


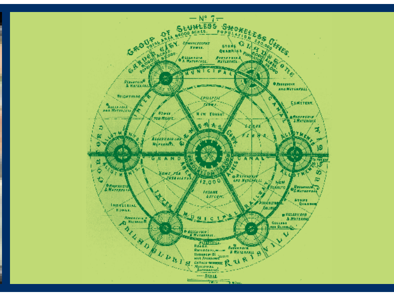


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Contents

From the Editors

This issue of the *Journal* opens with the first installment of a two-part essay by Wm. David Burns, which is based on his welcoming address at the 2010 SENCER Summer Institute at the Asheville campus of the University of North Carolina. As many of you already know, David has been a longtime advocate of engaged science education through his roles as Executive Director of the National Center for Science and Civic Engagement at Harrisburg University; as principal investigator of the SENCER and GLISTEN projects; and as the publisher of this journal. In part one, David reflects on the conceptual foundations of the SENCER approach and its goal of creating a critical intersection between science education and practice and democratic education and practice. In part two, to be published in the next issue of *SECEIJ*, he will summarize some of the lessons learned from over a decade of experience with SENCER-inflected STEM education reform.

In the category of Teaching and Learning, Farahnaz Movahedzadeh (Harold Washington University) explains the pedagogical strategy of "blended learning"—which includes both classroom and online components—and shows how this method improved students' attitudes towards science. The article is accompanied by an essay written by a student in the course, Eric Wozniak, who shares his first experience with a blended/hybrid course.

The issue contains three Project Reports that address diverse approaches to effective science teaching in the context of civic issues. Susan M. Mooney and Karen L. Anderson (Stonehill College) describe a collaboration between college students and community partners to design and implement innovative science instruction in resource-limited urban classrooms. Alan J. Friedman (a distinguished consultant for museum development and science education) and Ellen F. Mappen (National Center for Science and Civic Engagement) provide an introduction to the new SENCER-ISE project, which is establishing connections between formal and informal science educators with the goal of advancing STEM learning. Science and math educators who teach in traditional classroom environments can learn valuable lessons from the strategies of engagement that are used by the informal education community. The third project report addresses the complex topic of traffic in Los Angeles and is written by an appropriately interdisciplinary team: Nageswar R. Chekuri, Zelda Gilbert, Nick Roberts (all from Woodbury University), Anil Kantak (Jet Propulsion Laboratory), and Ken Johnson (City of Burbank, Public Works Department).

Many issues of civic importance are connected to the generation and consumption of energy. As a resource for educators, Pamela Brown (New York City College of Technology) and Heather Brown (University of Aberdeen) have written a Science Education and Public Policy article that examines the relationship between energy policy and technological innovation in the United States. They provide extensive data to show how the research and development investment in renewable energy sources is affected by the price of oil—lower oil prices correlate with fewer renewable energy patents—and how this pattern is repeated cyclically within the U.S. economy, which leads to a lack of long-term strategic planning for renewable energy development.

We wish to thank all the authors for sharing their work with the readers of this journal.

— *Trace Jordan and Eliza Reilly*
Co-editors in chief

TEACHING AND LEARNING

"But You Needed Me"

Reflections on the Premises, Purposes, Lessons Learned, and Ethos of SENCER PART 1

Wm. David Burns

Publisher, Science Education & Civic Engagement—An International Journal

This article is based on the opening plenary address at the tenth annual SENCER (Science Education for New Civic Engagements and Responsibilities) Summer Institute delivered by SENCER's co-founder, the article's author. SENCER, supported by the National Science Foundation, works to improve learning and strengthen civic engagement in undergraduate courses that teach through complex, capacious, unsolved civic issues to canonical knowledge and practice in STEM and other fields. Part one appears in this issue.

Introduction

At the SENCER Summer Institutes, I always acknowledge the sacrifices that our participants are making to take time away from their families to think about STEM education and civic engagement. Then I reference my own family and give an update on my twin daughters, Caroline and Helena, who are now fifteen years old.

Last summer, I reported some good news to those gathered for our Institute at the University of North Carolina in Asheville (UNCA). Our daughters had moved from thinking that science is "just definitions, Daddy," to something much more encouraging, something closer to "science as practice."

This happened after Helena got a chance, as an eighth grader, to "teach" basic geology to fourth graders. Both girls finally began doing some rudimentary labs, and they started getting better at math. Much of the shift in their thinking can be credited to good teaching, made possible in Caroline's case after we got her moved from a class whose instructor she had described as having been "deceased."

Things were going so well, indeed, that our girls were among a handful of ninth graders invited to take the junior-level honors chemistry course. I found this prospect terrifying. They, however, were excited. As I write this they are about to finish their freshman year in high school. They've studied really hard with a terrific teacher, done countless Moodle-based homework assignments and exercises, and completed many labs. Miraculously, they still seem to love chemistry, even if they wish their grades were a tad higher.

