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# Making Connections Between Science and Equity: A Motivation to Teach Science in Elementary Grades

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## **Making Connections Between Science and Ethical Responsibility: A Motivation to Teach Science in Elementary Grades.**

### **Purpose**

It has been clear to researchers for years that teacher quality is among the strongest correlates of student outcomes (Darling-Hammond, 2003; Monk, 1994). However, only about a quarter of the nation's elementary teachers consider themselves qualified to teach science (Weiss et al, 2001). Predictably, this translates into diminished instructional time spent on science, particularly in the current school climate in which math and literacy skills are disproportionately valued over other subjects by state and national testing practices. Our ultimate goal is to motivate primary grade teachers to spend more instructional time on science despite their self-assessed lack of qualifications to do so. We believe that one way to do that may be to help teachers make connections between science understanding and the ethical responsibility they accept as teachers to educate their students. Teachers often identify equity issues as among the most important issues in education, and research also suggests that an intrinsic altruistic desire to help others may be a primary motivator for becoming a teacher (see, for example, Guarina et al, 2006). We hypothesize that helping teachers see science instruction as a matter of equity may help them make connections to their ethical responsibility as teachers and may motivate them to teach it to their students more often. Thus, this project sought to help pre-service teachers explore connections between science and equity as well as their ethical responsibilities as teachers by helping them grapple with issues of equity related to science, particularly around issues of sustainability.

The findings reported here indicate that helping teachers see these connections may serve as an intrinsic motivator to encourage them to embark on the long road toward improving their science pedagogical content knowledge and ultimately to teach science to their students more often, regardless of a lack of confidence with science content.

### **A Brief History of Science Instruction in the U.S.**

The arguments for increasing science instructional time in school have evolved over the last century, from economic, to national security, to global stewardship. Early in the 20<sup>th</sup> century, a primary motivation for many to pursue an education in science was driven largely by the recognition that an understanding of science and technology was useful in terms of access to lucrative careers in science and engineering. As the nation industrialized and manufacturing jobs became a larger segment of the nation's available employment portfolio, an increasing number of positions requiring training in science, engineering, and math became available. Notably, many of these newly available positions promised those who could get them a path by which they might move away from the often brutish and low-paying work carried out on factory floors and toward the more lucrative jobs behind desks, in laboratories, and in corner offices. Despite the growth in the number of jobs that relied on science and engineering, however, science instruction was not widely viewed as essential in public schools, and while some schools at the turn of the century offered instruction in science, many did not.

During World War II, however, a shift occurred in the public's perception of the value of science, resulting in a concomitant shift in educational priorities of American

public schools. There was growing appreciation that science mastery was more than merely a path to a lucrative career, but also was a path to broad national economic, military and political dominance. The undeniable power of science to provide advantage to a country that could marshal the efforts of its scientists and engineers was on stark display in early August of 1945, when the U.S. dropped two nuclear bombs on the Japanese cities of Hiroshima and Nagasaki. To many, the technical and military advances produced by the Manhattan Project served as a shining example of the power of science and, for many, represented the height of the “golden age of physics” (Blumberg & Panos, 1990). Because advances in science and technology so clearly played a pivotal role in the victory of the Allied Forces over the Axis Powers, after the war it was far easier for the average citizen to imagine some of the benefits that might accrue to a nation willing to invest in science education, and this growing awareness was reflected in an increase in the number of schools that included science instruction in their curricula. This upward trend continued, with a notable spike precipitated by a single event during the cold war: the launching of Sputnik in 1957. When the USA awoke on the crisp October morning following the Sputnik launch to discover that the USSR had beaten the USA into space, many viewed the engineering feat as evidence of looming Soviet technological, and therefore military, world dominance, and many in the states were quick to blame poor public education in science, mathematics, and engineering in America’s K-12 schools for America’s failure to measure up (Dickson, 2001).

