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# Breaking from Tradition: Unfulfilled Promises of Block Scheduling in Science

*Using a national survey of more than 7,000 students from 128 different college introductory science courses, the authors compared students who experienced Block scheduling and Traditional scheduling in high school.*

With 66.7 % of high school graduates from the class of 2004 enrolled in colleges or universities (United States Department of Labor, July 2005), the importance of high school as a means to prepare students for a successful college experience is evident. Educators and administrators strive to find a schedule that allows for greater retention, provides for adequate content coverage, and produces high academic achievement across all subject areas. Prisoners of Time and the No Child Left Behind initiative focused attention on educational topics like the intensity of class time and the restructuring of school days (NECTL, 1994). The National Science Education Standards (Teaching Standard D) state that “Teachers must: ...Structure the time available so that students are able to engage in extended investigations” (NRC, 1996, p. 43). Having these goals in mind, many schools have shifted from Traditional scheduling systems to Block scheduling. In 1996 Rettig and Canady estimated that approximately 50% of American secondary schools were on some form of Block scheduling.

Much of the existing literature views the Block vs. Traditional

scheduling issue as an “either/or” debate, with voices on both sides of the scheduling divide (Canady & Rettig, 1995; Lindsay, 2000). Kienholz, Segall, and Yellin (2003) commented that Block scheduling allowed students to learn material at a “more relaxed, less frenetic pace” (p. 64) and that it enhanced the “environment for learning for both teacher and students” (p. 65). The extended class periods and

**Although Block scheduling reduces the amount of transition time between classes, it often reduces the total class time.**

modified scheduling frameworks necessitate a change in instructional practice as teachers shift away from traditional 50 minute classes. Some argue that the Block format increases scheduling flexibility, and is more conducive to team teaching, multidisciplinary classes, labs, and fieldwork (Center for Education Reform, 1996). Queen (2000) discussed a number of methodologies including the use of case method, synectics, and concept

attainment as well-suited to use within a Block schedule. Day, Ivanov, and Binkley (1996) reported the benefits of increased attendance, decreased failure rate, and an improved quality of instruction that came as a result of switching to a Block schedule. In terms of using the extended class period for science instruction, many articles have been published in science education journals focusing on creative lesson plans and time usage within a Block schedule (e.g. Barnes, Straton & Ukena, 1996; Bohince, 1996; Cooper, 1996; Craven, 2001; Day et al, 1996; Frank, 2002; Rapp, 1997).

On the opposite side of the scheduling debate, other studies reported that there was no evidence Block scheduling led to meaningful teaching innovations that resulted in higher student achievement (Center for Education Reform, 1996). In many cases, longer class periods meet fewer times per week, and the overall result is less total class time (Louden & Hounshell, 1998). The existing literature often cited continued use of instructional practices better suited for Traditional schedules and disuse of instructional practices better suited to Block-type schedules as reasons why Block

scheduling plans have not produced improvement in student achievement (Hackmann & Schmitt, 1997). Other important issues presented in the literature involved variations in the frequency of particular teaching formats used in different scheduling plans, and whether or not Block students were better prepared for future academic achievement than their peers in Traditional schedules (Knight, DeLeon, & Smith, 1999; Lawrence & McPherson, 2000).

**Overall, the results of the study indicated the students felt that individual teachers played a much greater role in their preparation (positively or negatively) than did the scheduling format.**

In a study focusing on science courses taught at a high school using Traditional, Block, and Hybrid scheduling, Veal (2000) discovered that there were benefits and drawbacks to each of the scheduling models. He found that while teachers reported some of the benefits addressed in the research literature on Block scheduling, they also reported challenges and tradeoffs when attempting to improve classroom practice. He reported that classes meeting on a Block schedule had 22 % less in-class time than those in the Traditional schedule. This reduced class time led to an increased pace of instruction in the Block classes and caused frequent use of lectures to cover material in a more efficient manner. These results beg the question of how this quickened pace affects students of varied ability levels.

Only a few large-scale studies have published research regarding the effects of scheduling format. Rice, Croninger, and Roellke (2002) presented evidence from an analysis of the National Education Longitudinal Study: 1988 (NELS:1988) data. They looked at the effect of block scheduling on math achievement and found that students taking part in Block scheduled courses performed below those in traditional classes. Jenkins, Queen, and Algozzine (2002) conducted a study involving 2,167 high school teachers in North Carolina. The authors concluded that the teachers in their survey did not use different instructional methods based on whether they were in Traditional or Block schedules. Nichols (2005) completed a longitudinal study focusing on English and Language Arts in schools within a single district that were changing over from Traditional scheduling to a Block format. The author reported only a slight overall increase for student achievement after conversion of these schools to a Block schedule. The largest study, conducted by Deuel (1999), investigated the implementation of a Block schedule at schools in an urban school district collecting data before and after the change. Deuel concluded that student achievement increased with the introduction of Block scheduling; however, the author noted that there were not any differences between the percentages of students passing science courses from either schedule format. Overall, these large-scale studies did not find convincing evidence that a change to Block scheduling leads to greater understanding or achievement by students.

None of the studies mentioned assessed outcomes of participation in a Block schedule over an extended

**Any school official looking to implement a scheduling change is faced with a literature base that is polarized.**

period of time. Salvaterra, Lare, Gnall, and Adams (1999) performed a qualitative study investigating perceptions regarding preparation for college math, science and foreign language of students who had studied in high schools using Block scheduling. Overall, the results of the study indicated the students felt that individual teachers played a much greater role in their preparation (positively or negatively) than did the scheduling format.

Zepeda and Mayers (2006) conducted a literature review of 58 empirically-based research articles involving Block scheduling. The authors found that overall, perceptions of Block scheduling were positive amongst the majority of studies they reviewed, but that the effect of a Block schedule on student achievement was mixed, with nearly equal numbers of reports of positive and negative effects. They concluded that additional longitudinal studies were needed and the authors found no studies looking at the effect that high school scheduling format had on college performance.

Any school official looking to implement a scheduling change is faced with a literature base that is polarized. Many of the articles on either side of the scheduling schism comment on a few of the benefits and drawbacks to each approach, but few of the research articles deal specifically with the long term effects of Block scheduling in high school science courses. Provided this research base, we sought to address the following questions:

1) Do students who participated in a Block science class report instructional practices at frequencies different from their counterparts in Traditional classes?

2) Controlling for secondary science achievement and differences in backgrounds, is introductory college science performance associated with students' reported participation in high school scheduling plans? Are the relationships observed between scheduling plans and instructional practice associated with introductory college science performance?

The use of a large sample in this study provided an opportunity to look at students with a wide range of backgrounds and to see if, and how, their high school scheduling framework affected performance in introductory college science.

### Methods

Many high school science teachers consider preparation for college science as a major objective in their courses (Hoffer, Quinn, & Suter, 1996). With this idea in mind, Factors Influencing College Science Success (Project FICSS) collected data from college students that included surveys and introductory college science grades (Sadler & Tai, 2001). Project FICSS collected survey data from students in 128 different first semester introductory college biology, chemistry, and physics courses. These courses were taught at 55 four-year colleges and universities (36 public and 19 private) in 33 states during the fall semesters of 2002 and 2003. The student enrollments at these institutions ranged from small liberal arts colleges to large state universities and

included historically black colleges and universities, and women's colleges. Faculty were asked to participate in the survey, and 29 biology departments, 31 chemistry departments, and 37 physics departments agreed. The sample totals were: 2,754 biology surveys, 3,521 chemistry surveys, and 1,903 physics surveys.

The format most likely encountered by introductory science students is a large lecture-based class, with smaller recitation/tutorial sections, and a separate laboratory session; therefore, this is the only course type included in this study. The surveys were administered during class meetings and professors entered the students' final course grades on the surveys before returning them to the researchers.

### The frequencies of teaching methods reported by students in Traditional and both Block scheduling plans are strikingly similar.

Three different scheduling plans were included in this analysis: traditional scheduling plans, A/B Block plans, and 4:4 Block plans. Traditional scheduling plans range from six to eight periods a day for an entire year with class time spanning from 45 to 55 minutes per period. One of the most common Block scheduling plans is the 4:4 Block. This plan involves four classes that meet for 75 to 90 minutes each period every day for half a year. Another of the Block options is A/B Block scheduling, which is three to four classes that meet every other day for an entire year. On an A/B Block plan, class times can range from 75 to 90 minutes. (Canady & Rettig, 1995)

For ease of comparison, other hybrid schedules that were less-prominent were excluded from this analysis.

### Results and Discussion

From the larger FICSS survey, a number of questions were selected for this analysis based on the students' backgrounds, high school experiences, and test scores. First, we present descriptive statistics for the sample. Classified by scheduling type, 4,160 respondents reported participating in traditional scheduling plans, 1,672 reported 4:4 Block plans, and 1,513 respondents reported A/B Block plans while in high school. Because we were looking at the effects of high school scheduling plans, it's important to comment on the geographic distribution of the students completing surveys based on hometown rather than college location. The sample included students from all 50 states, Washington D.C., and Puerto Rico, with 27 states each having 50 or more respondents.

To answer the first research question, we looked for variations in teaching methods across different scheduling plans. For this analysis, a comparison was made between the following measures of instructional methodologies in high school science: 1) number of labs per month; 2) number of demonstrations per week; 3) frequency of lectures, 4) whole class discussions, 5) small group activities, 6) individual work, and 7) peer tutoring; and 8) class time spent on standardized exam preparation. The instructional practices were compared for frequency of usage under each type of scheduling plan and are presented in Table 1.

The frequencies of teaching methods reported by students in Traditional and both Block scheduling plans are strikingly similar. Although there are

slight variations across the plans, it appears that no one scheduling plan stands out as a leader for use of these pedagogical methods. It must be noted that the frequency figures for A/B Block might be confounded because the survey choices of 2-3 times per week and Everyday can be seen as equivalent in that schedule.

**One common criticism of science teachers in Block scheduling plans was that they were not using instructional methods that would take best advantage of the extended class times.**

The second research question investigated the existence of a connection between high school scheduling plans and college performance while accounting for differences in student backgrounds and academic achievement. The question also called for analyses regarding interactive associations between scheduling plans and instructional practices. We chose to use multiple linear regression for this analysis. For the purposes of interpretation, we graphed the results in Figure 1 and 2.

Figure 1 compares differences in predicted college grades for prototypical students with a range of high school science grades across the three scheduling plans. For Traditional and 4:4 Block plans, the findings show similar trends, with 4:4 Block plan participants associated with grades incrementally (-0.81) lower than Traditional plan students. Interestingly, an interaction exists for students who experienced A/B Block scheduling in high school. Higher achieving A/B Block students

appear to be associated with slightly higher college science grades than students in all other schedule plans; however, lower achieving students were predicted to earn grades lower than their peers from Traditional and 4:4 Block plans. No more than a three-point difference separates the predicted

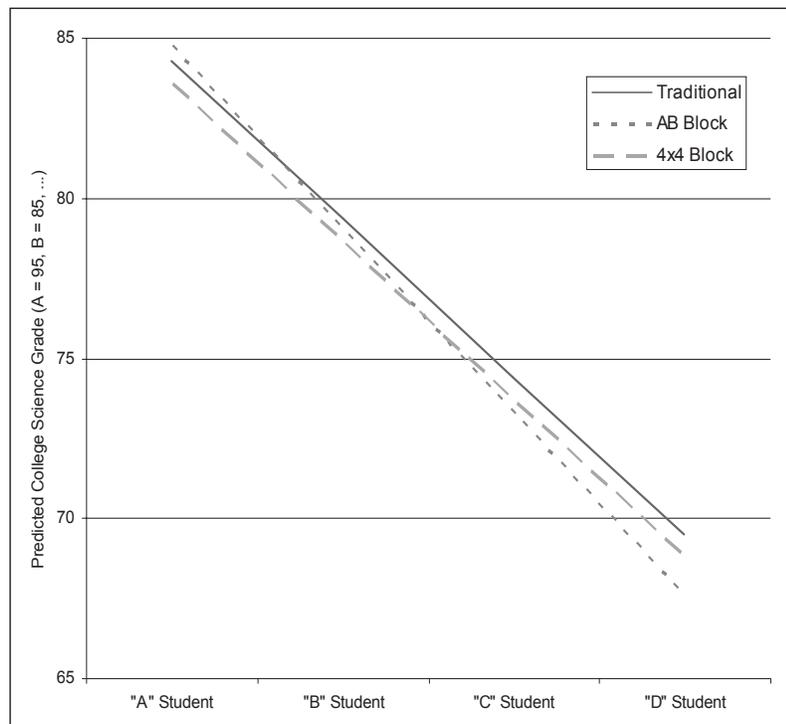
college science grades among the three scheduling plans within each level of science achievement. In other words, the predicted score for a prototypical “A” student in any plan is within 3 points of all the other predicted scores for that student, with the largest difference being only 2.30 points between

