For example, one source of uncertainty in predicting future climate change is the fact that scientists are still investigating the role that clouds play in both reflecting solar energy into space and absorbing terrestrial radiation. Understanding the question that these scientists are investigating is well within the capability of a student in an introductory high school environmental science course, whereas the boundaries of physics, chemistry, and biology have largely expanded beyond the point that an introductory high school student can appreciate them. The fact that many issues in environmental science are unresolved means that they can open a window into the process of science in a way that is more compelling when the process is ongoing than it is when the process was resolved a hundred years ago or more. Learning about climate scientist James Hansen's ongoing role in the development of the science of climate change is very different from learning about Galileo, Mendel, or even Alfred Wegener, the originator of the theory of continental drift in the last century, because the scientific questions he is investigating remain open and the vocabulary he uses is current, not archaic. When they have a window into current, unresolved science, students have an opportunity to see what scientific debate looks like and understand science as an ongoing process, not as the set of handed down answers that they receive in an introductory biology, chemistry, or physics class. The fact that in environmental science, these unresolved questions can have significant implications for their future and are often politically controversial makes them even more compelling for students, which contributes to the engagement that I discuss below.

Teachers report that administrators are more receptive to the idea of environmental science at other levels as a result of its acceptance as an AP course.

An Applied Science

While the core of environmental science is understanding how the natural physical and biological systems interact with each other and with human social systems, environmental science also provides the opportunity to learn how that science can be applied. An important component of environmental science is understanding the role that science can play in informing human decision-making. While physics, chemistry, and biology all have important applications, these applications are generally used as examples rather than context. In environmental science, the decisions that societies and individuals face regarding activities that impact environmental systems are inextricably intertwined with the science of environmental systems. Therefore, environmental science provides a valuable opportunity to teach students how science is applied. In particular, environmental science provides a context for students to see how scientific evidence is combined with social considerations and constraints in evidence-based decision-making. Environmental science also provides the opportunity for students to learn about probability to understand how applied scientists and policymakers make decisions under uncertainty.

An Engaging Context for Learning Science

Environmental science provides a compelling context for learning both science content and scientific practices (e.g., inquiry). The easily demonstrable importance of environmental science for students and their communities makes it easy to engage students in the demanding process of learning. The biggest challenge of high school education in our modern society is providing our diverse student population with a reason to learn that makes sense within their personal value systems. The default reason for learning in our current system is advancement through a system that will provide them with economic and quality of life benefits in the future. If they ask, students are usually told that the most important reason to learn fundamental chemistry, biology, or physics because it will prepare them for future education. If they are provided with an example of how they might use what they are learning outside of the educational system, it is typically in a context that feels remote to all but a small number of "scientophile" students.

Based on drop out rates nationwide, particularly among poor and minority students, and the small number of students who continue in science after meeting minimum secondary or postsecondary requirements, we must conclude that we are not giving enough of our students a good enough reason to put in the effort to learn. Because the value of learning environmental science for personal and societal reasons is immediately apparent to students, environmental science is able to create a level of engagement among students that exceeds that in traditional disciplinary courses. This makes it possible to engage students in learning activities based on students' understanding of the value of what they are learning, which research tells us will lead them to learn in ways that are different from the way they learn when they are pursuing a grade or a credit. In a system where environmental science were integrated fully into the curriculum, this sense of purpose for learning science would become internalized and might carry over to other courses as well.

Reconsidering the Status Quo

While the arguments in favor of environmental science might appear compelling, we should approach any change to the core curriculum with caution. Presumably, the inclusion of a new subject in the core curriculum is going to displace some element or elements of the existing course of study. Therefore, we should examine the rationale for the status quo, so that we may weigh the trade-offs of the proposed change.

The first step in evaluating the rationale for the current high school science curriculum is recognizing that the primary reason the curriculum looks the way it does is historical. For nearly a century, the most common requirements for high school students have been disciplinary courses in biology, chemistry, and physics. Our modern day curriculum has been handed down almost unchanged from a sequence of reforms that began in the 1890's and continued through the 1920's. At the end of the nineteenth century, science instruction was not yet universal at the secondary level, but in 1893, an influential report issued by ten university presidents and high school principals called for the inclusion of science in the core curriculum for all students. This report recommended that students take a combination of required and elective courses in botany, zoology, physiology, chemistry, physics, astronomy, and physical geography, including laboratory and field experiences, to prepare for college (DeBoer, 1991). By 1918, science had become an accepted part of the high school curriculum, and chemistry, physics, and a new course called biology that included elements of botany, physiology and zoology had emerged as the core curriculum. Astronomy, physiology, physical geography, and specialized courses in zoology and botany were relegated to electives. In fact, when the National Educational Association created the Committee for Reorganization of Secondary Education in 1918, they only created four subcommittees in science: general science, chemistry, physics, and biology. Reflecting what had already become the dominant practice, this committee recommended in their 1920 report that all high students, college-bound or not, should take biology, chemistry, and physics (DeBoer, 1991). These three disciplines have comprised the high school course of study in science for the vast majority of American high schools ever since then. While science instruction has undergone several waves of reform in the intervening years, those reforms have focused more on changing how science is taught than on which science is taught.