Responding to widespread fear that a continued failure of public schools to produce top-notch scientists and engineers would undermine the ability of the USA to meet threats from the USSR, the USA directed unprecedented resources toward bolstering national

science, technology, engineering, and mathematics (STEM) education (see, for example, Boerner, 2009; Bruner, 2003; Dickson, 2001, Rutherford & Ahlgren, 1990; Smith & O'Day, 1990; Yager, 1996). In 1958, for example, the US Congress passed the National Defense Education Act (NDEA), which added billions to the federal public education budget and resulted in sweeping changes in the way children were introduced to STEM subjects. Underlining the commitment of the times, in 1963, President Kennedy delivered a speech at the 90<sup>th</sup> anniversary convocation of Vanderbilt University (Kennedy, 1963), noting that “modern cynics and skeptics see no harm in paying those to whom they entrust the minds of their children a smaller wage than is paid to those to whom they entrust the care of their plumbing” (para 15). Kennedy sandwiched the comment about low teacher salaries between remarks about putting a man on the moon within the decade and about Americans’ patriotic responsibilities in times of tension, making clear the reasoning behind the sweeping national education reform policies of the late 1950s and 1960s that sought to bolster education, and in particular education in STEM areas: the nation was worried about being left behind; many saw STEM education reform as a path to technological and military supremacy; and the government was ready to fund the reform effort.

Today, fears about the USA’s ability to maintain global military dominance do not loom as large as perhaps they did in the Kennedy years. However, for a growing number of people, issues of sustainability and environmental degradation are moving increasingly to the forefront. It is becoming clear to more and more people that if we are to meet these new challenges as a nation and as a species, a robust understanding of science is necessary for us all, whether we are scientists or not. Unfortunately, the

majority of the nation's citizens are largely scientifically illiterate, and many believe that a lack of science understanding of teachers is at the root of the illiteracy problem (RNT, 2000). Weiss's (2001) report that nearly three quarters of the nation's teachers feel unprepared to teach science is not surprising in light of their exposure to science in college: fewer than 20% of middle school science teachers were undergraduate science majors, and among teachers of grades 1-4, fewer than 10% hold even a minor in science or science education (Greenwood & North, 1999).

As a consequence, while teachers generally appreciate that science instruction can be valuable as a gateway to a career in science, many under-appreciate the increasing centrality of science to everyday living (Raven, 2002). Similar to the "SEP field" described by novelist Douglas Adams (1979) as "something we can't see, or don't see, or our brain doesn't let us see, because we think that it's somebody else's problem," many elementary teachers seem to think of science instruction as generally quite important to their students but nevertheless do not take on the responsibility to do it themselves. This is problematic, because without quality science instruction at all levels of education, K-16, we are less likely to find solutions to the increasingly dire environmental, social, and economic problems we face.

## **Theoretical Perspectives**

### *Teacher Dispositions*

Teacher preparation often focuses on the cognitive and behavioral dimensions of teaching while giving less attention to teacher dispositions (Birmingham, 2009). To address this imbalance, the National Council for Accreditation of Teacher Education

(NCATE, 2008) mandated that teacher educators focus on dispositions as well as skills and knowledge. Drawing on Dewey's (1933, 1938) conception of dispositions, Ritchhart (2001) argues that teaching appropriate dispositions bridge the gap between skills and actual inclinations to act. One of the primary dispositions we view as appropriate, both in terms of this project specifically as well as in teacher education more generally, is provided by Nel Noddings, who offers a robust and well-articulated ethic of care (2001). Teaching children about science, a subject that can profoundly shape their lives, is an act of caring as conceived by Noddings (1995). Doing so in spite of real or perceived barriers is also an act of responsibility (Orr, 2004). And taking on the responsibility of teaching science to all students, even though most will not become scientists, is an act of social justice (Barton, 2001). Thus, we believe that positioning science instruction as connected to equity and sustainability may help promote the development of caring, responsibility in teaching, and social justice, three dispositions that NCATE lists. We hope that as teachers develop these dispositions surrounding science education, the result will be motivation to teach science more often.