**Table 1:** Pedagogical Frequency by High School Scheduling Plan

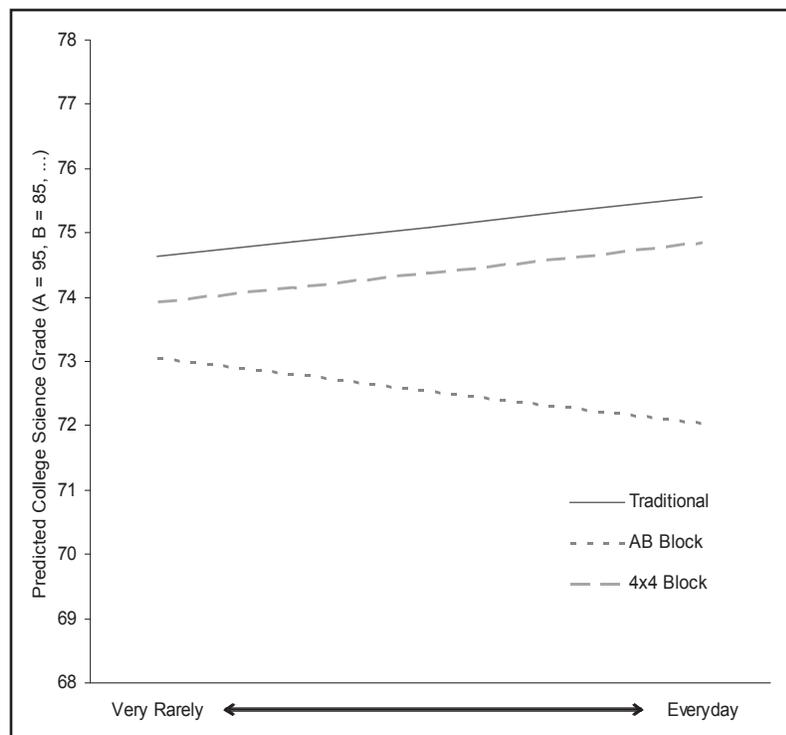
Pedagogical Method	Frequency of Use	Scheduling Plan		
		Traditional <sup>a</sup>	A/B Block <sup>b</sup>	4:4 Block <sup>c</sup>
# of Labs/Month	No Labs/Month	8%	7%	11%
	1 Lab/Month	20%	19%	16%
	2 Labs/Month	25%	25%	23%
	3 Labs/Month	16%	19%	19%
	4 Labs/Month	19%	19%	19%
	5 or More Labs/Month	11%	11%	12%
# of Demonstrations/Week	None	11%	10%	10%
	1 Demo/Week	37%	38%	34%
	2 Demos/Week	24%	30%	26%
	3 Demos/Week	17%	16%	18%
	4 Demos/Week	5%	3%	5%
	More than 4 Demos/Week	6%	4%	7%
Frequency of Lecture	Very Rarely/ Once per month	4%	4%	5%
	Once/Week	4%	7%	4%
	2-3 times/Week	19%	31%	19%
	Everyday	73%	58%	71%
Whole Class Discussions	Very Rarely/ Once per month	32%	35%	30%
	Once/Week	23%	25%	22%
	2-3 times/Week	24%	22%	26%
	Everyday	21%	17%	22%
Small Groups	Very Rarely/ Once per month	25%	24%	19%
	Once/Week	37%	40%	34%
	2-3 times/Week	28%	26%	34%
	Everyday	10%	11%	13%
Individual Work	Very Rarely/ Once per month	24%	28%	23%
	Once/Week	27%	31%	24%
	2-3 times/Week	31%	28%	31%
	Everyday	19%	14%	21%
Peer Tutoring	Very Rarely/ Once per month	74%	73%	74%
	Once/Week	13%	14%	12%
	2-3 times/Week	8%	9%	8%
	Everyday	6%	5%	6%
Exam Prep	Very Rarely/ Once per month	81%	80%	79%
	Once/Week	12%	12%	14%
	2-3 times/Week	5%	4%	5%
	Everyday	3%	3%	2%

<sup>a</sup> Traditional n<sub>average</sub> = 4,061. <sup>b</sup> A/B Block n<sub>average</sub> = 1,469. <sup>c</sup> 4:4 Block n<sub>average</sub> = 1,615.

**Figure 1:** Comparison of Predicted Final Introductory College Science Course Grade Across Three Scheduling Plans



**Figure 2:** Comparison of Predicted College Grades for Scheduling Plans Across Differing Levels of Peer Tutoring



plans. The existing minor variations in predicted college grades indicate that there are no meaningful differences in college performance between the students from different scheduling formats.

**A common criticism of Block scheduling is that teachers are not applying the methodologies that capitalize on its advantages.**

Our investigation also included an analysis of the interactions between the frequencies of the eight instructional methodologies previously listed and the three scheduling plans. One common criticism of science teachers in Block scheduling plans was that they were not using instructional methods that would take best advantage of the extended class times. The interaction analysis allowed us to assess whether differences in college performance exist among students who reported different frequencies of particular instructional methods, some of which have been cited as more advantageous to Block periods. Of the eight instructional practices analyzed, only one produced a statistically significant outcome, peer tutoring. Non-significance suggests that for the other seven instructional methodologies there did not appear to be an associated difference in college performance. The results for peer tutoring are graphed in Figure 2. They show that for Traditional and 4:4 scheduling plans, higher levels of peer tutoring were typically associated with higher levels of college performance, with Traditional students associated with the highest

college performance. A significant interaction appears for A/B Block and peer tutoring, predicting that A/B Block students reporting higher levels of peer tutoring did worse, a trend in opposition to the other plans.

In summary, this analysis does not find evidence for the purported advantages associated with Block scheduling plans in terms of college science performance. Students from

**Clearly, for science teachers, the allure of having more time to involve students in a laboratory assignment or other extended activities is appealing and the findings of this study do not disqualify extended class time as a benefit per se.**

all three scheduling plans reported similar frequencies for the selected pedagogical methods. Using introductory college science performance as an outcome measure, no real differences were demonstrated across the scheduling formats. Finally, only one of the selected pedagogical methods showed an interaction with college performance and the variations there were modest.

### Conclusions

The aim of this investigation is to present information that will allow teachers and administrators to make a more informed decision about the various scheduling plans and their performance in preparing students in secondary science. We studied whether students who participated in a Block science class in high school

reported instructional methodologies at frequencies different from their counterparts in Traditional science classes. The data indicate that there are no significant differences between the frequencies of methodologies reported across Traditional schedules and two common forms of Block scheduling. In fact, the scheduling plans were very similar in terms of frequency of instructional practices.

Next, we investigated the associations between student experiences in varied scheduling plans and the performance of these students in introductory college science courses. In terms of college science performance, the results showed no more than a 3 point difference among the scheduling plans. The differences amounted to only about one third of a letter grade, with Traditional plans associated with the highest level of college science performance. For A/B Block students, the results produced an interaction that suggested higher performing science students were advantaged in their college preparation, while lower performing students were disadvantaged. These findings may suggest that Block scheduling does not equally address the needs of all students.

A common criticism of Block scheduling is that teachers are not applying the methodologies that capitalize on its advantages. Our findings appear to support this contention. Therefore, we chose to perform an interaction analysis between scheduling plans and pedagogy. Our findings suggest that even in the cases where “Block-advantaged” methods are used at higher frequencies, student performance does not appear to differ much from Traditional scheduling plan outcomes.

There are several issues our study could not directly address and

therefore present limitations for our conclusions. One issue is that college science classes may be more similar to a Traditional format and therefore would benefit those students over those who experienced Block plans. However, college classes rarely meet every day; they commonly have extended laboratory and class periods; and they are typically structured to be completed in a semester or quarter; all characteristics that are more similar to a Block format. In fact, it may be argued that college course schedules are more similar in structure to some Block scheduling plans, than Traditional scheduling plans. Another concern may arise from the unbalanced research design, which is typical of large-scale survey studies. The students were selected to be representative of introductory college science students and not based on their high school scheduling plans. However, given that the sample included large numbers of students reporting Block scheduling plans (i.e. A/B,  $n = 1,513$ ; 4:4,  $n = 1,672$ ) these data still allow for a robust analysis.

Overall, these findings raise questions about the capacity of Block scheduling plans to deliver an instructional advantage. Clearly, for science teachers, the allure of having more time to involve students in a laboratory assignment or other extended activities is appealing and the findings of this study do not disqualify extended class time as a benefit per se. However, this analysis does offer evidence that implementation of Block scheduling plans does not result in stronger performance in introductory college science courses, even when coupled with instructional methods cited as best practices for extended class periods. Certainly, extending class time catalyzes a series of other

changes in schools. It may be that the ancillary changes necessary to accommodate longer class periods offset any advantage that extended periods offer. This study only analyzed Block plans as a whole. Further research is necessary to provide a more detailed picture of how the various characteristics of scheduling plans impact students' learning outcomes. But what is clear is that Block scheduling plans on the whole did not deliver on their claimed benefits.

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# Building a Leadership Network Supporting Science Education Reform in Rural East Alabama

*The authors argue that leadership networks when comprised of regional stakeholders including university faculty, school system administrators, and teacher leaders can begin to work together towards common reform goals.*

Many of us who are in science teacher education in rural and impoverished areas lament the lack of resources and support available for practicing a higher quality of science instruction in our regional schools (Harmon, Henderson, & Royster, 2003). While National Standards (National Research Council, 1996) call for teaching science through inquiry, most of our regional teachers do not have the hands-on resources or professional support needed to do so. What we teach and model in our science teacher education programs often gets 'washed out' upon entering our regional schools. Without support for inquiry, our science teachers are reliant on methods where content is disseminated through lectures and textbooks, including textbooks that can be more than five years old! To add insult to injury, these traditional approaches to teaching science are most detrimental to diverse populations of students who are steadily increasing in our schools (Lynch, 2000). Teaching through inquiry where students work together to seek scientific understanding through evidence meets the needs of all learners. This problem has not

**Without support for inquiry, our science teachers are reliant on methods where content is disseminated through lectures and textbooks, including textbooks that can be more than five years old!**

gone unnoticed, as many state and federal funding agencies have targeted underserved populations of students through various grant opportunities. However, over the years, these well-meaning efforts bring limited and temporary relief to the few schools that participate in them. Despite all the talk of what is needed for systemic reform, university faculty often continue to apply for science outreach grants in a 'hit-or-miss' fashion based on what opportunities are available. If successful, they will later gather together partners to discuss implementation to meet the grantor's requirements, and not the real long-term needs of science education reform (Hall & Hord, 2006). Yet, even with the best of intentions, grant-based

reform is elusive as big state and federal dollars for systemic reform in rural areas are limited. How can real change in science education begin to happen in such a harsh environment? How can we capitalize on the human resources and existing infrastructures in our large rural regions to make a real difference?

## Initiating Systemic Reform Efforts

Professional development experts in science education agree that meaningful and lasting reform requires three basic elements: (1) collaboration of all stakeholders, (2) ongoing professional development using research-based strategies that work, and (3) the availability of resources and materials for teaching science through inquiry (Loucks-Horsley, 2003). If reform is to occur in our regional schools and be sustainable, then these elements must be present. Our first step was to *develop a network of stakeholder support* as the vehicle for implementing a common vision of reform that we could all strongly share (Lasley, Matczynski, & Williams, 1992). Our initial stakeholders included higher educa-

tion faculty and administrators from education and science, K-12 teachers and administrators (including superintendents, principals, and curriculum coordinators). We needed to initiate meetings with all parties in order to reach consensus on shared expectations for reform. Many collaborative reform efforts fail because of diverse expectations for the collaboration and its work (Spector, Strong, & King, 1996). Networking and meeting to begin and support reform are low cost and vital to any successful long-term effort. Our first big decision was to discern who was best suited to initiate or broker this process.

### **Many collaborative reform efforts fail because of diverse expectations for the collaboration and its work.**

In rural East Alabama the two major universities, Auburn University and Tuskegee University, were best suited to initiate the building of the stakeholder network needed for systemic reform efforts in science education. Both land-grant institutions had historically garnered grants for science outreach programs in K-12 schools. Each had key leaders in science and education who spent much of their time working in outreach. Those of us in the College of Education at Auburn University initiated the conversation with the science faculty of the two institutions to create a new collaborative organization that could become both leadership and clearinghouse for reform efforts. Leadership was needed to develop and direct a common vision of science

education reform and help implement reform efforts in the region's school districts. We were keenly aware that successful partnerships treated all stakeholders with an equal voice but still required designated leaders who were responsible for making reform happen (Dallmer, 2004). Such a collaborative organization could both chart and direct professional development initiatives to meet our commonly held goals for reform. The decision to model this organization on similar successful efforts in math education in our region led to the name of TEAM-Science: Transforming East AlabaMa Science.<sup>1</sup> However, none of this would be possible without having the regional school systems as a partner in this process. How TEAM-Science was formed as a network of science education stakeholders and its early initiatives as a vehicle for 'doable' reform are discussed.

#### **Phase I: Building the Collaborative Network of Leaders**

To begin to develop the network of stakeholders, we began meeting with regional superintendents and district curriculum coordinators. We shared our intent to collaborate with all 15 regional school systems to help build the infrastructure needed to meet the goals of reform for our region. These initial goals included developing a network of science teacher leaders from each school district, initiating common professional development for these teachers, and working together to apply for systemic grant funding that met these goals. Application of the concept of *teacher leadership* empowered early teacher reformers

### **Leadership was needed to develop and direct a common vision of science education reform and help implement reform efforts in the region's school districts.**

to take leadership roles in changing science teaching in their districts. Our next goals were to garner support of regional school principals to develop school-based teacher practitioners (K-12) with the needed professional development to begin the process of reform at every school. Our approach to effective reform was always viewed as 'top-down' and 'bottom-up'. Without both administrative and teacher support any systemic reform would be doomed to failure (Loucks-Horsley et al., 2003). Our ultimate goal was the improvement of student motivation and achievement in science, reflected in the required '**No Child Left Behind**' legislation.

Forming the infrastructure for a meaningful higher education and K-12 partnership does require a limited amount of initial funding. Most of the fifteen rural school districts in our region operate on very limited resources, even foregoing textbook adoption cycles in order to use these funds for more immediate infrastructure needs. Local corporate partners could provide the initial needed funds, particularly if a relationship already exists. In these early networking efforts of TEAM-Science, the universities provided the limited funding needed for these meetings and the secretarial support to disseminate information. Auburn University's Regional Inservice Cen-

<sup>1</sup> The TEAM-Science initiative was seeded through internal university funding from Auburn University's Outreach Office and the Colleges of Education and Sciences and Mathematics.

ter was already set up as a vehicle for coordinating general teacher professional development and regional contacts. Most universities or regions have a similar organization already in place. School district leaders were more than happy to work with us in these efforts for the benefit of their teachers and students. Each district provided us with a list of possible teacher leaders at each grade level who could begin the grass-roots efforts for TEAM-Science.

**Forming the infrastructure for a meaningful higher education and K-12 partnership does require a limited amount of initial funding.**

## **Phase II: Using the Network to Tackle Immediate Needs**

Once teacher leaders were identified, the first agreed upon effort in professional development was to collectively operationalize the greater mission and goals of TEAM-Science. Mission and goal statements were crafted (See Figure 1). The first leadership project for teachers from the fifteen districts was an immediate need to create curriculum guides which met the state's new course of study. The development of curriculum guides (or frameworks) for planning and teaching was foundational for reform efforts and doable without external funding. The alignment of the state's new course of study standards with national standards and the new high stakes assessments would be the bedrock upon which inquiry-based

**Figure 1.** Transforming East AlabaMa-Science Mission, Beliefs, and Goals

### **Mission Statement**

The mission of TEAM-Science is to transform science education in the East Alabama region so that all students are empowered through scientific literacy to contribute responsibly to society.

### **Our Beliefs**

- We believe that science facilitates students' ability to think critically as they analyze and synthesize data in order to solve problems using a scientific approach.
- We believe that inquiry-based teaching is the best approach to developing scientifically literate students.
- We believe that students must take challenging, high quality science courses in order to meet their post-secondary education goals.
- We believe that curriculum alignment and high quality curriculum resources are essential for successful learning of science.
- We believe that science teachers must be supported through ongoing professional development and resources in order to successfully teach through inquiry.
- We believe science educators, school system administrators, scientists, elected officials, and the community should work together for the enhancement of science education.