I am not calling into question the importance of biology, chemistry, and physics. However, I do think it is valuable to consider the question of whether the 2-4 years that students spend taking high school science should be devoted exclusively to the study of these three disciplinary sciences, or do the benefits of environmental science justify a new compromise between the teaching of these traditional, disciplinary sciences and an inter-disciplinary science whose direct applicability to might make it more useful to students?

The most common arguments in favor of requiring the traditional three sciences are: (1) that they teach "the fundamentals" of science and therefore need to be understood before students enter into the study of inter-disciplinary sciences, and (2) these courses are important for college because they are either required for admission or recognized as being "college prep" courses in the college admissions. Both of these reasons for the status quo must be weighed seriously in considering a change to the status quo. However, I believe that both arguments reflect the inertia of the educational system more than they do sound principles.

The "Fundamentals First" argument

The question of whether or not science should be taught beginning with the fundamentals is an interesting and important one. The argument in favor of teaching fundamentals first holds that conceptual understanding should be built from the ground up, with logical antecedents taught before their consequents. Two of the most visible advocates of this approach are Project 2061 of the AAAS and the Physics First movement initiated by Nobel laureate Leon Lederman (Lederman, 2001). Project 2061 of the American Association for the Advancement of Science (AAAS) has even developed an "atlas" of science understanding that decomposes the scientific understanding that they believe students should achieve by 12th grade into branching trees of logical precedents (AAAS Project 2061, 2001). These "strand maps" are designed to serve as a blueprint for sequencing science instruction.

While the argument holds certain logical appeal, it does not necessarily reflect what we know about cognition and learning. What research on learning in science has shown is that students struggle when they are taught by a method that attempts to lay down a foundation of fundamentals and build up from it. A more natural way for students to learn is to connect new concepts to what they already know. That explains why undergraduate physics instructors were so unnerved when physics education researchers started to look closely at what students were learning in introductory physics classes and discovered that students could excel at the problem-solving required by physics exams without understanding the basic underlying physics concepts. Students find it difficult, for example, to make sense of force and acceleration, the fundamental building blocks of mechanics, because they cannot connect those Newtonian concepts to the world they know through experience. So, a process of deepening from existing understanding may be a better metaphor for guiding science learning than laying a foundation and building up.

The growth of environmental science teaching in high schools to date appears to be largely in the form of added electives, not in the form of integration into the core curriculum.

Thus, a benefit of environmental science is that it is a science that begins with the world that students inhabit and encourages them to deepen their understanding by introducing scientific processes to explain their observations. By and large, the disciplinary sciences begin with a world that students must imagine and attempts to build an understanding that they can eventually connect to the world they inhabit. Environmental science does the reverse by starting with consequential phenomena and deepening understanding from there.

This is not an argument against teaching fundamental science, but it is an argument in favor of teaching fundamentals by digging down to them from existing understanding. A common criticism of teaching inter-disciplinary science is that students cannot understand inter-disciplinary science without understanding the disciplinary fundamentals. In fact, they can. High school students understand a lot about the science of the world they inhabit without understanding the deepest fundamentals. But, more important, inter-disciplinary science can be a context for learning fundamental science through a process of developing deeper understanding in specific disciplinary areas and then reinforcing that deep understanding by integrating it with other understanding in the inter-disciplinary context.

Furthermore, as an inter-disciplinary science, environmental science is able to take advantage of these connections in ways that disciplinary sciences are not. For example, you could teach about environmental impacts of emissions from coal-burning power plants in a physics or chemistry or biology course, but you would be confined to considering the portion of the system that is explained by your discipline. Disciplines carve up the world into slices that correspond to what can be explained by the discipline and what cannot. In interdisciplinary environmental science, a student has the opportunity to learn about the biological, chemical, and physical processes that determine both the content of the emissions and the effects of those emissions on the physical environment and ecosystems.

The last point to make about the argument for teaching fundamentals first is that high school is not the first time that students study science. Even if we were to accept the premise that students should learn fundamental science before moving on to interdisciplinary science, then they should have had the opportunity to develop enough understanding of fundamental science by the time they enter high school to be prepared for some inter-disciplinary science in high school.