### *Science Understanding and Sustainability*

Issues of sustainability are inextricably intertwined with issues of equity, social justice, and education, and are becoming increasingly relevant (Hawken, 2007; Orr, 2004, 2009). In 1987, the United Nations Brundtland Commission published *Our Common Future* (Brundtland, 1987), recommending how we as a species might adopt sustainability. The commission purposefully defined the terms of reference in the report very broadly: "the "environment" is where we all live; and "development" is what we all do in attempting to improve our lot within that abode" (Brundtland, 1987, p xiv). This

broad conception of the terms of reference (and the report's title) makes it clear that the report was written for us all. However, the Commission addressed their message to the young in particular, and noted that "the world's teachers have a crucial role to play in bringing this report to them" (Brundtland, 1987, p xiv). The implied logic is simple: before one can be expected to choose wisely between one practice and another, one must consider the consequences of each choice; to properly consider consequences, one must thoroughly understand the interconnected phenomena involved; and to understand interconnected phenomena, one needs education. In other words, education must precede wise action. Because science understanding is particularly relevant in terms of environmental stewardship, economic well-being, and technological and cultural understanding, science education is critically important.

## **Methods**

In this exploratory and descriptive study, data were collected from a sample of convenience: 59 students enrolled in two sections of a semester-length elementary science methods course that was a required part of a post-baccalaureate elementary teaching credential program at a large Western state university. These two sections served as experimental groups. A third section of the course served as a control group. Each section met weekly for 2 hours and 50 minutes. Both sections of the experimental course were taught by the same instructor (one of the co-authors of this paper). One section was composed of a cohort of students enrolled in a combination credential-MA course of study with a particularly strong orientation toward social justice theory and critical theory (e.g. cohort classes explore writings by John Dewey, Paolo Friere, bell

hooks, Henry Giroux, Nel Noddings, Lisa Delpit, etc.). The other section was composed of general (non-cohort) credential-only (non-MA) students enrolled in a more traditional course of study. The composition of the sample in terms of race and gender was similar to the composition of the students enrolled in the credential program overall. The third section of 29 students, which served as the control group, was taught by another instructor during the same semester, and was also composed of general credential-only students.

To encourage students to explore connections between science and equity and to position science instruction as an ethical responsibility, we revised both of the experimental courses in similar fashion. Historically, stated goals of this required course were to provide an overview of the K-8 state science framework, to explore critical issues surrounding the teaching of science in the public schools, and to assist candidates to develop the knowledge, skills and strategies to plan and implement high quality science curriculum based on their students' diverse learning needs. Course revision added a goal to foster exploration of the connection between science instruction in the elementary grades and issues of ethical responsibility in terms of equity and sustainability. This additional goal was supported by assigning out-of-class reading that explored the relationship between science instruction and equity, using targeted "quick-writes" at the beginning of instruction that focused on the relationship between science and ethics, incorporating discussions of the subject into class lectures and activities, modeling K-8 level inquiry-based lessons focused on sustainability, exploring sustainability and equity in several course assignments, and fostering class discussions centered explicitly on equity issues and teachers' ethical responsibilities and their role as potential motivators to

dedicate instructional time to teach science.

A description of how one class meeting was revised from a rather “standard” methods-class approach may provide a sense of the revised focus of the course as a whole. Week three of the revised course, for example, was designed to support candidates as they explored how to use group activities during instruction. The week’s reading, which students were to read prior to class, included two articles, *The Tragedy of the Commons*, by Garrett Hardin (1968), and *Teaching Themes of Care*, by Nel Noddings (1995). *The Tragedy of the Commons* describes how the self-interested rationality of individuals attempting to maximize personal gain leads to actions that deplete shared resources or diminish the health of a “common” (e.g. an ocean or the atmosphere) despite the fact that such depletion or diminishment ultimately harms everyone, even those who benefit in the short term. *Teaching Themes of Care* is a call to re-organize school curriculum away from a focus on materialistic messages, using care ethics as a guiding theme, suggesting that “first, we should want more from our educational efforts than adequate academic achievement and, second, that we will not achieve even that meager success unless our children believe that they themselves are cared for and learn to care for others” (p. 675).