### **Our Goals**

- Students will successfully communicate scientific understanding and solutions to scientific problems in written and oral form.
- Teachers will enter the profession with the content knowledge and abilities to implement instructional strategies and high quality curricula that support inquiry-based education.
- Students will be prepared to enroll in advanced level high school science classes. Teachers in East Alabama will have access to a curriculum aligned with state and national standards, accountability testing, and the appropriate text resources to support it.
- Teachers and science education stakeholders will participate and benefit from professional development that is ongoing and embedded in classroom practice.
- Higher education, local school systems, state education agencies, business partners and parents will work together to build collaborations that systemically support science education in East Alabama.

reform efforts would start. This same approach in developing a "standards-based curriculum of the highest quality" (Brady, 2002, p. 38) was also an

important step to improving student achievement in other similar reform efforts. Aligning 'what was taught' in science at each grade level could

have a substantial impact on science achievement scores similar to mathematics (Schmidt, Houang, & Cogan, 2002). It also would form the basis on which professional development on 'how to teach' through inquiry would occur.

**One of the most important parts of educational collaborations that works is the professional personal relationships and trust that are developed through working together towards a common vision of reform.**

Working over the course of one summer, teacher leaders crafted curriculum guides that would align what was taught in science at each grade level and across grade levels. Within these curricular frameworks other initiatives flowed including the evaluation and selection of appropriate textbooks supporting the frameworks; textbooks that were often the only purchased resource for teachers (See TEAM-Science web site: <http://teamscience.auburn.edu>). Guided discussion and reflection on effective teaching approaches and what was most important for student learning became a routine part of this process.

### **Phase III: Linking the Network to State Initiatives**

The initial TEAM-Science leadership, composed of higher education professors, district superintendents, district curriculum coordinators, and select teachers, soon began working on sustainability efforts for the collective vision of reform. Private and

public grant funding opportunities that met our long-term goals were discussed and sought. One opportunity in particular was the state's initiative to fund local centers that would provide kit-based inquiry science resources (STC™ and STC-MS™) and ongoing professional development for teachers in grades K-8. This initiative was already funded in many regions of the state with early successful results in improving student test scores in science (Alabama Math, Science, and Technology Initiative (AMSTI), 2006). Toward this endeavor, we used our collaborative network of stakeholders to disseminate information about this program and how we could collectively work to obtain it for our region.

In an effort to better position ourselves for such funding we began a summer professional development effort with the middle grades science teachers in our region on how to use these kit materials. We recruited these teachers through the TEAM-Science network. The response to our request was overwhelming with as many as 40 middle school teachers from all fifteen school districts volunteering to participate. Our original teacher leader network only totaled approximately 50 teachers, K-12. Although university personnel set up this development, teacher leaders in the original network actually led the training and professional development on these materials. In a fairly short timeframe of 18 months, we began to reap the benefits of a functioning network of stakeholders and leadership where regional teachers and administrators were an integral part. This ongoing work did not go unnoticed by our state, and through our lobbying efforts our region was recently designated a new

site to begin receiving limited funding to begin the AMSTI initiative in the middle grades (grades 4-8).

### **Early Fruits of a Collaborative Leadership Network**

One of the most important parts of educational collaborations that works is the professional personal relationships and trust that are developed through working together towards a common vision of reform (Darling-Hammond, 1994; Spector, Strong, & King, 1996). By including all stakeholders in our early reform efforts, we have been able to sustain a school system-university network working towards systemic change in our region's science classrooms. Teacher leaders are a vital part of this network if reform is to eventually occur in each teacher's classroom. We

**Teacher leaders are a vital part of this network if reform is to eventually occur in each teacher's classroom.**

have already seen the development of inter-school networking where leaders in each school system reach out to each other in TEAM-Science reform efforts in the classroom. As time passes, we are confident that our continued work through the TEAM-Science collaboration will reap further benefits, as teachers already in the collaboration mentor their colleagues in effective, inquiry-based practices, and they in turn become new teacher leaders. In addition, pre-service teachers in formation at both universities will be able

to work with these same teacher leaders in the classroom as they jointly enact inquiry practice with new resources provided through the AMSTI program. The universities' role will continue to provide leadership in helping coordinate these efforts through sustainable professional development meeting our shared vision for the improvement of science education in our region. We still have a long way to go in systemically leading this work as we continue to hear from university colleagues of their varied and many outreach efforts in science education that are not part of the mission of TEAM-Science. Coordinating all our efforts in this systemic endeavor will be required for a greater collective impact on schools and lasting reform. We have at least begun this process. The seeds of inquiry-based science instruction have been planted into rich, fertile ground. With continued care and attention, we look forward to a bountiful harvest of student achievement in the future.

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# What Results Indicate Concerning the Successes with STS Instruction

*This study investigates the effectiveness of the Iowa Chautauqua Professional Development Program.*

The National Science Education Standards emphasize a goal that all students should achieve scientific literacy which is defined as the knowledge and understanding of scientific concepts needed in daily living (NRC, 1996). The National Science Teachers Association has declared that a scientifically literate person is one who can ask and determine answers to questions derived from curiosity about everyday life experiences (NSTA, 1996).

Several NSTA reports and position papers illustrate the meaning and importance of scientific literacy as a way of improving K-12 science (NSTA, 1991; Harms & Yager, 1981). Scientific literacy enables people to not only use scientific principles and processes in making personal decisions but also to participate in discussions of scientific issues that affect society. Scientific literacy increases many skills that people use in everyday life, like being able to solve problems creatively, thinking critically, working cooperatively in teams, and using technology effectively. An understanding of scientific knowledge and processes contributes in essential ways to attaining these skills. The economic productivity of society is related to the scientific and technological skills of the people which is another reason

for encouraging a more scientifically literate citizenry.

Achieving the goal of scientific literacy for all will take time. The National Science Education Standards call for dramatic changes in what students are taught, how student performances are assessed, and how teachers are educated and remain current (NRC, 1996). Understanding the relationship among science, technology, and society is essential

for achieving basic science literacy. Students, the next generation, need to be able to analyze evidence, to understand the relevance of science-based issues in their everyday lives, and to understand that scientific endeavors are governed by social values (NRC, 1996; AAAS, 1990). The National Science Standards urge specific changes in the way teachers teach, the way they continue to grow as teachers, the way content is defined, how learning

**Table 1:** Changing Emphases for Teaching Science as Advocated in the NSES

Less Emphasis on :	More Emphasis on:
Treating all students alike and responding to the group as a whole	Understanding and responding to individual student's interests, strengths, experiences, and needs
Rigidly following curriculum	Selecting and adapting curriculum
Focusing on student acquisition of information	Focusing on student understanding and use of scientific knowledge, ideas, and inquiry processes
Presenting scientific knowledge through lecture, text, and demonstration	Guiding students in active and extended scientific inquiry
Asking for recitation of acquired knowledge	Providing opportunities for scientific discussion and debate among students
Testing students for factual information at the end of the unit or chapter	Continuously assessing student understanding
Maintaining responsibility and authority	Sharing responsibility for learning with students
Supporting competition	Supporting a classroom community with cooperation, shared responsibility, and respect
Working alone	Working with other teachers to enhance the science program

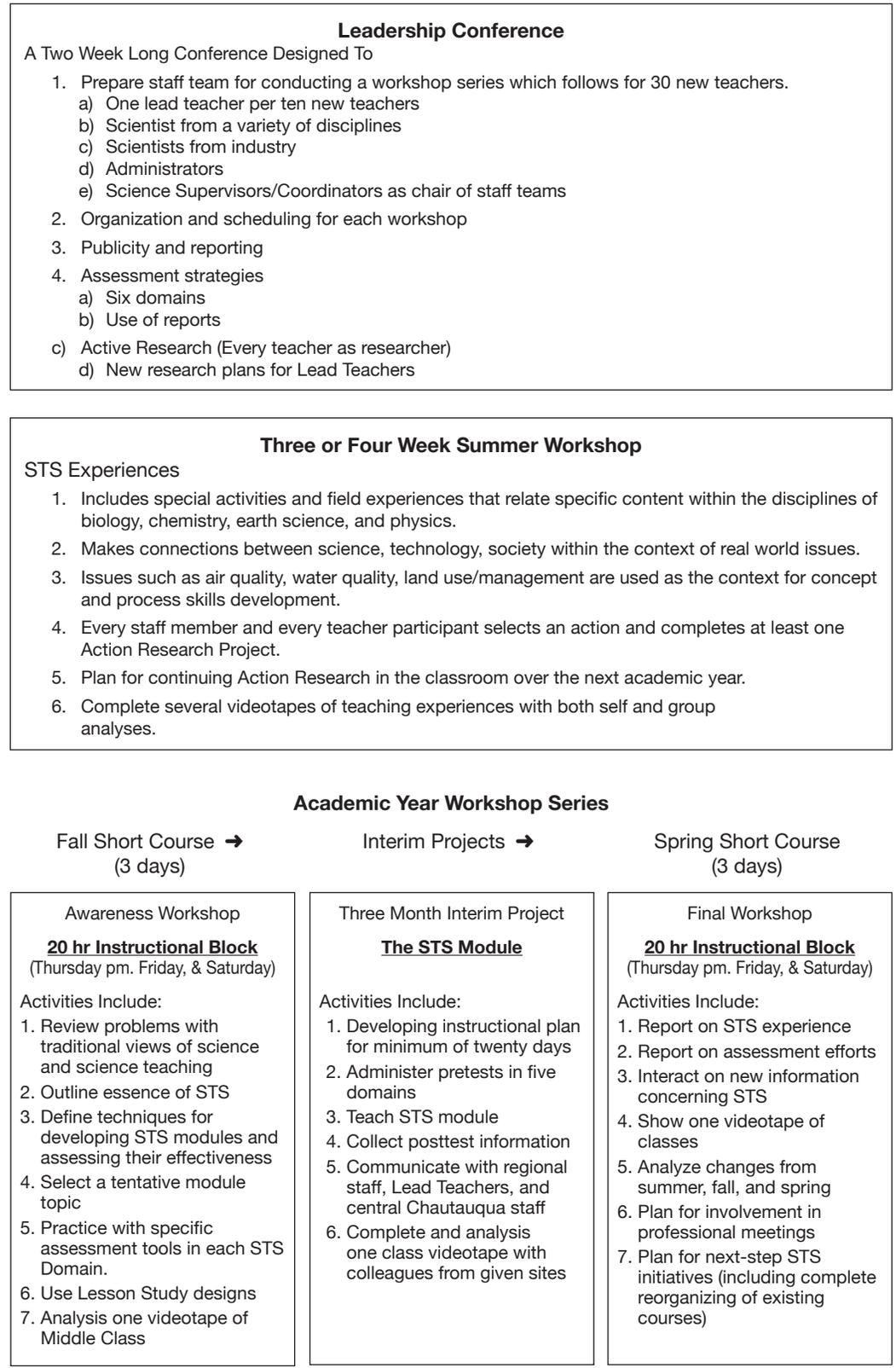
\* could also be assumed to apply to students working alone vs in groups (NRC, 1996, p52)

is assessed, how science programs are built, and how the entire school system supports the needed reforms. But the needed changes in teachers are seen as a first requisite for reforms to succeed. Table 1 is a summary of the changes in science teaching envisioned by the Standards. These recommended changes were the least controversial as the standards were developed but remain a major challenge to achieve.

The Iowa Chautauqua Program was developed in 1983 with support from National Science Foundation (NSF) which awarded the National Science Teachers Association (NSTA) a major grant to study an inexpensive in-service model for stimulating reform in K-12 science classrooms. Iowa was one of the six Chautauqua sites which were modeled after a program for teachers from small colleges and operated by the American Association for the Advancement of Science. In Iowa this new Chautauqua effort focused upon STS materials and teaching strategies with primary attention directed to teachers in grades 4 through 9. The program began with 30 teachers enrolled in a program in one center and increased annually to number 230 teachers enrolled in five centers across the state. The program was expanded with funds from various of private industries and Title

**Figure 1:**

**Iowa Chautauqua Model**



II projects. Over 15,000 teachers have been enrolled during last two decades. The focus and unique feature was the Science-Technology-Society (STS) teaching approach as reform in science education. Figure 1 illustrates the features of the Iowa Chautauqua model.

The National Science Teachers Association (NSTA) defines Science- Technology-Society (STS) as the teaching and learning of science in the context of human experiences (NSTA, 1991). STS means focusing upon current issues and attempts at their resolution as the best way of preparing students for current and future citizenship roles. This means identifying local, regional, national, and international problems with students, planning for individual and group activities which address them, and moving to actions designed to resolve the issues investigated. The emphasis is on responsible decision-making in the real world of the student. STS provides a means for achieving scientific and technological literacy for all. The emphasis is on responsible decision-making in the real world of the student where science and technology are components. To be considered STS, the reforms envisioned and characterized include ten basic features that are central to those in the NSTA policy statement regarding STS. These include:

1. student identification of problems with local interest and impact;
2. the use of local resources (human and material) to locate information that can be used in problem resolution;
3. the active involvement of students in seeking information that can be applied to solve real- life problems;

### **A major component of the Iowa Chautauqua Program is assessment, just as it is in science itself.**

4. the extension of learning beyond the class period, the classroom, the school;
5. a focus upon the impact of science and technology on each individual student;
6. a view that science content is not something that exists merely for students to master for tests;
7. a de-emphasis upon process skills *per se* just because they represent glamorized skills used by practicing scientists;
8. an emphasis upon career awareness—especially careers related to science and technology;
9. opportunities for students to perform in citizenship roles as they attempt to resolve issues they have identified;
10. identification of ways that science and technology are likely to impact the future. (NSTA 1990; Bybee and Yager 1982; Blunck and Yager 1990; Yager 1992)

A major component of the Iowa Chautauqua Program is assessment, just as it is in science itself. There must be evidence that others can see before explanations are accepted by the community of experts (scientists). One aspect of the assessment efforts of the Chautauqua program focuses on the effect of STS on students. Six domains of science education proposed by Yager and McCormack (1989) are used to assess student growth over a period of time of at least one full calendar year with the use of a variety of assessment

instruments in each domain. These assessments arise from published instruments as well as from instruments and techniques devised by teachers as a means of collecting evidence of the validity and successes their instruction has achieved. Frequently, pre-assessments are involved as a part of the study successes, especially related to the concept and attitude domains. The decision concerning the other domains was left the preferred of the twelve teachers involved.