The "Preparation for College" argument

The second concern about including environmental science in the required high school curriculum at the expense of some portion of the traditional curriculum is the implication of the change for postsecondary education. Since one of the most important goals of high school is to prepare students for college, high schools clearly cannot change their course of study without paying attention to this concern. This concern really has two dimensions: preparation for college study and meeting college admissions requirements.

As far as preparation for college study goes, the arguments in favor of environmental science that I've already presented certainly apply to preparation for college. Students who understand the role of science in personal and societal decision-making, who have experienced inter-disciplinary science taught in meaningful contexts, and have had the opportunity to apply science will be better prepared for undergraduate study than students who have only experienced science within traditional disciplinary boundaries and divorced from the familiar context of the world they inhabit. Undergraduate science faculty say that the biggest problem they face is not students' lack of specific knowledge, but their lack of understanding of the scientific enterprise. When their science education consists entirely of the study of well-understood, disciplinary science, they do not have the opportunity to understand science as an active and ongoing process. By studying a controversial, unresolved, contemporary science, students have the opportunity to understand the scientific enterprise that will help them in all subsequent science courses, particularly advanced disciplinary ones.

As far as meeting the requirements for college admissions or maximizing competitiveness in that process, high school administrators, teachers, and counselors are clearly under the impression that colleges are looking for biology, chemistry, and physics from high school students, but I have not seen or heard evidence from colleges that they are. In nearly every case of admissions requirements that I've looked at, including the large public universities and the highly competitive top tier of private and public schools, the requirement is expressed in terms of laboratory science courses. In the minority of cases where specific disciplines are required, I have not found any university that requires more than two of the traditional disciplines, which does not preclude additional study in another area.

So, we have to ask the question, why are teachers, administrators, and counselors convinced that admissions officers are specifically looking for biology, chemistry, and physics? It may well be the case that they have simply grown accustomed to seeing college-bound students, particularly the top ones, taking those three courses. If so, then the solution would be to disseminate more accurate information about what colleges are looking for. Another possible explanation is that physics, chemistry, and biology have been the most demanding high school science courses historically. In that case, the solution is simply to make sure that environmental science has the same rigor and expectations that the disciplinary courses have traditionally had. There may be an opportunity for universities to take some leadership in overcoming the bias toward the traditional sciences, by actively encouraging college-bound and highly competitive students to take environmental science.

To summarize, it may be that the arguments for the status quo are base on out-of-date and faulty reasoning, or—in the case of preparedness for college—in correct assumptions about admissions requirements and considerations.

What might a course of study that includes environmental science look like?

It is one thing to propose that environmental science be part of the core curriculum for high school in principle. It is a whole different matter to figure out how to incorporate it in practice. I recently had the opportunity to think this through with colleagues in responding to a request for proposals from the Chicago Public Schools (CPS) to design and provide implementation support for a 9-11th grade course of study in science. This instructional reform program is one element of a larger High School Transformation project that CPS has undertaken with the support of the Bill and Melinda Gates Foundation. We were asked to design a three-year "vertically-integrated" science curriculum that would both meet the Illinois standards for high school science (as assessed by the statewide examination required of all 11th graders) and prepare students for college. Starting with the premise that environmental science should be a component of the high school curriculum for the reasons I've presented here, we found ourselves with three important questions to answer, *Which other subjects should be included in the curriculum? What should the sequence of courses be? And how should the limited time be allocated across subjects?* Below, I describe the course of study that we developed, then I consider some alternatives and the trade-offs among them.

The course sequence that we developed consists of: a yearlong environmental science course in ninth grade that includes one quarter of geology, a one-semester chemistry course and a one-semester physics course in tenth grade, and a yearlong biology course at eleventh grade.

In particular, environmental science provides a context for students to see how scientific evidence is combined with social considerations and constraints in evidence-based decision-making.

Playing off the "Physics First" slogan, we characterize this approach as "Environmental First". We argue that the benefits of environmental science—its connections to the worlds of students, their personal decisions, and societal decisions, and its inter-disciplinary nature, make environmental science a powerful introduction to high school science. Its inter-disciplinary nature allows students to draw on the disciplinary science they have learned in middle school, and it helps to motivate the disciplinary science that they will delve deeper into as they advance through high school. By starting high school with an interdisciplinary course that puts fundamental science into meaningful contexts, students have the opportunity to see the value of the fundamental science they will learn later for them and their communities. Our course sequence then moves on to the more fundamental of the disciplinary sciences, chemistry and physics, in the tenth grade.

Together, the environmental, chemistry, and physics courses lay a foundation for the eleventh grade biology course that draws on the content and skills taught in the prior three. In contrast to the ninth grade biology course that has become the norm in many places, an eleventh grade biology course that follows these other courses is able to deal with life processes, the interactions among living things, and the mutual influences of the biota and the physical environment on each other at a much deeper level. For example, students with coursework in chemistry, physics, and environmental science are much better prepared to understand matter and energy cycling in organisms and ecosystems.