The class opened with an analysis of two inquiry-based activities that we had completed in the previous class, one very structured and one very unstructured. Using the Noddings reading as a guide, we considered how each approach suited various learning styles, strengths, challenges, and preferences of the individuals in the class (and by proxy, hypothetical elementary students) and whether or not each or both foreclosed or opened opportunities to teach students to care, and, with that as an underpinning, considered the

responsibilities teachers have to adapt chosen instructional approaches to meet the needs of their students as individuals.

We then conducted a group-based hands-on inquiry activity to explore some of the ideas that resulted from the discussion. This activity itself modeled some of the major concepts underpinning Garrett's paper and consisted of playing two versions a game in which students in groups of four took turns "fishing" from a cup, using chopsticks to withdraw goldfish crackers under a pressing time limit of 20 seconds. Rules in the first version of the game were designed to mimic many aspects of real-world tragedy-of-the-commons situations: each player required two fish to survive a round, the legal limit was four fish, and one could stockpile fish against future scarcity (representing both an opportunity and an incentive to accumulate "wealth"); some students had an impressive mastery of chopsticks, while others did not (representing differences in how one's education, skills, cultural values, and cultural capital might map to a given set of "essential" life skills); the student to fish first, and thus the student fishing when the cup was at its fullest and the fishing was easiest, was the student whose birthday was next (representing accidents of birth, such as whether one is born into riches or poverty); the legal limit of four fish per round was above the level of sustainability - although the students did not know it, there were 16 fish in the cup at the beginning of the game (representing the relationship between current legal fishing limits and ocean fish stock availability and sustainability); students were not allowed to look in the cup (representing limited understanding of the carrying capacity of a given food system as well as limited food chain management technology); students were not allowed to talk (representing social, cultural, and practical barriers to communication); and finally, students were not

allowed to share fish (representing the structural, political, and material barriers that often prevent aid from reaching those who need it). Notably, before the five rounds that made up a single game were over, every group suffered the loss of at least one member, while at least one other member had fish to spare (representing the separation of wealth and the material consequences that invariably follow from such a separation).

The second version of the game differed in several regards: students could talk (representing advances in communication avenues, as well as political stability); students could look in the cup (representing advances in fish harvesting technology as well as advances in fish management possibilities, both brought about by advances in science); and finally, students could share fish if they chose to do so (representing some of the ethical dilemmas surrounding wealth accrual, resource management, poverty, and social responsibility).

Discussion of the tragedy of the commons activity was three-pronged. First, we discussed the activity itself, articulating our insights, wrestling with our frustrations over our inability to prevent inequity or to stave off tragedy, and discussing possibilities for re-imagining ecological stewardship. Second, we discussed the groupwork itself, highlighting insights and observations regarding the challenges and opportunities of supporting elementary students to play the game in groups and how we might structure the situation to meet various student needs. Finally, combining the two assigned readings, we considered the implications of Garrett's thesis and discussed whether or not teachers have a responsibility to help their students grapple with such matters in the context of care ethics. The class ended with a homework assignment to respond to the following writing prompt: What does Garrett define as a "no-technical-solution" problem? Are the

major problems of education such problems? Why or why not?

### **Data Sources and Analysis**

Data was both quantitative and qualitative. A survey instrument was developed to gather information regarding participants' views about science, their self-assessed level of science understanding, their motivations to teach in general and to teach science in particular, and their comfort level with providing science instruction to elementary grade students, as well as to gauge their understanding of the relationship between science instruction and matters of equity. The survey consisted of nine open-ended questions, two Likert-style questions, and two multiple-choice questions. Survey face validity evidence was provided by reviewing the instrument for clarity of wording, relevance of items, and absence of biased words and phrases (Fowler, 2002). Two faculty were asked to review the instrument, which was revised based on the reviewers' recommendations prior to administration. The survey was administered at the time of first contact with the students in both experimental groups as well as the control group. Each administration took most participants about 20 minutes to complete. At the end of the semester, the survey was again administered to the three groups.