The first domain is the concept domain. Science aims to categorize the observable universe into manageable units for study and to describe physical and biological relationships. Ultimately, science aims to provide reasonable explanations for observed relationships. Part of any science instruction may involve learning by students in terms of the information developed over time through scientific pursuits of the past. The concept domain includes: facts, concepts, laws (principles), and existing hypotheses and theories being used by scientists. This vast amount of information is usually classified into such manageable topics as: matter, energy, motion, animal behavior, and plant development (Enger & Yager, 2001; Myers, 1996).

The second domain is processes. Scientists use certain identifiable processes (skills) in their inquiry efforts. Being familiar with these processes concerning how scientists think and work is an important part of learning science. Some processes of science are: observing and describing, classifying and organizing, measuring and charting, communicating and understanding communications of others, predicting and inferring, hypothesizing, hypothesis testing, identifying and controlling variables, interpreting data, and constructing instruments,

simple devices, and physical models (Enger & Yager, 2001; Wilson & Livingston, 1996).

The third domain is creativity. Most science programs view science instruction as something to be done to students to help them learn a given body of information. Little formal attention has been given in science programs to development of students' imaginations and creative thinking. Little has been done to encourage curiosity, questioning, explaining, and testing – all the basic ingredients of science. Some of the specific human abilities important in this domain are: visualizing; producing mental images, combining objects and ideas in new ways, producing alternative or unusual uses for objects, solving problems and puzzles, designing devices and machines, and producing unusual ideas. Much research and development has been done on developing students' abilities in this creative domain, but little of what has been learned about creativity has been purposely incorporated into science programs (Enger & Yager, 2001; Penick, 1996).

The fourth domain is attitude. In these times of increasingly complex social and political institutions, environmental and energy problems, and general worry about the future, scientific content, processes, and even attention to imagination are not sufficient parameters for science programs. Human feelings, values, and decision-making skills need to be addressed. This domain includes: developing positive attitudes toward science in general including both science in school and science teachers, developing positive attitudes toward oneself (an "I can do it" attitude), exploring human emotions, developing sensitivity to and respect for the feelings of other people, expressing

personal feelings in constructive ways, making decisions about personal values, and making decisions about social and environmental issues (Enger & Yager, 2001; McComas, 1996).



**Many in education are looking to technology (the application of science concepts) or the applications domain as a starting point for initiating reform in the K-12 classroom.**

The fifth domain is applications and connections. A successful program must include information, skills, and attitudes that can be transferred and used in students' everyday lives. Many would question if real learning had occurred unless there is evidence of the use of it in new contexts. Also, many now argue against a divorce between "pure" science from technology. The National Standards include technology as one of eight facets of content standards for school science and thereby note the interdependence of the two disciplines (NRC, 1996). Students need to become sensitized to these experiences they encounter which reflect ideas they have learned in school science. Some dimensions of this domains are: seeing instances of scientific concepts in everyday life experiences, applying learned science concepts and skills to everyday technological problems, understanding scientific and technological principles involved in household technological devices, using scientific processes in solving problems that occur in everyday life, understanding and evaluating mass media reports of scientific developments, making decisions related to

personal health and life-style based on knowledge of scientific concepts rather than on "hear-say" or emotions, and integrating science with other subjects. For many, the applications of science can provide the entry to the knowledge and process domains. For others (probably a definite minority) applications represent moves to the use of the science known and developed over time. Many in education are looking to technology (the application of science concepts) or the applications domain as a starting point for initiating reform in the K-12 classroom (Enger & Yager, 2001; Varrella, 1996).

The sixth domain is world view. Science should portray the nature of the discipline – not just a study of the current views that comprise the current understanding of the various disciplines. Often scientists themselves are poor students of what they do, how they do it, and how their discipline changes (and has changed). Many, however, feel a primary justification for science in the general education of all students, kindergarten through college, is to portray the nature of science as a major intellectual pursuit of all humankind. Once again the National Standard includes the history and philosophy of science as one of the eight facets of science content for school science (NRC, 1996). This domain is concerned with: ways in which scientific knowledge is created, the nature of research processes; the meaning of basic concepts of scientific research (e.g., hypothesis, assumption, control, replication), the history of scientific ideas; the ways scientists work, and the interactions among science and the economy, politics, history, sociology, and philosophy (Enger & Yager, 2001; Kellerman & Liu, 1996).

Experienced STS teachers have always been major parts of the instruc-

tional team for the Iowa Chautauqua Program. These are the teachers who were excited with their own STS initiatives, who spend most of their time in their courses with STS instruction, who were anxious to complete assessment projects, and who were willing to be a part of the annual leadership conferences as a new Chautauqua cycle was planned.

As one might expect, some of the most exciting assessment results are provided by the most successful STS teachers. As assessment instruments were developed, twelve of the most successful teachers with STS volunteered to help. Many assessment strategies and instruments developed have been published as new ideas were developed and publicized in the workshop series. Some of them were adaptations of other published instruments. Most of these have now been published for all to use (Enger & Yager, 2001).

### Methods

This study involved twelve teachers who agreed to share assessment information from their students regarding the six domains previously described. One section for each teacher utilized traditional instructional methods while a second section utilized STS teaching strategies. Instruments used were included in annual publications of assessment tools. The same instruments were used with students in both sections. The teachers selected similar class sections and times of the day for the section experiencing the STS approach and the one relying almost fully on a textbook. Students in the two sections were almost identical in terms of gender, socio-economic levels, class size, student grade point averages, educational and career aspirations, extra-curricular activities,

## The ability of students to utilize information and processes in new situations is greater for STS students than it is for non-STS students.

previous success with science courses, variations with interest in other aspects of the school program. The administrative and counseling staff in each of the twelve schools reported that they could find no significant differences between the make-up of the students in two sections who were selected for the study. In most instances the teachers involved planned similar instruction in the other 2 or 3 sections which comprised their teaching load. The instruments were given near the end of the school year. A comparison of learning results between STS and non-STS sections were noted and recorded and represent the results of this report. Although not collected in all domains and by all teachers, pre-assessments were collected, especially those concerned with concept mastery and student attitude.

### Results of the Study

All twelve teacher leaders taught in grades 6 through 9. They were interested in the degree to which concepts were mastered as well as student ability to use them in new contexts. Some were especially interested in stimulating and measuring growth with respect to process skills; others were more interested in the development of creativity skills, and encouraging changes in student attitudes.

When teachers express interest in such areas and expect students to grow, more positive results emerge regarding all domains. Teacher owner-

ship and their expectations of student achievement may be more important than a specific STS format and/or the exclusive focus on more typical textbook topics. Nonetheless, the Iowa Chautauqua program and the twelve teachers agreeing to collect the evidence for the study obtained the following results. Tables 2 through 7 show the comparisons of results regarding student successes in STS and typical science classes for a variety of aspects for each of the six assessment domains. This means reporting the percentage of all students from all 12 sections who report or demonstrate certain abilities or attitudes.

The data from Table 2 indicate percentages of students who recognize the meaning of selected basic concepts. None of the differences between treatments is significant between STS and non-STS science classes. STS students perform just as well regarding concept mastery for the sample concepts used as did students enrolled in more typical courses which emphasize such mastery as the main instructional goal.

**Table 2:** Percentages of Students Recognizing the Meaning of Eight Basic Science Concepts

Concepts	STS	Traditional
Volume	65	75
Organism	71	67
Motion	62	65
Energy	45	54
Molecule	48	54
Cell	43	46
Enzyme	31	24
Fossil	48	54

Table 3 indicates the comparisons of students demonstrating effective use of specific science process skills for students in both sections. STS students

outperform non-STS students in their mastery of fourteen process skills.

**Table 3:** Percentages of Students who Can Demonstrate their Abilities to Use Fourteen Process Skills

	Skill	STS	Traditional
1	Using Space/Time Relations	51	12
2	Observing	84	30
3	Classifying	87	26
4	Interpreting Data	88	31
5	Inferring	74	19
6	Communicating	88	38
7	Controlling Variables	63	21
8	Drawing Conclusions	82	24
9	Predicting	71	19
10	Using Numbers	89	40
11	Measuring	91	33
12	Comparing & Differentiating	84	31
13	Hypothesizing	63	18
14	Selecting Best Experiment Procedure	52	24

In Table 4 the differences in use of various creativity skills are indicated between students enrolled in the STS and typical science classrooms. The data indicate the percentage of students demonstrating specific creativity skills. Student creativity, as observed in terms of quantity of questions gen-

**Table 4:** Percentages of Students Demonstrating Their Abilities to Use Various Creative Thinking Skills

		STS	Traditional
1	Devise Unique Tests	94	6
2	An unique Explanations	87	13
3	A distinguish Between Cause and Effect	75	25
4	Prepare Unique Questions	83	17
5	Number of Student Questions Raised Per Class Period	67	33

erated, predictions of certain consequences, and ideas about possible causes for given phenomena increased more for students in STS sections. Student creativity in terms of quality/unique questions, prediction of consequences, and ideas about possible causes are much greater for STS students than for students in non-STS sections.

The data in Table 5 indicate the percentages of students enrolled in all twelve sections who reported given attitudes. Results show that attitudes are more positive for STS students than they are for non-STS students. The results were similar regarding science as a field, science courses, relative usefulness of science, and effectiveness of science teaching.

The results included in Table 6 report on the percentage of students who demonstrate that they can apply information to completely new situations. The ability of students to utilize information and processes in new situations is greater for STS students than it is for non-STS students. The “application” of the concepts and skills encountered in the classrooms were encouraged for all students with the teachers reacting to the applications proposed and the relative differences in the complexity of the various proposed applications and use. Often this became a next assessment and

**Table 5:** Percentages of Students with More Positive Attitudes Toward Classes, and Science Teachers

		STS	Traditional
1	Science is least favorite course	6	19
2	Science is favorite course	22	11
3	Information from science classes is useful	81	69
4	Science teachers admit to not knowing	74	22
5	Science teachers like my questions	88	48
6	Science teachers help me make decisions	63	31
7	Science classes make me curious	71	24
8	Science classes are boring	14	31
9	Science classes are fun	81	40

**Table 6:** Percentages of Students in STS and Non-STS Sections Concerning Their Abilities to Apply Information and Skills

		STS	Traditional
1	Use Information in new settings	81	25
2	Relate Phenomena in new settings	66	18
3	Identify questions used for discussions	83	17
4	Choose information to solve problems	91	26
5	Choose appropriate action based on new information	89	35

resulted in active student discussions of the various applications proposed by other students.

The results from Table 7 indicate that the STS approach produces students who better understand the nature and history of science. Students in STS classrooms improved in their understanding of the nature and history of science more so than did students in non-STS classrooms.

**Table 7:** Percentages of Students Concerning Their Understanding of the Nature and History of Science

Samples Features of Science	STS	Traditional
Questioning, Exploring & Testing	46	19
Tentativeness of Science Constructs	65	12
Nature of Science Theories	33	24
Science Changes over Time	44	16
Creative and Imaginative Nature of Science	80	8.3
Social and Cultural Features	20	12
Over-all Scores	66	22

### Discussion

The data from this study certainly indicate the power of STS instruction and what happens when the organization of the content for instruction arises from local issues, current examples, and personally relevant situations. Of course the data reported are dependent on the information provided by the assessments in each of the assessment domains. Further, the effectiveness of the twelve teachers in their use of the teaching strategies could produce another variable. The results obtained merely report what happened with students in two sections taught by the twelve experienced STS teachers. This could provide unfair advantages for students in the STS sections since the teachers by definition preferred this teaching approach.

The data also help define factors useful in defining student achievement. Too often a single test score is used as the primary indicator that students have learned and allows a relative rating resulting from performance on one examination. Too often traditional achievement is simplistically defined by students checking the most accurate definitions for major terms (often italicized in textbooks).

The results indicate the importance of specific teaching strategies in developing the differences reported in the six tables. Significance would be added if more teachers were to report similar data and if additional instruments and different procedures were used for data collection. The teachers involved with this study were special teachers who were helping others move to STS teaching approaches. It is important to mention that the teachers involved with the study helped develop and evaluate the research instruments. Some were more involved and interested in some of the domains than were others. Several were actively involved with helping shape the National Standards; many assisted new teachers to move to STS approaches. Many used the differences in their own teaching in two sections (video taping) to illustrate the approach for new teachers. Some became involved in staff development efforts with pre-service programs. Of special interest is the degree that desired teaching practices correspond to the visions for change needed in teaching that are central to the National Science Education Standards as included as Table 1 (NRC, 1996, p.52).

The development of more positive attitudes concerning science, science teachers, and science careers for students in STS sections is extremely exciting. Most results reported since 1978 as part of the National Assessment of Educational Progress (NAEP), which first included assessment of students' attitudes, have indicated a decline in positive attitudes each year that students are enrolled in science classes K through 12. It is said that so few are concerned that student

attitudes become more negative the longer students study science, including college. One of key benefits of STS is that the classrooms become more student-centered and the study more related to daily life. Perhaps this explains the increase in more positive attitudes.

The results concerning student ability to use the basic science concepts and skills on their own in completely new situations is of utmost importance. This is possibly the best evidence that real learning has occurred instead of the ability to remember and/or to repeat what textbooks and teachers say. The focus on student projects and real problems provides the way for many STS teachers to illustrate the importance of the concepts and processes that too often are taught directly with no apparent use and too often with no efforts to encourage students to find such uses. Again, the National Standards provide an important rationale for STS with the four goals that should frame school science. These include assuming that all students:

1. Experience the richness and excitement of knowing about and understanding the natural world;
2. Use appropriate scientific processes and principles in making personal decisions;
3. Engage intelligently in public discourse and debate about matters of scientific and technological concern; and
4. Increase their economic productivity through the use of the knowledge, understanding, and skills of the scientifically literate person in their careers (NRC, 1996, page 13).

The results reported in this paper illustrate how these goals can be more effectively met with an STS approach to instruction.

### Conclusions

More evidence and more ideas regarding student growth as a result of STS efforts in K-12 science classrooms are needed. Admittedly the results reported in this study are from students who were in schools taught by experienced STS teachers and who were also staff members in the Iowa Chautauqua Program assisting as new teachers became involved. They were not drawn from a random sample of teachers nor do they represent an unbiased group concerning the power and value of STS instruction.