We did not expect that including environmental science in this sequence would be controversial in the Chicago Public Schools, where a year of Earth or environmental science has been required to graduate for some time. However, sentiment has been growing in recent years for eliminating the Earth/Environmental science requirement to allow students to take the biology, chemistry, and physics course combination that is the norm in the surrounding suburbs. In fact, in the first year of implementation of this program, only three of the fourteen schools participating in the High School Transformation Project selected the sequence with environmental science. The others all selected one of the two biology, chemistry, and physics course sequences offered. In our discussions with schools subsequently, both the schools who selected our course sequence and those who did not reported that the sequence, specifically the trade off between including Environmental science or a full year of both chemistry and physics, was the primary factor in their considerations of our program, overshadowing such other factors as the pedagogical approach of the courses and the nature of the supports for implementation being offered.

Comparing the sequence we developed to a three-year biology, chemistry, and physics sequence brings into stark focus the trade-offs associated with incorporating environmental science into the core high school curriculum. In the sequence we've developed, students only receive one semester each of chemistry and physics. On the other hand, they receive a year of environmental and earth science, which, in addition to the benefits cited above, figure prominently in the Illinois Learning Standards for science and the high stakes assessment that derives from them. And, for those students who have a specific interest or educational goal that makes physics or chemistry particularly important for them, they still have the opportunity to take additional coursework in these areas in twelfth grade or by taking an additional science course as an elective in grades 9-11.

In developing this sequence, we considered several alternatives, including replacing the split between chemistry and physics with an entire year of one of them and/or moving environmental science to the third year. On the question of one semester each of the two physical sciences versus a whole year of one, we considered the possibility that more depth in a single discipline would be more valuable than a shorter exposure to two disciplines. In the end, we decided that enough chemistry and physics could be covered in a semester each to minimize the downside of trying to cover two disciplines in a single year. Furthermore, we felt that both chemistry and physics were sufficiently important for meeting state standards and for preparing students for biology that neither could be eliminated from the sequence all together.

On the question of moving environmental science to the third year, we felt there were good arguments both ways. In this particular context, we felt that the value of environmental science as a foundation for subsequent disciplinary courses would be greater than its value as a capstone experience that allows students to integrate and apply their disciplinary learning. There were two aspects of the local context that led us to place environmental science at ninth grade. First, we felt the motivational benefits of starting with environmental science would be important in an urban school district with large numbers of under-prepared and poorly motivated students. Second, we felt the specific instructional materials that Chicago had chosen for this initiative would work best in this sequence. We felt that the demanding biology program they selected (Biological Sciences Curriculum Study, 2006) would be most effective if used at the eleventh grade level, and that the environmental and Earth science materials (American Geological Institute, 2001; Edelson, 2005) were well-suited to an introductory level course for ninth graders.

There are certainly alternative sequences that would make sense in other contexts. One would be to use a different allocation of time for each course. Our particular design placed a higher priority on environmental science and biology as reflected by the time devoted to each. However, a different group with different priorities might choose to allocate equal amounts of time to the five subjects of chemistry, physics, biology, Earth science, and environmental science. Another might choose to devote two years to the physical sciences and reduce biology and environmental science to a single year.

Our modern day curriculum has been handed down almost unchanged from a sequence of reforms that began in the 1890's and continued through the 1920's.

A second alternative, mentioned above, would be to have environmental science as a capstone experience. In fact, it appears that the most common way for students to take environmental science currently is as their final high school science course. In many schools, environmental science is an elective course taken by 10-12th graders after they opt out of the more challenging biology, chemistry, physics sequence, or by 12th graders who have completed that sequence. As I mentioned earlier environmental science is increasingly being offered as an advanced placement course, again, mostly for students who have completed a biology, chemistry, physics sequence.

A third alternative would be to use the environment as the context or theme for one or more disciplinary courses instead of a free-standing course on environmental science. In fact, environmental themed high school textbooks for general science, chemistry, biology, and Earth science already exist (*Science and Sustainability*, *Chemistry in the Community*, *Biology in the Community*, and *EarthComm*).

Is environmental science the best alternative to the status quo?