Additional qualitative data were gathered from two sources. First, the quick-writes in which students wrote ten-minute responses to science and equity prompts, as well as relevant homework assignments, were collected. Second, the course instructor kept a teaching journal that included a descriptive account of each lesson, notes about discussions and interactions with individual students, and notes about class happenings that were related to ethical responsibility, equity, motivation, and the like.

Quantitative data was analyzed using Statistical Packages for the Social Sciences (SPSS) version 17 (SPSS, 2010). In addition to basic descriptive analysis (e.g. means, standard deviations, frequencies and percentages), we conducted a chi square test of independence to examine the relationship between the students' perceptions of science instruction as an ethical responsibility and an issue of equity and their motivation to include science in their teaching.

Qualitative data was analyzed based on an interpretive philosophy (Caudle, 2004). The content of all available qualitative data was coded to identify major themes as well as patterns within these themes and connections to other themes. To increase validity and reliability of the analysis, we each coded the data independently and resolved our code lists afterward. Our conclusions are based in large measure on these themes, patterns, and connections, in conjunction with quantitative analysis.

## **Findings**

Initial findings suggest that positioning science instruction as an issue of equity, particularly around sustainability, strengthened teachers' awareness of their ethical responsibility to teach science, and thus was perceived as a strong motivator for in-service teachers to include science instruction in their future elementary classes, even when they themselves felt uncomfortable with their own science content understanding.

### *Qualitative Results*

An analysis of open-ended survey responses, quick-writes, instructor notes, relevant homework prompts, and student interviews all suggest that as the revised course unfolded, teachers became more aware of the connections between science and equity,

and often that awareness enabled them to make or strengthen connections between their ethical responsibilities as teachers and science instruction. This, in turn, seemed to translate directly into an increased motivation to provide science instruction to their students.

Pre-study survey responses as well as quick-writes regarding students' ability to connect science to issues of equity could be described as one of three types: (1) an inability to do so at all, (2) an ability to do so, but only in terms of equalizing opportunity for all students, or (3) an ability to do so, but only in terms of opening avenues for future employment opportunity. Responses of each type were stable across all available qualitative data sets.

A sizable number of students (~25%) fell into the first group, which had limited ability to connect science to issues of equity at all. When asked to respond to a prompt about how science and equity in education are connected, responses typical of this group include: "Hmmm...I'm not really sure;" "I don't know what you mean by this question;" and "I don't know. I never thought about it."

Responses typical of the second group (~35%) are well represented by the following reply to the same prompt:

"Yes. A child from a wealthy family may have experienced things like museums and aquariums, whereas a kid with free lunch has only seen it in movies or books. It is a teacher's job to provide access to everyone."

This candidate notes that there may be issues of equity related to science education, but seems to conceive of them only in terms of equal access to experiential opportunities, and relates her responsibility as a teacher as "merely" to ensure that all

students have access.

Responses typical of the third group (~40%) are well represented by the following reply to the same prompt:

“Yes, in terms of giving kids a chance to learn about a field that can lead to successful careers. If you don’t teach science, you’re closing off a potential avenue.”

This candidate notes a connection, but frames it teleologically. Her responsibility as a teacher, as she seems to conceive of it, consists of making sure her students have every opportunity to find their way into careers of their choice, and recognizing that knowledge of science can provide many such opportunities, seems duty-bound to keep those opportunities open.

End-of-semester responses to the same prompt were strikingly different. Almost every candidate (> 90%) was better able to articulate a connection between issues of equity and science that went beyond “mere” economic metrics, future employment opportunities, or issues of unequal access to science-laden extracurricular experiences. Two responses capture the two major themes reflected in much of the qualitative data around this prompt. Interestingly most candidates articulated both of these themes, indicating that both were relevant to their thinking. The first response recognizes science as an important way of knowing:

“Yes. Science has become an important lens. If we don’t teach science, we’re not giving our students the opportunity to understand things from a really powerful point of view.”