The Iowa Chautauqua Program has enrolled 15,000 K-12 teachers during its twenty-five year history. Assessment information from classrooms taught by twelve key teachers permits some statements regarding the advantages of STS instruction as it is defined and practiced in Iowa and as defined by an NSTA policy statement. However, there are limitations to studies that include lack of pre-assessment data in all domains and the use of instruments constructed by teachers and Chautauqua staff over the course of several decades. With these limitations in mind the following statements are offered as summary conclusions from pooling the results from twelve teachers—each with an STS and a non-STS section of students.

1. There is little or no differences between student achievement in STS and non-STS sections with the development of conceptual knowledge among the 724 students involved with the study.

2. Students who experience their science courses taught with the STS approach achieved more process skills than did students in the non-STS sections.
3. Student in STS sections were able to demonstrate their creativity skills better than students in the non-STS sections.
4. Student experiencing their science with an STS approach developed more positive attitudes concerning science, science teachers, and science classes than did students in non-STS sections.
5. Students experiencing their science with an STS approach were better able to apply science concepts and process skills in new contexts than were students who experienced science with a non-STS approach.
6. Students experiencing their science with an STS approach developed more accurate views of the history and philosophy of science than did students who experienced science with a non-STS approach.

Generally the study, even with some limitations of design and lack of fully validated and reliable instruments, indicates advantages of the STS approach in many different domains. All of these can be defined as achievement areas in characterizing the Iowa Chautauqua model and the reforms in teaching as envisioned in the National Science Education Standards.

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# A Study of the Association of Autonomy and Achievement on Performance

*The authors find that autonomous learning activities in high school science interact with high school mathematics grades to produce a significant association with college science grades.*

Inquiry-based instructional practices are a mainstay of the National Science Education Standards (National Research Council, 1996). The National Research Council (NRC) teachers' guide asks the critical question, "How does a teacher decide how much guidance to provide in an inquiry?" (NRC, 2000, p. 30). Another primary concern is the quality of student work produced in these activities. For many teachers who assign inquiry activities, the reality is that while some students may produce good work, others languish (O'Neill & Polman, 2004; Polman, 2000).

A major finding of prior interaction research was that higher achievers responded better in less-structured learning environments, such as student designed projects and labs, while lower achievers responded better to more-structured environments, as in labs using worksheets and detailed directions (Cronbach & Snow, 1977; Tobias, 1981). Based on this finding, optimal levels of academic performance would be expected if instructional methods were chosen to more closely match students' backgrounds. Will matching a student's academic achievement with particular teaching practices have a long-range impact on their academic performance? A review of existing literature shows that these

types of studies are not common (e.g. Cronbach & Snow, 1977). With more students going to college (Bureau of Labor Statistics, 2005) than during the past few years, and most high school science teachers naturally emphasizing college preparation (Hoffer, Quinn, & Suter, 1996), one option for a long-range measure of performance is introductory college science. Research linking high school preparation to college performance may provide some insight into best practice.

This study investigated the interaction between students' academic background (high school grades, standardized exams, and enrollment in advanced high school courses) and how

**A major finding of prior interaction research was that higher achievers responded better in less-structured learning environments, such as student designed projects and labs, while lower achievers responded better to more-structured environments, as in labs using worksheets and detailed directions.**

much autonomy they reported having in high school science through labs and projects. Our objective was to see if students who reported experiencing more or less self-directed projects and labs performed differently in college science when we took into account their prior academic background. To provide a more solid foundation for our conclusions, we performed the same analysis on three different data sets in biology, chemistry, and physics.

## Methodology

The data used in this study is a subsample taken from a national survey entitled *Factors Influencing College Science Success* (Project FICSS, NSF-REC 0115649). A sample of 67 four-year colleges and universities was selected from a comprehensive list of nearly 1,700, using stratified random sampling based on size to insure that the sample spanned the range from small colleges to large universities. Of the selected schools, 55 schools from 31 states participated.

Faculty in 29 biology departments, 31 chemistry departments, and 37 physics departments participated and data was collected from college science students in 128 different first semester introductory college science courses all taught exclusively in the Fall Semesters of 2002 and 2003. Insti-

**Table 1:** Summary of Institutional Characteristics of Participating Schools

Field (# of Schools)	Participant Totals	Affiliation		Avg. ACT	Avg. SAT	School Size <sup>a</sup>			# of States
		Public	Private	Range of Avg. ACT	Range of Avg. SAT	S	M	L	
Physics (37)	1903	24	13	17-30	830-1320	18	12	7	26
Chemistry (31)	3521	20	11	17-27	830-1210	16	11	4	22
Biology (29)	2749	19	10	17-30	840-1320	13	9	8	23

<sup>a</sup> Small schools < 5,000 student enrollment (full-time equivalent student enrollment totals, FTE), medium-size schools between 5,000 and 15,000 FTE, and large schools >15,000 FTE.

tutional data is displayed in Table 1. To check for institutional “self-selection” bias, we compared participating and non-participating schools across measures such as school size, admissions selectivity, and geographic location and found no indications of bias.

For continuity in comparison across courses, we chose to include only courses with the ubiquitous large lecture format, by far the most likely to be experienced by high school students who take introductory college science. All courses in this survey filled program requirements for majors within their respective disciplines. All 67 schools originally selected for the survey used this class format. The total sample sizes were: 2,754 biology surveys, 3,521 chemistry surveys, and 1,903 physics surveys. These sample sizes offer a high degree of statistical power (Light, Singer, & Willett, 1990).

The survey instrument was designed by the researchers to collect information about a large number of curricular issues in high school science. The survey was vetted through a series of focus group interviews and pilot surveys. For retrospective self-report surveys, limitations of accuracy and reliability are important considerations. A review of research (Kuncel, Credé, & Thomas, 2005) concluded that self-report surveys of

college students are reasonably accurate and produce valid information. To improve accuracy and reliability, the survey was designed with characteristics associated with improving recall (Niemi & Smith, 2003; Sawyer, Laing & Houston, 1988; Schiel & Noble, 1991; Valiga, 1987). The reliability of the questionnaire was assessed through a separate test-retest study of 113 introductory college chemistry students, not included in the sample analyzed here. The reliability study required students to complete the survey on two separate occasions, two weeks apart. The resulting reliability coefficients ranged from 0.46 to 0.69, which were considered reasonably high for analyses of groups of 100 students (Thorndike, 1997). Finally, to further enhance accuracy, the surveys were administered during college science class sessions, (i.e. lectures, recitation meetings, or lab sessions) and the students’ final grades were reported by professors.

As is common in many surveys, not every participant answered every question. Many students left blanks, or marked multiple responses to the same question. Recommended research practice favors data imputation over the more commonly used tactic of list-wise deletion (Peugh & Enders, 2004). We employed the Expectation – Maximization (EM) Algorithm<sup>1</sup> to

impute missing data for the predictors: SAT-Mathematics, SAT-Verbal, Last High School Mathematics Grade, Last High School Science Grade, and Last High School English Grade (Allison, 2002; Little & Rubin, 2002; Scheffer, 2002). With data imputation, 88% of the surveys were retained for the analysis. The final sample sizes were 2,430 students for biology; 3,187 students for chemistry, and 1,577 students for physics.

The first step in data analysis was a descriptive comparison across different demographic and general educational background variables. Next, multiple linear regression models were fitted to the outcome variable, final college science course grades, hereafter referred to as GRADES. Controlling for differences in demographic and general educational backgrounds, this analysis included students’ academic background measures (high school grades, standardized exams, and patterns of advanced course taking), and students’ experiences with inquiry-related pedagogies (Student-designed Projects and Level of Freedom in laboratory exercises).

## Research linking high school preparation to college performance may provide some insight into best practice.

College science grades are a common choice to gauge science performance (Gainen & Willemsen, 1995; Ozsogomonoyan & Loftus, 1979; Spencer, 1996). A review of course syllabi shows that college grades are not a single measure, but a composite

<sup>1</sup> An extended explanation of the process of data imputation is available upon request from the corresponding author.

**Structured learning activities are essential to building the knowledge-base necessary for understanding more advanced scientific concepts, while autonomous learning forms the foundation of scientific inquiry.**

of several different measures (e.g. tests, quizzes, homework sets, and exams) collected over months, and as a result, are collectively more indicative of student performance than a single achievement test. In addition, college-level content subsumes high school content, often in just a few weeks. Therefore, one would expect that students with a deeper conceptual understanding of the fundamental science topics would have an advantage and earn higher college grades. To address concerns about comparability across courses and institutions, college effects variables were included to account for these differences (Pike & Saupe, 2002).

The academic achievement predictors included SAT-Quantitative and Verbal scores; Last High School grade in Mathematics, Science, and English; high school enrollment in calculus (regular, Advanced Placement® Calculus A/B, and Advanced Placement® Calculus B/C); and enrollment in Advanced Placement® science courses. The inquiry-type learning activity predictors included Number of Student-designed Projects and Level of Freedom in Designing/Conducting Labs.

The demographic background predictors included gender, racial/ethnic background, parental education levels, average county household income, and high school type (i.e. public or private) which past studies have shown to be important (e.g. Bryk, Lee, & Holland, 1993; Burkam, Lee, & Smerdon, 1997).

**Results and Discussion**

The descriptive statistics for the predictor variable, Number of Own Projects, were very similar across all three data sets, with the average number reported by students in all three

disciplines at about one per high school course (see Table 2). However, Level of Freedom in Designing/Conducting Labs varied widely between students in biology and the two physical sciences. The biology ratings appear to be nearly half of a standard deviation below the other averages. This result suggests that college chemistry and physics students reported more freedom in their corresponding high school classes than college biology students reported about their high school biology classes.

The mathematics achievement measures show some differences

**Table 2:** Descriptive Statistics for Continuous Predictors

	Min	Max	Biology Mean (s.d.)	Chemistry Mean (s.d.)	Physics Mean (s.d.)
Number of Student-designed Projects (None = 0, More than 3 = 4)	0	4	1.2 (1.2)	1.0 (1.2)	1.2 (1.3)
Level of Laboratory Freedom (None = 0, Complete = 4)	0	4	1.2 (1.2)	1.6 (1.3)	1.7 (1.2)
SAT Score					
Quantitative	220	790	580 (100)	590 (100)	620 (90)
Verbal	200	800	570 (100)	570 (100)	580 (100)
Last HS Grade in ... (A = 5, F = 1)					
Mathematics	2	5	4.3 (0.8)	4.3 (0.8)	4.5 (0.7)
Science	1	5	4.4 (0.8)	4.4 (0.8)	4.5 (0.7)
English	1	5	4.6 (0.6)	4.6 (0.6)	4.6 (0.6)
Highest Parent Education Level (Attended HS = 0, Grad. School = 4)	0	4	2.8 (1.1)	2.7 (1.1)	2.9 (1.0)

**Table 3:** Frequency Statistics for Categorical Predictors

Predictors		Number of Students					
		Biology		Chemistry		Physics	
AP® Science	Did Not Enroll	2428	88%	3155	90%	1747	92%
	Enrolled	326	12%	366	10%	156	8%
HS Calculus	No HS Calculus	1775	65%	2000	57%	842	44%
	Regular	373	14%	518	15%	351	18%
	AP® A/B	473	17%	792	22%	526	28%
	AP® B/C	133	5%	211	6%	184	10%
Race/Ethnicity	Native American	33	1%	36	1%	27	1%
	Black	207	8%	202	6%	102	5%
	Hispanic	134	5%	177	5%	89	5%
	Asian	167	6%	293	8%	151	8%
	Multi-racial	73	3%	93	3%	38	2%
	Not Reported	53	2%	95	3%	106	6%
Year in College	White	2087	76%	2625	75%	1390	73%
	Freshman	1496	54%	2103	60%	234	12%
	Sophomore	691	25%	811	23%	733	39%
	Junior	404	15%	393	11%	579	30%
	Senior	127	5%	143	4%	273	14%
	No Response	34	1%	64	2%	82	4%

across the three samples. As one might expect, physics students report having taken more mathematics and also report generally higher mathematics achievement. The percentage of students reporting high school calculus enrollment varied across the three disciplines: 35.4 % for biology, 43.2 % for chemistry, and 55.8 % for physics students. The average SAT-Mathematics scores (see Table 2) for biology and chemistry students were 580 and 590, respectively; while the average SAT-Mathematics score for physics students was 620. Also, biology and chemistry students' average high school mathematics grades were the same at 4.3 (A = 5; B = 4), while the average for physics students was 4.5, roughly one quarter of a standard deviation higher. In general, introductory college physics students were higher math achievers than introductory college biology and chemistry students.

## **Autonomous learning is the seed of scientific research.**

In other measures, we found very similar results across the three separate samples. A comparison of the averages for SAT-Verbal, Last HS Grades in Science and English, and Highest Parental Educational Level found them all to be similar. Fewer than 12% of the students in all disciplines enrolled in the corresponding Advanced Placement® science course in high school. A comparison of gender differences showed more females than males in biology and chemistry, and more males than females in physics. Students enrolled in introductory sciences are overwhelmingly white, comprising three quarters

of the sample in each discipline (see Table 3). For Year in College, biology and chemistry students were primarily freshman, while physics student were primarily sophomores, which may be due to the calculus co-/prerequisite for some physics courses. In general, the descriptive data is consistent with well-known educational trends. This consistency is important, since our analysis is intended to produce generalizable findings.

### **Regression Models**

The main focus of this study was to investigate the interaction between differences in students' academic achievement and their high school learning experiences. We wanted to study what influence the level of autonomy students reported experiencing in high school had on their college science performance when taking into account their academic background, specifically with respect to mathematics achievement. The analysis found a significant interaction between Last High School Mathematics Grade and Level of Lab Freedom for the biology ( $\alpha$  - level = 0.05) and chemistry ( $\alpha$  - level = 0.05) analyses, but not for the physics analysis. Figure 1 presents a comparison of the results of the multiple linear regression analysis. All three regression models accounted for roughly one third of the overall variance, a strong result for such large-scale analyses.<sup>2</sup>

At first glance, these findings may seem inconsistent with results for physics lacking a significant interaction. However, looking back at comparisons of the students' backgrounds in Tables 2 and 3, the average college physics student appears to have higher levels of mathematical achievement than his or her peers in chemistry or

biology. This artifact suggests that fewer students with low and very low Last High School Mathematics Grades enrolled in college physics. Therefore, it seems reasonable to argue that the interaction was not found in the physics data because students with weaker mathematics achievement in high school may choose not to enroll in physics courses.