If we are willing to reconsider the status quo, then we should also be open to the possibility that the integration of environmental science into the core curriculum might not be the best alternative. Given that the argument for environmental science is based on the benefits presented earlier, we must consider whether there are other science courses that offer those benefits as well as environmental science does, if not better. Environmental science is certainly not the only inter-disciplinary or applied science available to high schools. Others include Earth science, health science, forensics, and engineering. The science with the most students enrolled nationwide after biology, chemistry, and physics is Earth science, making it a plausible alternative to environmental science. Like environmental science, Earth science is inter-disciplinary and both draws on and motivates physics, chemistry, and biology. However, it does not share some of the other benefits of environmental science. For example, many of the topics of Earth science as it has been conceived historically, are not well connected to the environment that most students inhabit or the concerns they and their communities face. While Earth science is the science of our planet, it deals primarily with phenomena that play out over very long time-scales and very large distances, and that few students experience directly. Earth science is only partially the science of our immediate environment. The result is that much of Earth science is an abstraction for high school students and doesn't have the same engaging quality for them that environmental science does. In that respect, Earth science is more of a fundamental science than environmental science. In fact, Earth science concepts and methods are necessary components of a good environmental science course. So, one way of looking at the proposal to include environmental science in the core curriculum is as a proposal to dramatically increase the role of Earth science in the curriculum. However, the focus of environmental science on the immediate environment (in space and time) that we inhabit, on both ecosystems and the physical environment, and on the interactions between society and the environment make it both more engaging and more important for students and society.[1]

The other applied sciences that are taught at the high school level, including health science, forensics, and engineering, bear consideration as well. As interdisciplinary and applied sciences, these courses have attributes that make them representative of contemporary science and engaging, as well as providing opportunities to apply science. Therefore, a school or district that was considering a change to the core curriculum based on the reasons I've offered above, would want to consider these sciences as alternatives to environmental science. However, these other sciences are not as well positioned to become part of the core curriculum as environmental science is. They do not have the same range of available textbooks, level of current acceptance in high schools, or number of experienced teachers in place that environmental science does. So, for pragmatic reasons, these sciences are not likely to be candidates for widespread inclusion in the core curriculum in the near term, but they make sense to consider as alternatives, depending on local context.

Moving the proposal forward

In the introduction to this essay, I stated that even a public discussion of modifying the core curriculum would be a productive activity for schools, regardless of the outcome. While I believe that, I believe more strongly that it would be to the benefit of students and society for all students to study environmental science in high school. Therefore, in this section I consider how like-minded educators might bring this proposal to fruition.

As a caveat, though, I must say that I do not believe that there is a single, most appropriate course of study for all students at either a national or a local level. Therefore, I am not proposing that the U.S. adopt a national curriculum that includes environmental

1. I note that in the last fifteen years there has been a broad re-conceptualization of geosciences research and education using a model called "Earth Systems Science" (NASA Advisory Council, 1988) that treats the Earth as a set of interacting systems, including human systems. To the extent that Earth systems science education is developing to fit the description that I've provided for environmental science, my arguments apply to Earth systems science education as well. I do not mean to argue that the core curriculum should include a course with the name "environmental science". Rather my argument is that the curriculum should include a course with the properties that I have ascribed to environmental science, regardless of its name.

So, we have to ask the question, why are teachers, administrators, and counselors convinced that admissions officers are specifically looking for biology, chemistry, and physics?

science. I am proposing that schools and districts, at the local level, consider making environmental science a part of the expected course of study for all students. My hope in making this argument is that many local educational authorities will decide to integrate environmental science into their science curriculum. However, I believe that local school authorities should make those decisions based on local priorities and local conditions, and I recognize that there are sound reasons that many schools and districts would not adopt this proposal.[2]

So, how might we bring about widespread inclusion of environmental science into the core curriculum? Without a doubt, any modification of the core curriculum involves trade-offs that must be carefully considered. However, in considering these trade-offs, it is important to recognize that the justification for the current curriculum rests more on tradition than it does any such careful consideration within recent history. Educators are currently operating in an era of accountability and increasing calls for "evidence-" and "scientifically-based" decision-making in education. While the motivation behind this desire for sound empirical evidence for decisions is well-meaning, it does serve to bolster the status quo, which has never been subjected to the same level of scrutiny. Nevertheless, any effort to effect large-scale change in education must be attentive to this policy and political context.

How can such change be made? We might look to other science education reform efforts for lessons. Two relevant prior efforts are the recent Physics First movement and the Science-Technology-Society (STS) movement of the 1970's and 1980's.

Lessons from the Physics First and Science-Technology-Society Movements

The Physics First movement has had some high-profile successes in reforming science instruction since it was initiated in the late 1980's. The Physics First movement is based on sound justifications that are compelling to educational stakeholders, and some high-profile advocates with the support of a broad constituency of educators, including professional societies of both physicists and physics teachers.