Here, the candidate has come to recognize that science is one of humanity’s

master narratives, and seems to recognize that depriving a child of the opportunity to understand the world from a scientific viewpoint by omitting it from the curriculum is an ethical decision that is not easily justified.

The second response also illustrates a connection between science and issues that will increasingly dominate our lives, and in addition, reveals a more sophisticated view of the connection between science and equity. When asked if she could articulate how a knowledge of science might be connected to social issues, this student replied:

“After this class, definitely!! I can see how knowing about science is very much related to important social choices, like environmentalism, or global warming, or any number of issues like that.”

Her response to a follow-up question reveals how her awareness of the connection between science understanding and issues of equity are related to her conception of her responsibility as a teacher:

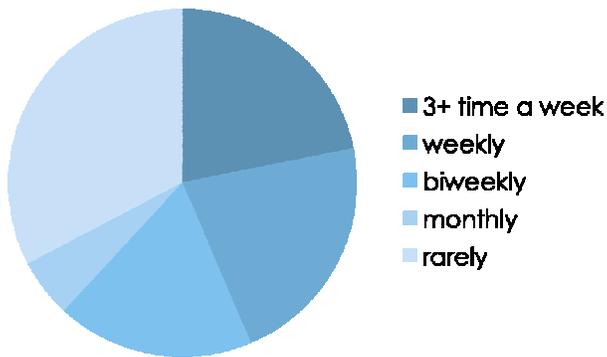
“We’re all on the same planet, and as big as it is, there are so many of us that we’re no longer free to act like it’s infinite. We all have a responsibility to be aware of problems, and along with that, we all have the right to be involved in solutions too, and knowing some science is a big part of that. If I don’t teach science to my kids, what I’m doing is denying them that right. It’s my job as a teacher to make sure rights like that are preserved.”

### *Quantitative Results*

Chi square analysis of quantitative data showed a significantly increased awareness of the connections between teaching science and a teacher’s ethical responsibility ( $p < .05$ ), science understanding and equity ( $p < .05$ ), as well as a

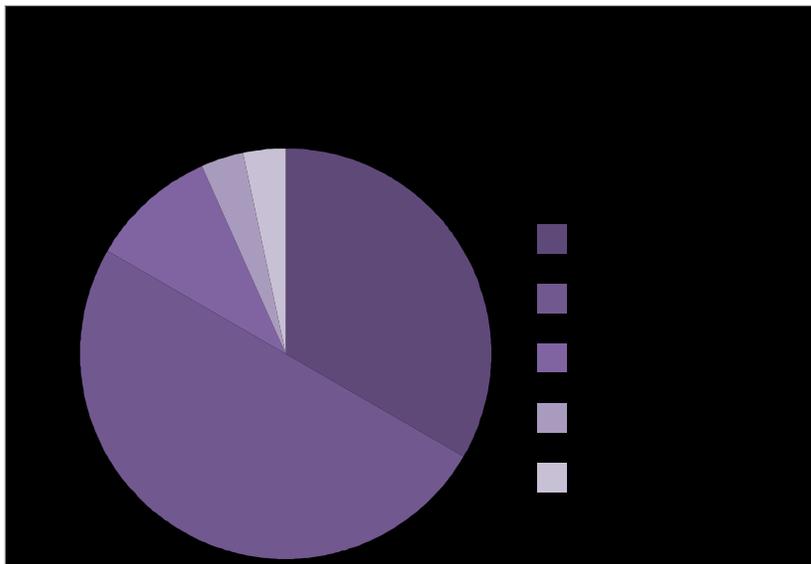
significant increase in self-reported motivation to spend more time on science instruction in their own classrooms ( $p < .05$ ). We are reluctant to share more details of our quantitative results, however, because we feel that the quantitative data we were able to gather as well as the method we used to gather it gives rise to the very real likelihood that errors due to both sampling and non-sampling bias significantly influenced our findings, despite the fact that the effect size we observed was quite large. This, coupled with the low statistical power of our analysis due to the relatively small number of participants we surveyed leads us to invest little confidence in the positive predictive value of our statistical conclusions. However, although we stop short of claiming the conclusions based on quantitative data that we offer are statistically meaningful, we do note that they are consistent with what we were able to conclude based on qualitative data. For example, a comparison of pre-semester and post-semester data regarding the frequency that candidates thought they would engage in science instruction in their future classrooms suggests that the ability to make connections between science and equity and to view the teaching of science as an ethical responsibility may result in an increase in instructional time they devote to science instruction. Figure 1 shows pre-study response frequencies, indicating that more than half of the pre-study candidates envisioned themselves teaching science once every two weeks, or less. Figure 2 shows post study response frequencies, indicating that more than 80% of the post-study candidates envisioned themselves teaching science at least once a week.