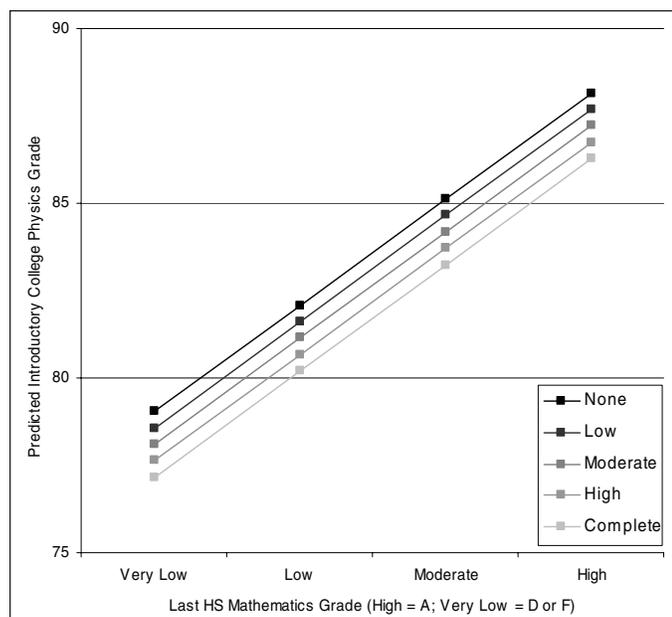
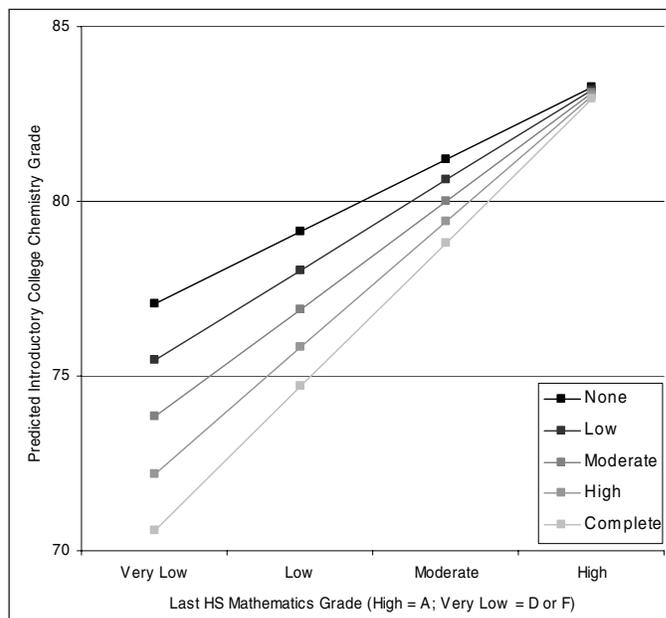
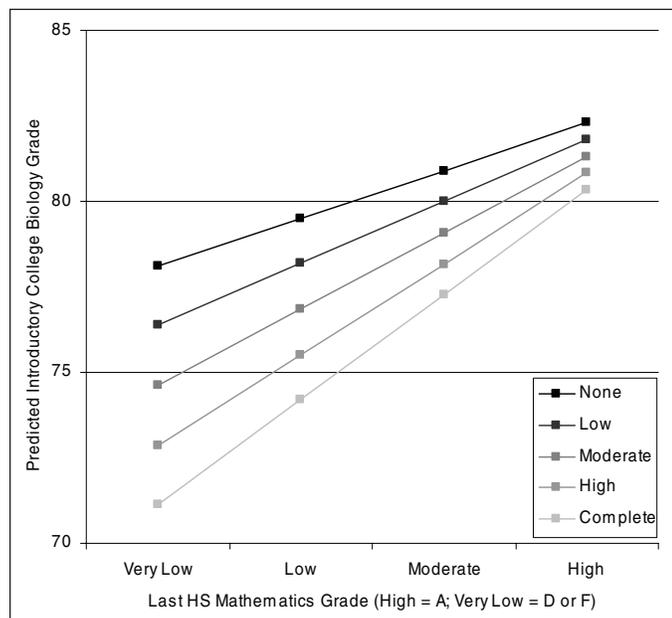
At first glance, the graphs in Figure 1 appear to indicate that students who reported complete freedom in designing and conducting labs were at a disadvantage in all disciplines. However, a closer look shows that large differences are mainly for students reporting low to very low Last High School Mathematics Grades in the biology and chemistry. For the students in the high and moderate groups, the differences are much more modest with results similar to the physics analysis which showed no interaction. The regression results predict that students earning low and very low Last High School Mathematics Grades who also reported Complete Lab Freedom were predicted to have college biology and chemistry grades approximately one half of a letter grade lower than their peers who reported no freedom. These results imply that higher autonomy in high school labs may not be the best way for students with low mathematics grades to learn science in high school.

### **Conclusions**

The results from this study suggest that decisions about how much freedom to give students in high school science activities such as labs and projects should also include considerations of students' achievement in mathematics. Structured learning activities are

<sup>2</sup> Tables comparing the three replicate multiple linear regression models are available from the first author upon request.

**Figure 1:** Association of Level of Lab Freedom (None to Complete) and Last HS Mathematics Grade on Predicted Introductory College Science Grade



with lower levels of high school mathematics achievement had greater success in college science when they reported more structured high school lab experiences. Students with higher levels of high school mathematics achievement did not reveal much variation with differences in lab structure. These results agree with earlier research and extend these conclusions to longer range outcomes.

This study compelled us to think more deeply about teaching and learning science, and the outcomes. Final course grades were chosen for this analysis primarily because of their clear impact on students' career paths; however, other outcomes are also important to consider. While some forms of teaching may be highly effective in building students' background knowledge and enhancing their performance in science, other methodologies seem to raise students' interest in learning science and spark their imagination, possibly contributing to their continuance in the study of science.<sup>3</sup> Performance and continuance may be two different dimensions of science pedagogy. Other studies have found important positive impacts of instructional methods on student interest and attitudes (e.g. Hofstein, Shore, & Kipnis, 2004; O'Neill & Polman, 2004).

essential to building the knowledge-base necessary for understanding more advanced scientific concepts, while autonomous learning forms the foundation of scientific inquiry. The findings from this study suggest that students

<sup>3</sup> The term "continuance" is used here rather than the term "persistence," which refers to long-term student commitment in the pursuit of an educational goal (e.g. Seymour & Hewitt, 1997). This study captures only shorter-term course-taking. Science course-taking is but one step in science persistence. We wish to acknowledge Mary M. Atwater for her insight (Personal correspondence, May 16, 2005).

## This study compelled us to think more deeply about teaching and learning science, and the outcomes.

If freedom in laboratory design is associated with lower college science performance for many students, should this approach to instruction be abandoned in high school science courses? Abandoning freedom for students to design and conduct their own experiments in science labs is very short-sighted. Autonomous learning is the seed of scientific research. Scientists must achieve some level of research independence in order to make contributions to the knowledge-base. Certainly, there have been questions raised about the authenticity of students' laboratory work as a reflection of scientific practice (Hodson, 1996). However, laboratory work in school science is a pedagogical tool to teach both content and practice in scientific inquiry, thus a balance must be struck between structure and autonomy in inquiry-type learning activities.

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# Japanese Lesson Study, Staff Development, and Science Education Reform — The Neshaminy Story

*A school district's experiment with Japanese Lesson Study has provided the impetus for change in both curriculum and instructional strategies*

As the Science Coordinator, K-12 for the Neshaminy School District, I am frequently reviewing educational literature for new approaches addressing the design and delivery of curriculum. The reality of high stakes testing, NCLB, the curricula that have been characterized as a mile wide and an inch deep, the need for quality professional development programs, and the standards movement have all educators searching for ways to improve teaching and increase achievement.

I became interested in Japanese Lesson Study after attending a conference in fall 2001. A workshop facilitator modeled a mathematics lesson that he has presented to secondary students. He explained the process of a lesson study cycle and the philosophy upon which lesson study is based. At the same conference, a mathematics teacher who is currently practicing lesson study with his colleagues, presented a research lesson to his students. I and twenty other educators observed. I was able to see, first hand, the power of lesson study and immediately recognized it as an exceptional professional development approach. Additionally, Catherine Lewis' book entitled *Lesson Study: A Handbook of Teacher-Led Instructional Change* and *The Teaching Gap* by James

Stigler and James Hiebert provided a wealth of information concerning the process and implementation of lesson study.

**Criteria used in this selection process included the presence of divergent educational philosophies, mutual trust and respect among colleagues, extent of their teaching experience, and their fundamental knowledge of multiple instructional strategies.**

In Neshaminy, we use the Wiggins and McTigue Understanding by Design (UbD) model for all curricular revision in science. This backwards design strategy begins with the identification of the enduring understandings, proceeds to the development of the assessment piece(s), and concludes with the design of cohesive and coherent learning activities and strategies which will then provide the pre-requisite knowledge and skills for students to successfully complete the perfor-

mance assessment and demonstrate the depth of their understanding.

During the 2001-2002 school year, a core group of science staff received training regarding a program entitled Schools Around the World (SAW). SAW is one of the programs coordinated by The Council of Basic Education in Washington D.C. It provides a non-judgmental process to effectively examine student work to determine depth of understanding. While this is a worthwhile process in and of itself, SAW also provides a systematic approach that examines the actual teacher designed assignment that generated the work. As staff members review the assignment, they focus on the clarity of the language, its alignment to standards, the level of student engagement and, the degree to which higher order thinking skills are encouraged. Participants in SAW have seen the synergistic power of the group and believe that the process has improved their assignments.

Becoming familiar with lesson study via the aforementioned resources coupled with the staff involvement in SAW and UbD, I had an epiphany and envisioned a combinatorial approach using UbD and SAW as the supporting foundation of our lesson study efforts. Understanding by Design provides

the framework to build robust units of study rich in essential content and replete with authentic assessment practices and well crafted learning activities that foster inquiry, constructivism, and student engagement. Research lessons could easily be designed from these units. Schools Around the World provides the strategy to determine if both the student work and teacher assignment meet the intended goals and standards and if the students are encouraged to demonstrate critical thinking and problem solving. Lesson study also seeks the same end. Thus I developed a plan to wed the three programs into a single amalgam and began its implementation in December 2003. The logistics of the plan included staff selection and staff training.

**During the work of the team, one member is selected to present the lesson to his/her class while the other team members observe the lesson.**

### **Staff Selection:**

To insure success, select staff members in grades 2 through 11 inclusive were invited to participate. Teams consisted of three to six teachers at each grade level. Criteria used in this selection process included the presence of divergent educational philosophies, mutual trust and respect among colleagues, extent of their teaching experience, and their fundamental knowledge of multiple instructional strategies. Many of the staff members selected had already been working together on other curricular issues and some had taught side by side in the

same building for years. As a result, the teams coalesced quickly.

### **Staff Training:**

Using full day workshops, the participants were trained in UbD and SAW. Following the initial training session, time was provided for each team to begin their unit design. The SAW training consisted of each teacher bringing three samples of un-graded student work to the table and a copy of the teacher assignment. Using the SAW template (see figure # 1), each team member took the role of facilitator and teacher and worked through the template. This experience provided the necessary practical expertise for teams to engage in this process in a non-threatening, non-judgmental fashion. Teams were then trained in the lesson study process.

Each lesson study cycle consists of the following:

- **Selecting a Goal**

One method of determining the goal for students is to identify where they are now regarding some educational benchmark and then determining where you would like them to be at the end of the unit, the academic year, or some other period of time. The goal should be designed to bridge the gap between the students' present status and future growth and should be ever present in the minds of each lesson study team member as they proceed through the cycle.

- **Identifying the Content Topic**

In her book, Catherine Lewis suggests that lesson study teams select a topic that is fundamental to subsequent learning, persistently difficult for students or disliked by them, difficult to teach, or something new to the curriculum. Using one or more of these

criteria will focus the work of the team and provide an excellent venue to produce quality units of study and lessons.

**It addresses the isolationism in which teachers work by promoting greater staff collaboration.**

- **Designing the Unit of Study**

Using Understanding by Design, each unit includes one or more enduring understandings with accompanying essential questions. Additionally, the knowledge and skills the students must attain or be able to do are determined, the assessment instrument is developed, and the learning activities and instructional strategies defined. We have found UbD to be a very teacher friendly vehicle and one that creates excellent results.

- **Creating the Research Lesson**

A five-column template (See figure #2) is utilized in developing the research lesson. Column headings include the steps of the lesson, student activities and their possible responses and reactions, sources of student misconceptions and a plan to address them, specific points to observe and evaluate and, necessary materials and instructional strategies. The design of the template allows the observer to read it from top to bottom and also from left to right. This template provides an efficient, effective method to design a cohesive research lesson.

- **Research Lesson Presentation and Observation**

This stage of the cycle is critical to future lesson study participation and team success. Team members must

have a great deal of respect for their colleagues as well as a high degree of trust. During the work of the team, one member is selected to present the lesson to his/her class while the other team members observe the lesson. The observers use an observation template of their own design which focuses their data collection. The observation is meant to determine how the students receive the lesson, not as an evaluative tool to assess the teacher. Observation data should include but not be limited to the level of student engagement, student attitudes toward learning, gender differences, the degree of student-to-student interaction, success of the instructional strategy, and/or social behavior of the students. Team members immediately process the lesson observation following the instructional period. The protocol suggests that the lesson presenter begins the process with his/her reflections and is followed by a general discussion of how the lesson was designed, the data collected, and substantive changes to the lesson with an eye toward improvement. At the conclusion, the presenter should be thanked and the team should celebrate their success in improving instruction and learning. Lewis advises to avoid the “shoals” of happy talk and harping. That is, the feedback must be open, honest

**As veteran teachers team up with those new to the profession or teachers with varied content expertise team, the end result is a broader and deeper understanding of the content material for all participants.**

and allow for constructive criticism without becoming negative.

- **Distribution of the Unit of Study and Research Lesson**

Following the final edits of the research lesson which are based upon the observed data, both the lesson and the unit of study are distributed to each member of the staff teaching that grade level or planned course. All are encouraged to revise the lesson to meet the needs of their students and implement the lesson with their class, thus the lesson study cycle never ends.

Lesson study has truly had a positive impact on instruction at all levels in Neshaminy. It addresses the isolationism in which teachers work by promoting greater staff collaboration. Student misconceptions are identified and strategies to address them are built into the research lesson. Decisions made to improve teaching and learning are data based not superficially engineered or left to chance. Using positive peer pressure among colleagues creates an inherent demand for staff improvement. Since teachers are directly in charge of this process and its outcomes, they have a sense of empowerment and feel valued. As veteran teachers team up with those new to the profession or teachers with varied content expertise team, the end result is a broader and deeper understanding of the content material for all participants. It encourages a thoughtful and thorough examination of student work and an analysis of their learning using the SAW templates. Through extensive planning sessions, it promotes a more frugal curriculum that concentrates on fewer topics to a greater depth.