The science-technology-society reform movement that began in the 1970's, achieved considerable levels of success among a committed community of science educators and even widespread awareness among science educators at its peak in the 1980's, yet failed to achieve widespread adoption and has not been able to sustain a high level of visibility among the broad K-12 science education community. The history of the STS movement contains lessons that we can learn from, particularly because the arguments for STS and for environmental science both rest on their importance for citizenship. For example, Gallagher (1971) argued that "For future citizens in a democratic society, understanding the interrelationships of science, technology, and society may be as important as understanding the concepts and process of science. (p. 337) While I am not a historian myself, I have been able to draw a few lessons from accounts of the STS movement (e.g., Aikenhead, 2003; DeBoer, 1991; Hurd, 1991; Rubba, 1991; Yager, 1996b). One is that STS achieved early success because it was in tune with the growing social and political concern at the time over the environmental and social costs of technological progress (DeBoer, 1991). A measure of its success is the 1982 statement of the National Science Teachers Association entitled *Science-Technology-Society: Science Education for the 1980s* (National Science Teachers Association (NSTA), 1982) which called for the integration of the STS theme into science education. On the other hand, while STS rode a wave of political and social liberalism, it eventually ran into a wave of disciplinary and educational conservatism, in

2. In fact, I do not even believe in *requiring* a particular course of study for all students at a local level. Therefore, my proposal is to create an *expectation* that all students will study environmental science in high school, with an understanding that for some percentage of the student body, there will be reasons that it would be better for them take an alternative course of study. I, realize of course, that this flexibility is not practical in many schools and districts, and that in many, if not most schools, the only way to establish an expectation for all students is to enact a requirement. Even with the reality that in many places an expectation means a requirement, I believe that a course of study that includes environmental science is in the best interests of all students and their communities.

the form of opposition to the idea of reorganizing science instruction in the disciplines around social issues. As Aikenhead (2003) laments, "Unfortunately two major American science education initiatives, [*Benchmarks for Science Literacy* and *The National Science Education Standards]*, have completely dominated the science curriculum agenda in the USA. There is little but lip service paid to STS perspectives in these reform documents." In addition, at the time that the STS movement emerged, the subject matter and pedagogical approach were truly novel, with few existing practices and no instructional materials for teachers. In a 1996 overview of STS, Robert Yager wrote:

> *Many cannot deal with a movement like STS, which is not curriculum based. Instead of a curriculum it is a context for a curriculum. Many want to reserve judgment on STS until they see a curriculum and some goals and assessment instruments focused on basic concepts.* (Yager, 1996a, p. 13)

In fact, Bybee (1991) reports a study completed in 1987 that found that 89 percent of 317 science teachers surveyed said they had considered incorporating STS into their courses and that over 90 percent said they would incorporate the STS theme if materials and strategies were available. However, Yager (1996a) explains that there were principled reasons why STS advocates were reluctant to respond to the need for instructional materials:

> *Many in the STS movement are resisting the temptations of preparing a curriculum outline, of adding STS strands to existing courses and textbooks, of identifying new lists of concepts and processes, or preparing new examinations to assess the degree of recall of the new concepts and process skills.* (p. 13)

Because STS advocates have been largely opposed to both the content and form of traditional textbooks, they were not inclined to develop the concrete instructional materials that would ease the process of implementing STS for teachers. Thus, for most of its history STS has taken the form of a new and demanding approach to teaching, without instructional materials that teachers could pick up and implement. By the time that STS curriculum materials had been developed and published—e.g., *Issues Evidence and You* and *Science and Sustainability* cited by Aikenhead (2003) as "rare exception[s]" to the minimal influence of STS on pre-college science in the U.S—the opportunity of STS to capitalize on its early momentum to jump to widespread implementation had passed.

Strategies for Moving the Proposal Forward

Looking at Physics First, Science-Technology-Society, and other precedents in the history of science education reform, I conclude that the following would be necessary to successfully move environmental science into the core curriculum broadly:

1. Anticipate broader social, political, and pedagogical movements that either favor or conflict with the reform and develop strategies for responding to them.
2. Cultivate both high profile advocates and a broad constituency among practitioners to support the reform.
3. Insure that sufficient materials, supports, and expertise are in place to support the growth of reform beyond the early adopters.

Social, political, and pedagogical contexts

At this time, I have identified four movements that will be most important to attend to in an effort to advance this reform:

> **Sustainability,** the social and political movement in favor of sustainable practices and environmental protection,
>
> **Competitiveness,** the political and educational reform movement focused on improving American competitiveness, particularly through the improvement of math and science instruction,
>
> **Accountability,** the political and educational reform movement focused on improving accountability and achievement on measurable outcomes in education,
>
> **Intertia,** the inherent conservatism of the educational system.

For each of these movements, it will be important to develop strategies to address possible support or opposition posed by them.