**Frequency of Science Lessons**



**Figure 1: Frequency that pre-study candidates envisioned themselves teaching a science lesson to their students**

**Figure 2: Frequency that post-study candidates envisioned themselves teaching a**



**science lesson to their students**

As the two figures illustrate, post-study candidates indicate that they envision themselves teaching science far more frequently than they did when the semester began. Interestingly, half of the post-study students indicated that they envisioned themselves teaching science weekly, but not 3 or more times a week. When asked what they envision

would prevent them from teaching science more often than weekly, many candidates expressed concerns that administrative restrictions and emphasis on high-stakes testing in other subjects would interfere with their ability to teach science every day, despite what they might want to do. A typical response follows:

“Well, yeah! I mean, if I had my own school, maybe I would teach science every day! But where I volunteer, everybody’s worried about the test scores. I know I wouldn’t be able to teach science every day. They have to teach math and reading, math and reading. Everything else is extra, and they have to fight to put it in.”

Our next steps are clear. This exploratory study has convinced us that this avenue is worth the time, effort, and expense required to design and conduct a more robust investigation of the phenomena involved. Currently, we are designing such an investigation, and plan to begin gathering both qualitative and quantitative data in Fall, 2011.

### **Scholarly Significance**

Recognizing that teacher preparation programs are well positioned as "key change agents," the UN declared the decade from 2005-2014 as the United Nations Decade of Education for Sustainable Development, with a goal “to integrate the principles, values, and practices of sustainability into all aspects of education and learning” (UNESCO, 2005, para 4). We are more than halfway through that decade, and although many of us are becoming increasingly aware of the pressing need to live sustainably, we have a long way to go: the average U.S. citizen’s lifestyle requires the equivalent of more than six Earths to support it – five Earths too many (Center for

Sustainable Economy, 2010). As UNESCO (2005) points out, we must learn our way out of this problem.

This project is concerned with far more than simply encouraging elementary teachers, many who do not have strong science backgrounds, to include more science instruction in the nation's classrooms. It is an exploration of the fundamental question that every educator must answer: What is an education for? David Orr (2004) reminds us that education for education's sake is at best foolish, and at worst, destructive: when we train teachers, engineers, accountants, scientists, lawyers, and artists in a vacuum that does not help them understand the environmental consequences of actions, we are doing nothing more than training them "merely to be more effective vandals of the Earth" (p. 5). In the presence of so much information that points toward ecological collapse – a warming climate, over-fished oceans, unprecedented rates of species loss, ever-increasing rates of consumption of non-renewable resources, oil spills and radiation leaks - it is difficult to maintain optimism for the future of the ecosystem. It is not, however, difficult to maintain hope. Orr (2007) illustrates the difference between the two: "Optimism is the recognition that the odds are in your favor; hope is the faith that things will work out whatever the odds. Hope is a verb with its sleeves rolled up. Hopeful people are actively engaged in defying or changing the odds" (p. 1392). This project is a recognition that teachers are our best hope.

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