Lesson study's impact on learning has also been significant for our students. The UbD model tailors the les-

son to meet myriad learning modalities and varied student needs thus fostering a deeper understanding of the content by the student. Research lessons are designed to integrate science process skills with content so that the skills are taught in context thus increasing student achievement levels. All three processes - UbD, SAW, and lesson study - provide venues to develop, deliver, and evaluate the extent to which students are encouraged to employ critical thinking and problem solving skills.

**Research lessons are designed to integrate science process skills with content so that the skills are taught in context thus increasing student achievement levels.**

Staff members involved in lesson study have provided very positive feedback regarding their experience. Some of their comments include the following:

- “I value the collaborative nature of this process as it has eliminated the isolationism I often felt when I closed my classroom door.”
- “The time we’ve been given to plan together and to benefit from our respective strengths has been invaluable.”
- “The self-reflective nature of the lesson study cycle as helped me re-evaluate my teaching strategies.”
- “Lesson study has empowered me to become a better teacher and work with a team to plan my own professional development activities.”

## SAW Template

**Figure 1**

<p><b>Step 1</b> – The sharing teacher distributes a copy of the assignment and describes the context of the lesson. Questions to be asked include:</p> <ol style="list-style-type: none"> <li>1. How clear was the language?</li> <li>2. Does the assignment provide students an opportunity to work with significant ideas that are included in the state/district standards?</li> <li>3. How does the assignment actively engage students in constructing their own knowledge?</li> <li>4. How does the assignment stimulate higher order thinking and discussion?</li> <li>5. What evidence would you use to determine if the student understood the content of the lesson?</li> </ol>	<p><b>Step 3</b> – The sharing teacher presents his/her assessment of the student work. Questions to be asked include:</p> <ol style="list-style-type: none"> <li>1. How did the teacher’s assessment reflect the objectives of the lesson?</li> <li>2. Why do you agree or disagree with the teacher’s assessment?</li> </ol>
<p><b>Step 2</b> – The sharing teacher distributes three samples of the student work without identifying his/her own evaluation of the work. Other group members review and analyze the student work. Questions to be asked include:</p> <ol style="list-style-type: none"> <li>1. What is the evidence that the student used good thinking and reasoning skills?</li> <li>2. How does the student connect the mathematics/science they were learning to the real world?</li> <li>3. What is the evidence that the student achieved the goal of the lesson?</li> <li>4. How would you assess the work?</li> <li>5. Which piece of student work exceeded your expectation? Meet your expectation? Not yet meet your expectation?</li> </ol>	<p><b>Step 4</b> – The group reflects on the assignment and proposes improvements.</p> <ol style="list-style-type: none"> <li>1. What interventions should be considered to help students who do not meet the expectations?</li> <li>2. What additional evidence is needed to make this collection of student work a more complete picture of student understanding of the concepts addressed?</li> </ol>

Figure # 1 Reprinted with permission from the Council for Basic Education, Washington, DC.

**Figure 2**

## Plan for the Research Lesson

<b>Steps of the Lesson: Learning Activities and Key Questions</b>	<b>Student Activities: Expected Student Responses/ Reactions</b>	<b>Possible Sources of Misconceptions</b>	<b>Points to Notice and Evaluate</b>	<b>Materials, Instructional Strategies, etc.</b>
<p><i>This column is usually laid out in order by parts of the lessons and includes the allocation of time for each segment. It should also include a description of key questions or activities that are intended to move the lesson from one point to another.</i></p> <p><i>Finally, include things you meant to remember to do/not to do within the lesson of other reminders to yourself.</i></p> <p><b>Guiding Questions:</b>            How should lesson progress?            How much time should be spent on each segment?            Is there anything specific I want to remember to do?            Any reminders for my students?</p>	<p><i>This column describes what students will be doing during the lesson and their anticipated responses to questions or problems you will present.</i></p> <p><b>Guiding Questions:</b>            What do I expect of my students?            How will they respond?</p>	<p><i>This column contains any student misconceptions you anticipate the students to harbor based upon past experience and how you will address them.</i></p> <p><b>Guiding Questions:</b>            What naïve thinking or misconceptions to students typically embrace regarding this content?            How will you plan to address these misconceptions?</p>	<p><i>This column delineates what the observers are looking for during the lesson presentation and the specific observational data to be collected.</i></p> <p><b>Guiding Questions:</b>            What student behaviors are you interested in observing?            At what part of the lesson did students seem engaged, reach understanding of the content, or perhaps become disinterested?</p>	<p><i>This column contains the instructional strategies which the lesson employs and any hands-on materials required.</i></p> <p><b>Guiding Questions:</b>            Will this lesson utilize direct teaching techniques, a discussion format, cooperative grouping, etc.?            What materials must be prepared in advance of the lesson?</p>

- “This is one of the hardest professional development activities I’ve ever been involved in but it is the most valuable.”

Lesson study has allowed teachers to share and adopt best practices while simultaneously conducting action research in their classrooms. They have come to the realization that lesson study is a “process” as opposed to an “event” and that it is a powerful gateway for continued curriculum renewal, improvement of their craft, and increased student achievement. It should be noted that lesson study is not an inexpensive process to implement. Full day workshops require the hiring of substitute teachers and teachers conducting workshops before or after the normal day usually must be remunerated. Additionally, the synergistic nature of lesson study promotes professional growth far beyond other models and its effects on teaching and learning are extraordinary.

The future plan for Neshaminy involves the addition of lesson study teams at the remaining elementary and secondary grade levels. It also calls for the formation of multiple teams at each grade level. Though ambitious in nature, the Neshaminy staff will continue to press the limits of their professional growth. Our current experiment with lesson study has ignited an intense amount of interest among staff. Many see its intrinsic value and are eager to participate. Engaging in this process has heightened awareness among staff concerning their practices as they relate to learning. It has provided the impetus for change in both curriculum and instructional strategies and we believe that over time student achievement levels on state and district assessments will rise.

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# Museums and Teacher Professional Development in Science: Balancing Educator Needs and Institutional Mission

*The author examines the museum as a valuable resource for providing professional development within informal learning environments, especially in the area of science instruction and curricular methods.*

A distinct need for quality professional development in the area of science instruction for all educators has been identified by recent reform documents such as the National Science Education Standards (National Research Council, 1996) and independent researchers (O'Brien, 1992). In working within urban areas, like the community surrounding the museum at the focus of this study, Huinker (1996) further highlights the difficulties faced by these educators who cite a lack of appropriate professional development as one reason why the science programs at their schools suffer. Neatherly (1998) asserts informal learning institutions can assist with this challenge by providing educational resources for classroom instruction and "valuable knowledge" for use in developing science lessons (1998, p. 44). This support is shared by national science organizations such as the National Science Teachers' Association which recently issued a statement acknowledging informal learning sites as providers of quality professional development (National Science Teachers Association, 1998).

**In addition to supporting classroom science instruction, and pedagogical theory, in-services held in museums can serve to prepare educators for field trips they may take later with their students.**

In addition to supporting classroom science instruction, and pedagogical theory, in-services held in museums can serve to prepare educators for field trips they may take later with their students. Research has shown that field trips can be better utilized when educators receive training prior to coming with their classes (Smith, McLaughlin, & Tunnicliffe, 1998) and thus maximizing the learning experience of all involved. Cox and Pfaffinger (1998) suggest that museum educators and teacher educators should be partners in presenting in-service training to assist educators with using informal sites with their students. Kubota (1997)

speculates that it is a lack of this collaborative modeling that often leads a teacher to "close their doors to their colleagues, ignore the rich resources outside the classroom" (p. 138). This is in direct opposition to the National Science Education Standards that advocate "good science programs require access to the world beyond the classroom" (p. 220). While a number of different natural history museums do cater to educators, offering a pathway into this "outside" world of science, research in this area is limited (Melber & Cox-Petersen, 2005) and would benefit from further study.

## **Changing Models Reflect Changing Priorities**

With the focus on basic skills, and primarily literacy, occurring nationwide, the professional development needs of area educators are constantly changing. Contradictory to Howe and Stubbs (1996), who emphasize the importance of educator in-services serving as vehicles for empowerment, rather than skill development, professional development activities at the time of this study and within the com-

**With the focus on basic skills, and primarily literacy, occurring nationwide, the professional development needs of area educators are constantly changing.**

munity surrounding the museum, were becoming more focused on intense methods instruction. This was primarily true in the areas of language arts and math. In the district from which study subjects were drawn, principals were under strict orders that “all professional development activities that do not support literacy and mathematics will be discontinued” (Cortines, 2000, p. 1) leaving little room for an in-service focused on elementary science methods. This decree came after two of the four in-services had already been conducted, lending a natural situation for comparative study.

Theory does support the importance of clear integration between science in-service content and classroom expectations (Desimone, et.al. 2003). Thus, in line with this research base, district policy and specific request of the organizing principal, an alternative model emphasizing language arts/science integration was implemented for the final two of the four scheduled in-services. The issue at the focus of this study is whether or not this adherence to district policy- though it may fall outside the area of expertise of the in-service provider- is in the best interest of the participating educators and whether without this change, the in-services are sufficiently supportive of educator needs.

**Study Focus**

This study focused on a half-day educator in-service program for elementary educators delivered by a large, natural history museum. There were two different models of in-services provided, one focused strictly on science (Model A) and one focused on the integration of science and language arts (Model B). This study focused on gaining insight into the impact these in-services had on participating educators, and to inform in-service efforts in the future.

**Program Models**

Four groups of elementary educators (N=72) participated in the two types of in-service programs at a large natural history museum: Model A (n=42) and Model B (n=30). Each educator attended only one model and did not have a choice of models. While the in-service programs were similar in most regards, Model B had a stronger language arts connection in the material that was presented. This resulted in each of the models carrying slightly different goals.

For both Model A and Model B, specific activities and discussions were created to meet the following goals (see Table 1).

While some of the activities were similar for both Model A and B, the

emphasis for each was slightly different. For example, creating a classroom museum was discussed in both workshops. In Model A, methods of engaging in scientific inquiry were the focus of the activity while for Model B, the concept of literacy skills was the focus, highlighting the exercise of creating labels during the activity as a real world connection to development of writing skills as emphasized by Reed (1996). Vignettes A and B provide examples of how the same activity was presented differently to meet the respective goals of each model.

A museum educator and author of this study, who held a state teaching credential and had elementary classroom experience, facilitated all four in-service programs. This prior classroom experience of the facilitator addresses Kubota’s position that professional development providers be aware of the K-12 culture where teachers “cope with constant pressure, the lack of privacy, no phone, no office, no bathroom break, a 20-min lunch” (1997, p. 145). To address the needs of this particular group of urban educators, an understanding of linguistically and culturally diverse students, overcrowding, unsafe environments, and minimally prepared educators was also imperative.

**Table 1:** Workshop Goals for Model A and Model B

Model A	Model B
1. Provide educators with information on how to access museum resources.	1. Provide educators with information on how to access museum resources.
2. Provide educators with information on how to connect museum visits with classroom curriculum.	2. Provide educators with information on how to integrate science with language arts activities
3. Provide educators with methods of integrating informal learning techniques into traditional classroom environments	3. Provide educators with concrete project ideas that integrate science and language arts

### **Program Vignette: Model A**

As the teachers filed into the museum classroom they were excited to see unique objects placed in front of each of their seats. Seed pods, bones, antlers, stones, and fur pelts were just a few examples of the treasures strewn around the table. They were going to take on the role of a museum scientist and create an information label for a specimen of their choice. The facilitator provided directions for the first stage of the project.

“When creating a label, it’s important to remember that many people do not stop to read labels. After all, how many labels did you read today?” The teachers smiled to themselves in agreement. “You’ll want to identify the most engaging aspect of the object. Perhaps it’s the first question that came to your mind. Maybe it is something specific about the structure of the specimen. Let that be the start of your label”.

**In the district from which study subjects were drawn, principals were under strict orders that “all professional development activities that do not support literacy and mathematics will be discontinued.”**

The facilitator holds up a skull with a set of curly horns. Carefully, she pulls the keratin sheath of one horn off, exposing the bone inside. She asks the group what aspect of this specimen is the most intriguing- engaging enough to be the headline of their labels.

One teacher whispers to a colleague, “I didn’t know horns were made of two different materials!”

The facilitator responds aloud to the overheard whisper, “I think you just found your topic sentence! Our next job is to review this resource material and determine exactly what the structure of a horn is so we can continue work on our label.”

### **Program Vignette: Model B**

The educators almost had a hard time focusing on the facilitator with the collection of unique specimens and reference materials in front of them. They were excited to see how investigation of a scientific specimen could translate into an exercise in expository writing.

“Okay... our next step is to explore label writing as an exercise in expository writing. You’ll remember that expository writing is focused on sharing factual information with the reader. Students sometimes find the creation of a concise expository piece difficult. There is often so much scientific detail they are interested in sharing, they may find it a challenge to narrow that information down to the most important facts. Some students may find themselves incorporating language that is more persuasive in nature. It will be important to keep them on track with expository narrative, devoid of personal opinion. This is science- information presented in a public forum such as museum must be supported by the research. A second challenge in expository writing may be new vocabulary. We’ll need to work with students and resource materials to be as accurate as possible in our vocabulary choices. For example, the word “amphibian” holds a different meaning than “amphibious” though the two look and sound similar. Lastly, we’ll want to work on appropriate grammar and punctuation. Successful labels rely heavily on declarative

sentences, with simple sentence structure. These are often easiest for a visitor breezing by to read quickly and move along.”

## **Methodology**

### **Research Questions**

- (1) To what extent did each of the models meet its respective goals?
- (2) What elements of the in-services were cited as the most helpful to educators?
- (3) Did the addition of the literacy component to Model B create an in-service model perceived as more helpful by participating educators?

### **Subjects**

Participants (N=72) were from two different elementary schools within the same, large urban district. Both schools served a primarily Latino student body. One school was comprised of 70% English Learners and 93% of the student body received free or reduced lunch (2006a) at the time of the study. The other school was comprised of 64% English Learners and 91% received free or reduced lunch at the time of the study (2006b). Students from both schools performed at the bottom tier of the state’s academic performance index (API) during the academic year the in-service took place (California Department of Education, 2003).