Clearly the "sustainability" movement is an opportunity for this reform, especially since concern for the environment has become mainstream, with more than 61% of Americans in a 2003 Gallup poll reporting that they are either active in (14%) or sympathetic to (47%) the environmental movement, 32% reporting that they are neutral, and only 16% unsympathetic. This means that more educators and community members are likely to support environmental science as a means of increasing environmental awareness and responsible behavior than in the past. Furthermore, as more traditionally conservative groups, such as hunters and ranchers, have become concerned about environmental degradation, advocacy for a balance between human activities and environmental impacts is no longer the polarizing issue that it was in the past. Therefore, it is less likely that such an initiative will run into opposition than in might have in the past.

Nevertheless, if this reform is perceived as being about environmental advocacy, rather than about the science of the environment, then there will be a risk of opposition from potentially vocal social and political groups that see environmentalism as contrary to their interests. For that reason, it is important to maintain a distinction between environmental science, which I frequently define as the "science of environmental systems," and sustainability education or other similar approaches that imply a set of values. While in, environmental science may be taught from the perspective increasing sustainable practices, it need not be taught that way. In other words, it can benefit from the advocacy for sustainability education, but environmental science education is not the same as sustainability education, and advocates for environmental science would be making a mistake to nest their cause underneath the sustainability education cause. If the goal of enhancing environmental understanding becomes tied to a particular set of values then it becomes vulnerable to the criticism that increasing the teaching of environmental science is just a strategy for advancing a political cause. Scientists who study environmental systems face this same tension between science and advocacy, and the cause of environmental science educators should maintain the same neutrality with respect to action in response to scientific understanding that scientists strive for in their capacities as scientific researchers. If environmental science education reflects the current understanding and uncertainty of environmental science and the full complexity of the factors that must be weighed in environmental decision-making, then it can be a form of education that all political constituencies can support as preparing students to make informed decisions.

The "accountability" movement has the potential to be either a source of support or a source of opposition. The importance of accountability in the current educational policy context cannot be overlooked in considering any educational reform. In this context, growing beyond the natural constituency of early adopters will require empirical evidence that outcomes for students who take a high school curriculum that includes environmental science are better, or at least, no worse than outcomes for the status quo. However, that evidence does not currently exist. Given that environmental science is already widely taught as an elective, it may be possible in the short term to assemble some empirical evidence about outcomes associated with electing to take environmental science. In the longer term, it will be necessary for interested researchers to initiate a program of research to collect the type of outcomes-oriented data that educational policy makers are currently looking for to guide their decision-making.

The "competitiveness" movement also has the potential to go either way on environmental science, depending on how successfully advocates for environmental science are able to make the case that the benefits of environmental science teaching will have broad impact on the skills of high school graduates. These arguments can be made if environmental science courses are constructed to develop the skills of analyzing data, constructing and responding to arguments based on scientific evidence, and weighing trade-offs systematically in decision-making that fall naturally within the study of environmental systems. Otherwise, the tendency of the business and political leaders to have a traditional view of education and its outcomes will weigh against environmental science.

With the growth in popularity of environmental science, virtually all of the mainstream textbook publishers offer at least one high school environmental science textbook.

The final movement to contend with is not so much a movement as the educational system's resistance to change and tendency to revert to old practices when the pressure to change is relieved. Historically, all the stakeholders in the educational system—administrators, teachers, students, parents, higher education, and employers alike—are reluctant to change their practices and roles. This inertia may take the form of teachers' not wanting give up an old subject or teach a new one, parents' and other adults being skeptical of the value of a science that was not offered when they were in school, or everyone's fears of a change that might compromise students' preparedness or competitiveness for postsecondary educational or employment. Strategies for addressing these inertial tendencies taking the time to gain buy in from stakeholders rather than forcing it on them before they are ready, using the experiences of early adopters to demonstrate benefits to them in the terms they care about, and engaging them in planning and implementing change so that it matches local needs and conditions.

Justifications and Constituencies

The second lesson of prior reform efforts is the need to develop arguments and constituencies to support change. The specific case of Physics First shows the value of having both high-profile advocates and a broad constituency of scientists and educators. This essay is designed to contribute to the justifications that will help to move environmental science into the core curriculum. While it is not yet apparent that there are high-profile advocates for environmental science education that are capable of bringing this proposal into the sphere of public consideration, the widespread adoption of environmental science courses as electives is reason for optimism that there is a constituency of educators who will support such a proposal, as is the growing number of educators who identify themselves with the sustainability education movement. However, unlike physics, chemistry, biology, or Earth science, there is currently no national organization of K-12 environmental science educators that might take on this cause. So, clearly there is important groundwork to be laid in moving the environmental science agenda forward. Fortunately, there are numerous organizations that are committed to advancing environmental understanding in our society who could bring substantial resources to moving this proposal forward if they chose to.

Materials and Expertise to Support Expansion of the Reform

A third lesson of history is that the success of any instructional reform depends on having resources available to help schools and teachers implement it. As I stated above, one of the reasons that the STS initiative did not sustain is that there were not sufficient instructional materials to support the broad spread of the initiative. Similarly, the post-Sputnik science education reforms foundered in part because their instructional materials were beyond the capacity of large numbers of teachers to implement. The resources necessary to implement a reform include: high-quality instructional materials in sufficient quantity and diversity to accommodate the variety of settings and teacher capacities in real world schools; professional development programs that address the attitudes, knowledge, and skills that both administrators and teachers need implement and sustain a new educational program; and organizations with the mission, expertise, and resources to advise and support schools in implementing the reform over a long enough period for the reform to be institutionalized. Without all of these resources, a reform, such as the one I propose here, is unlikely to spread beyond the early adopters and is at risk of not even being sustained by early adopters, as the initiators of the reform either leave or move on to other causes.

With respect to this proposal, there may be sufficient resources in place to support a wave of early adopters, but these resources are probably not sufficient to support a broader reform. In this case, the problem is probably not a lack of instructional materials. With the growth in popularity of environmental science, virtually all of the mainstream textbook publishers offer at least one high school environmental science textbook. These textbooks tend toward more traditional pedagogical approaches, but several organizations with reform agendas (including my own) have developed environmental science programs with more inquiry- and project-based approaches. This means that there is sufficient quantity and diversity of instructional materials to suit the needs of the broad educational audience.

Most high schools in America have a core curriculum for science that consists of traditional disciplinary perspectives and focuses on science that students perceive as being remote from their lives and concerns.

In addition, several organizations have created research-based resources to support the development, selection, and implementation of environmental science materials. These include recommendations for which environmental science content to be taught at which level, guidelines for effective environmental science teaching, and critical reviews of existing instructional materials (e.g., Anderson *et al.*, 2006; North American Association for Environmental Education (NAAEE), 2000a, 2000b, 2000c). Similarly, a number of well-respected organizations throughout the country offer professional development to environmental science teachers. These professional development programs could serve as models for the large-scale professional development for teachers and administrators that would be necessary to support the broad implementation of environmental science as an element of the core curriculum. However, it does not appear that there is sufficient capacity to support that sort of large-scale professional development initiative in place currently. Such a broad implementation would require a dramatic increase in the number of teachers prepared to teach environmental science and would therefore either require a substantial investment in professional development for the existing teaching corps or the development of pipeline that prepares environmental science teachers through pre-service programs. Either one of these strategies will require a sustained effort and investment over a period of a decade or longer.

A Realistic Strategy: Patience and Persistence

The picture that emerges from considering the available contexts, constituencies, and resources is that many of the pieces are currently in place to *initiate* a reform focused on the integration of environmental science into the core curriculum over time. There are sufficient political and social trends, natural constituencies, and resources in place to support a first wave of adoption of environmental science as an expected high school course. However, the constituencies and resources to support a large-scale implementation of the reform do not appear to be in place. In fact, an effort to implement this reform on a large-scale would be likely to fail in the effort to move beyond early adopters. In the American policy context where there are no second chances, overreaching can be a fatal error for a reform initiative.

Therefore, it appears that the path to success with this proposal will require a two-pronged strategy. One side of the strategy would be to begin to cultivate a community of schools and districts that are prepared to take the lead on an admittedly experimental basis to explore the value of environmental science in the core curriculum. These early adopters would need to be convinced enough by the arguments to implement the environmental science requirement without the evidence that others will demand. These early adopting districts could provide the setting for collecting the data necessary to convince others to follow and developing the resources and expertise necessary to support broader reform.

The second side of the strategy would be to begin to develop the connections to broader social and political movements, to cultivate both high-profile advocates and broader constituencies, and to develop the resources necessary to support the transition to a large-scale reform. These steps might include the establishment of a professional society for K-12 environmental science educators, the creation of programs for in-service professional development and pre-service preparation of teachers qualified and committed to environmental science education, and the institutionalization of these programs in universities and other organizations whose missions include the preparation and ongoing development of teachers. It is not realistic to believe that this proposal could be implemented without a long-term effort. On the other hand, the lessons of prior reform efforts do lay out a path that builds on our present opportunities. However, it is a path that will require patience and perseverance.

Conclusion

Given that the state of science education in the United States is a matter of considerable concern, not just among educators, but also among business leaders and policy makers, the time may be right to make changes in the status quo. Most high schools in America have a core curriculum for science that consists of traditional disciplinary perspectives and focuses on science that students perceive as being remote from their lives and concerns. Incorporating environmental science into this core curriculum could help to improve students' perceptions of science while preparing them both for the use of science in their lives and for postsecondary education. With the dramatic growth of environmental science as an elective in the recent past and favorable trends in the social and political context of schooling, the pieces appear to be in place to begin a process that could, over time, lead to the widespread incorporation of environmental science into the core high school curriculum.

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