In order to accommodate the large number of residents in the urban area, many schools are year-round. Students and educators are arranged into three tracks, with two tracks overlapping at any one time. Three of the four groups that participated in the program were three tracks from the same school. The fourth group was from a second school in the same area. Over half (52%) of the attendees were teachers

with five or fewer years of experience, 16% had between six and ten years of experience, 11% had between 11 and 15 years of experience, and 13% had between 16 and 20 years of experience. Lastly, 8% of participants had over twenty years experience. As all faculty members of each school were required to attend, all grade levels were represented equally- from developmental kindergarten through fifth grade and inclusive of special education teachers.

**Data Collection and Analysis**

All participants were given a retrospective questionnaire at the end of the half-day program. Questionnaires of this nature ask participants to respond both to their current status as well as their past status retrospectively. The questionnaire was organized in order to (1) address model-specific goals, (2) compare responses of participants from both models, and (3) address topics that were common to both models. In addition, several questions were asked to determine how participants felt museums could be most helpful to their classroom instruction overall.

The questionnaire relied on both Likert scale responses and open-ended questions. Likert scale responses were analyzed quantitatively using a paired samples t-test to determine significant differences between participants self-report of knowledge before and after participation in the program. Statistical analysis of current and retrospective views on the same instrument is a technique found to be effective by Smith, et. al. (1998). Open-ended responses focusing on helpful and useful aspects of the program were analyzed qualitatively by identifying recurrent themes through a constant comparative technique and later category construction (Merriam,

1998) and then grouping responses into categories. Response percentages were then calculated in order to make comparisons between participants of the two different models, as supported by Miles and Huberman (1994) and in line with the combination of qualitative and quantitative data in order to lend more depth to reported results.

**Analysis and Results**

Data analysis indicated that both Model A and Model B clearly met their respective goals. Participants of both Model A and B (N=72) indicated statistically significant knowledge gains in how to access museum resources after the in-service as opposed to before (see Table 2) meeting the first goal which was shared by the two models. In addressing the second goal specific to Model A, “provide educators with information on ways to connect museum visits with classroom curriculum”, participants (n=30) indicated statistically significant knowledge

gains after in-service participation in linking classroom curriculum with visits to informal learning environments as opposed to before (see Table 2). In addressing Model A’s third goal of providing educators with information on incorporating informal teaching techniques in the classroom, participants indicated statistically significant knowledge gains in ways to use informal instructional techniques within their classroom setting after in-service participation (see Table 2). Model B also met its second goal of assisting teachers with linking science and social science activities with language arts as participants indicated statistically significant knowledge gains after in-service participation in (1) perceived knowledge of methods to link science and literacy in the classroom as well as (2) projects that incorporate science and language arts (see Table 2).

In addressing the second research question, determining which elements

**Table 2:** Perceived Helpfulness of Workshop Models

	N	Pre-In-service		Post-In-service		T	P
		Mean	SD	Mean	SD		
Model A and B Knowledge of... museum resources.....	72	2.00	.65	4.22	1.15	18.93	<.05
Model A Only Knowledge of... linking classroom curriculum with museums.....	30	2.33	.96	4.33	.66	11.15	<.05
Informal teaching techniques.....	30	2.83	1.23	4.27	.69	6.92	<.05
Model B Only Knowledge of... Linking science and literacy in the classroom.....	42	2.88	.99	4.29	.67	8.58	<.05
Projects incorporating science and language arts.....	42	2.88	.99	4.29	.67	8.40	<.05

**Table 3:** Categories of Museum Support as Cited by Participants

Category of Support	Percentage Cited	
	Model A	Model B
Contact with Real Objects	20%	26%
Museum Tours	10%	5%
Resources/Programs for Teachers	10%	12%
<b>Resources/Programs for Students</b>	<b>23%</b>	<b>14%</b>
<b>Activity Connections to Curriculum</b>	<b>37%</b>	<b>36%</b>
Affective (enrichment, motivation, etc.)	7%	12%
Exhibit Reference	3%	7%
Other	4%	5%
Blank	9%	12%

\* Percentages total more than 100% due to responses in multiple categories

of the in-services were perceived as helpful to educators, the question was addressed in several different ways. First, educators were asked in an open-ended question to “please explain how you feel a museum can best support your classroom curriculum”. Most of the elements most commonly cited by the participants fell into the category of “Activity Connections to Curriculum” (see Table 3).

When the results of this question are compared across models, the area that shows the greatest disparity is the category of “Resources/Programs for Students”. Due to Model B’s emphasis on language arts activities, discussion of student programs within this model was more limited due to time constraints.

Secondly, participants were asked in an open-ended question “What activities and/or information from the workshop will you be most likely to use?” Again, responses were grouped into categories and the frequency of each response was calculated in a percent format (see Table 4). For Model B, where learning about specific activities connecting science and language arts was at the focus of the program, responses more often fell into the categories of “Creating Museum-

like Exhibits” but also cited categories referring to more theoretical information related to museum-specific services such as “Members’ Loan Service Information” and “Field Trip Related”. Within this model, the focus was more on transforming perspectives and empowering educators as professionals than on training on a specific activity.

When asked through an open-ended question to explain “How helpful was this workshop to your classroom teaching”, those that participated in Model B and elaborated beyond the Likert scale response cited elements equally within the categories of “Museum Resources/Offerings” and “Worksheets/Lessons/Activity Ideas” where as participants in Model A overwhelmingly cited “Museum Resources/Offerings” (see Table 4). These resources included the museum’s Members’ Loan Service which provides educa-

like Exhibits”, “Worksheets/Activity Ideas”, and “Object Related Activities”— all categories with an emphasis on ‘ready-to-implement’ curricular support. Participants of Model A, also most frequently cited elements within the category of

tors with the opportunity to “check out” natural items such as taxidermied animals or skeletons, for use in their classroom.

An interesting disconnect is observed when the results of both Table 3 and Table 4 are reviewed in connection to each other. In Table 3, participants within both models indicate that “Activity Connections to Curriculum” were a significant resource that museums can provide educators. However, in Table 4, with reference to specific in-service components participants were most likely to use, “Activity Ideas” and “Instructional Techniques” were cited with different frequencies by participants within the two models. Model B participants were more likely to cite “Worksheets/Activity Ideas” than participants in Model A. More Model A participants cited “Instructional Techniques” than did participants in Model B. It is possible that these differences are reflective of the school site curricular emphasis. Model B provided very specific activities linking science and language arts, immediately replicable in the classroom under the new curricular emphasis on language arts. Perhaps some of the science specific activities presented

**Table 4:** In-service Component Participants Were Most Likely to Use

Category	Percentage Cited	
	Model A	Model B
Members’ Loan Service	27%	10%
Other Museum Resources	13%	12%
Field Trip Related	27%	10%
Creating museum-like exhibits	30%	41%
Worksheets/activity Ideas	7%	27%
Specifically object related activities	10%	27%
Instructional techniques	20%	10%
Content topic or exhibit	10%	7%
Other	0%	5%
Blank	7%	2%

\* Percentages total more than 100% due to responses in multiple categories

in Model A were deemed helpful in Table 3 yet the reality of a language arts emphasis in the classroom made the actual implication of these more difficult as indicated in Table 4. Another possible reason is that Model A provided instruction on a slightly broader scale, devoting time to general instructional techniques in the area of science (i.e. importance of experiential learning) than within Model B. This led to citation of instructional technique by Model A participants over specific activity ideas.

In addressing the third and final research question, it was determined through paired t-tests that participants from both Model A and B (n = 69) felt their respective in-service was more helpful to them than other non-mu-

**Table 5:** Museum and Non-museum In-services Compared

n	Other In-services		Museum In-services		T	P
	Mean	SD	Mean	SD		
69	3.07	.67	3.75	.99	-6.96	<.05

seum in-services in which they had participated (see Table 5).

However, it was not evident through statistical analysis that the added literacy component increased perceived helpfulness making one specific model more “helpful” than the other. Rankings of helpfulness of participants in Model A and Model B were compared through an independent samples t-test and no statistically significant differences in perceived helpfulness were demonstrated. This indicates that the addition of a language arts emphasis did not make the in-service any more helpful as perceived by the participating educators. Though overall rankings of the two models did not display statistically significant differences, there were differences observed between the individual elements participants

within each model found most helpful (see Table 6). While differences are clear, it is important to note that many respondents left this question blank so those responses that are present represent the views of only a percentage of the participants. Further studies into this area are warranted.

It could be argued that trying to infuse an emphasis not core to the specialty of the museum too deeply may have compromised the transmission of information that would have been helpful and well received by participating educators and most appropriate for delivery by the museum. The area that is perhaps the museum’s strongest asset is the student programs it provides, yet when faced with the question of “how a museum can best support your classroom curriculum” nearly 10% fewer participants in Model B than in Model A identified this as a way the museum can support their instruction. As these participants were from the same district, city area, and sometimes the same school, it can be inferred that this lack of mention is due to the different formats of the two in-service models.

### Limitations

There are several key limitations to this study that should be considered before broad application of these

**Table 6:** In-service Component Participants Found Most Helpful

Category	Percentage Cited	
	Model A	Model B
Connecting museums w/classroom curriculum	7%	12%
<b>Museum resources/offerings</b>	<b>30%</b>	<b>14%</b>
Exhibit Hall Related	13%	0%
<b>Worksheets/lessons/activity Ideas</b>	<b>0%</b>	<b>14%</b>
General Science Instruction	3%	7%
General Positive Reference	7%	7%
In-service Format/instructor Reference	3%	2%
General Negative Comments	3%	0%
Other	10%	7%
Blank	27%	41%

\* Percentages total more than 100% due to responses in multiple categories

results. Though the study instrument adequately addressed the three focus areas of the study, it is not without its limitations. There were no reliability measures for the instrument. In addition, though retrospective self-report is an oft used technique, many will argue it is not the most desirable way to measure actual gains in knowledge. Lastly, the small number of indicators/questions scored with a Likert scale can also be considered as problematic.

In addition, a longitudinal follow-up of the educators and the lasting impact (if any) the program may have had on their classroom instruction would have greatly contributed to this study. Unfortunately, longitudinal studies can be difficult for fiscal and logistical reasons and continued contact was not possible in this case due to those barriers.

A final limitation not of the study itself but of the two models is their half-day nature. A significant literature base indicates half-day in-service programs do not carry the impact that lengthier and intensive educational opportunities, particular the National Science Education Standards that cautions specifically against “fragmented, one-shot sessions” (1996, p.

72). However, one might argue that with school district budgets as they are and the many competing demands or educators' time, though not the most pedagogically effective, the half-day workshop is the most we can expect at the present, in line with actual district protocol.

### **Conclusions and Implications**

Three themes emerged from the data that future studies can build upon in looking at effective models of using informal learning institutions as the setting for elementary educator in-service programs in the area of science. Both museum in-service models were ranked more positively than in-services attended outside the museum setting, indicating that informal venues are indeed institutions that can successfully support professional development efforts in the traditional setting. This reinforces what earlier studies have found: informal learning sites can be effective venues for teacher professional development. The novelty of these locations can go a long way in sparking educator interest and creating a dynamic science learning environment much like that the environment we advocate for students. Research indicates that learners who are intrinsically motivated may demonstrate greater cognitive gains (Covington, 1998). The physical context of the learning environment can go a long way toward promoting intrinsic motivation.

Secondly, while informal institutions can certainly create professional development programs that connect with issues that are at the forefront of reform efforts within the traditional education setting, this may not be necessary from the educators' view in creating a meaningful experience.

In fact, it may hinder the transmission of resources and information that are precisely what makes informal learning venues unique places for professional development. While the literacy-based in-service in this study did significantly increase participants knowledge in connecting science and literacy, it did so at the expense of information specific to museum offerings in the area of science education for educators and students, perhaps the strongest selling point for holding an in-service within such an environment. Subjects of this study clearly indicated that the most helpful resources museums could provide would be well grounded in the area of the museum's science and social science expertise as resource provisions strongly linked to the museum's mission (i.e. specimen access, integrated curriculum projects, field trip destinations) were those most often cited as desirable by educators.

### **The physical context of the learning environment can go a long way toward promoting intrinsic motivation.**

The reality is that language arts is a critical component of the work that science and social studies researchers do at the museum on a daily basis. Museum researchers are consistently taking notes on specimens- in the field and in the laboratory. Discoveries are routinely summarized in publications, oral presentations, and exhibit labels. Research libraries are extensive and routinely visited by the curatorial staff. Thus there are infinite possibilities for creating K-5 curriculum opportunities

that authentically integrate science and language arts in connection with the work of these researchers. However, while elements of these authentic connections between science and language arts were included at the most basic level within the two models, time precluded a more in-depth treatment of how these connections can be implemented into a K-5 curriculum.

This brings us again to the conversation of what instructional priorities should take precedence in the reality of a limited duration professional development program. And more importantly, what can be infused into an in-service on the school site and what unique elements can only be effectively transmitted in an informal setting? Instruction on how to take scientific notes related to an unknown specimen can be done in any setting- museum or school. Demonstrating effective use of exhibits, visits to a working curatorial lab, or displaying the items available for loan from a local museum cannot.

It is clear that educators clearly took away from the workshop exactly what was presented. If student programs and resources were not discussed, knowledge in this area was not cited as helpful or important. This reinforces again the potential museums have for providing educator professional development but also reinforces the importance of constructing these experiences with attention to the unique messages science museums are best positioned to deliver.

Certainly, this small case study is only the start of what should be a further investigation into the role of museums as in-service providers. However, it does emphasize the importance of focusing on the unique qualities and offerings of the institution in creating a professional development model

to improve science instruction in the classroom while tapping into the rich resources informal learning institutions offer. These findings can serve to further efforts in creating stronger formalized partnerships between museums and school districts and look to creating formalized professional development collaborations that build on the strengths of the institution together with the needs of the schools.

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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 commonly 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

## **The most common story is that a specific teacher or teachers lobbied in favor of offering environmental science and volunteered to teach it.**

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.

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 hu-

man 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 in-

habit. 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

### **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.**

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.

### **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 Reorganiza-

tion 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 12<sup>th</sup> 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 based 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 9-11<sup>th</sup> 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 11<sup>th</sup> 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 ques-

tions 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 10-12<sup>th</sup> graders after they opt out of the more challenging biology, chemistry, physics sequence, or by 12<sup>th</sup> 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 *Earth-Comm*).

### **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.<sup>1</sup>

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

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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.<sup>2</sup>

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,

**Inertia**, 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 it 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 environ-

mental 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 adopt-

ers. 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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