Our daughters were only eight months old the last time our family visited Asheville. (That was a trip!) We were there to participate in the Asheville Institute on General Education, a remarkable program then co-sponsored by UNCA and the Association of American Colleges and Universities (AACU). I was working at AACU at the time establishing the Program for Health and Higher Education (PHHE).

The book we eventually wrote on PHHE, *Learning for Our Common Health*, summarized our program as follows:

> [PHHE] centers on a complex social problem, framed within a simple, powerful approach. We ask: if higher education would place a strong, academic focus on a problem—such as HIV and health—would the end result advance our greater expectations for student learning, academic rigor, faculty authority, collaborative leadership, social responsibility and civic engagement? Moreover, would such a strong academic focus lead to solutions to the complex problem itself? In a word, we think the answer is yes (Burns, 1999).

That was the notion we were working on fifteen years ago. At the time the idea seemed a bit odd to most people. What did HIV have to do with liberal education? In the mid-1990s, a few scholars saw the enormous potential in "materializing" otherwise abstract notions like liberal education, critical thinking, interdisciplinarity, and civic engagement in real world problems requiring urgent attention. Now, nearly everybody talks about making learning, especially STEM learning, real and relevant. The first part of this two-part article will attempt to consider this shift in thinking and to suggest where we may be going. I will introduce newcomers to the SENCER approach and suggest how SENCER helps occupy a critical intersection between science education and practice and democratic education and practice. In part two, to be published in the next issue of *SECEIJ*, I will summarize of some of the lessons we have learned from this work and I will outline four promises that those embarking on SENCER-inflected STEM education reform ought to consider making to one another.

Origins

Back in the late 1980s, I was an administrator at Rutgers, The State University of New Jersey. I had responsibilities for student health among other things. Our health educator, Peggy Clark, who lived in New York City, brought us early and alarming news. She told us about something called GRID (Gay-Related Immune Disorder) that was taking the lives of young people in the city. We now call GRID HIV disease.

The more we learned about AIDS[1] in the 1980s the more alarmed we became, especially because we knew so much else about patterns in our students' private lives. Students' sexual activities (and their alcohol and drug use) exposed them to particular risks if, in the course of these activities, the intracellular parasite of HIV was also present.

AIDS was complicated. June Osborn, the first chair of the president's commission on AIDS, famously called HIV disease "multidisciplinary trouble." (Osborn 1986) As the set of issues she identified began to emerge in spiraling and stunning ferocity, some of us believed that a whole generation of young people would die. Many did. (That many did not is a topic that also deserves investigation.)

We needed to act. Cooperative agreements from the United States Centers for Disease Control and Prevention (CDC) supported a national higher education response.[2] The agreements focused on work in policy development, teacher education, and prevention education. As the principal investigator and director of one of the first five national agreements, I looked over our efforts at Rutgers and other places. I saw some innovative co-curricular programs, some impressive bench research, and modest attention in pre-professional training targeted on what many were calling a "modern day plague." What I didn't see at Rutgers was anything about AIDS in the curriculum. You could take introductory biology and never hear about AIDS. You could major in criminal justice and not study the relationship of prisons to the AIDS epidemic. You could prepare to become a teacher and not receive instruction of how to manage a classroom situation in which child living with AIDS was enrolled. As far as AIDS was concerned, our college classrooms were, at least at first, zones of silence.

I wanted to change that, not because I cared so much about learning or science education, but because I genuinely wanted

1 The changing names for GRID, AIDS, HIV disease reflect emerging notions about the phenomenon. See Rosenberg (1962) for another example. I am indebted to Professor William Cronon for this suggestion.

2 The Rutgers program was supported by a cooperative agreement from the Centers for Disease Control and Prevention, Division of Adolescent and School Health. The program is described in this excerpt from an article in *Public Health Reports*: "In 1990, CDC awarded a cooperative agreement to a university in each of five States among those with the highest cumulative incidence of AIDS. Each university will establish a consortium of colleges, universities, trade schools, and other agencies in the State to develop and implement education programs that could prevent the spread of HIV infection and other health problems among college students in the State and to train school administrators and teachers to help implement effective health and HIV education. The five universities are Illinois State University, Rutgers, The State University of New Jersey, San Diego State University, Southwest Texas State University, and the University of Central Florida. Additional support has been provided to Rutgers and San Diego State to enable each of them to train teams of personnel from universities in other states who may be interested in establishing such consortia in their own states." (Moore et al. 1991)

to save lives. I thought that if students had a chance to seriously and deeply learn about HIV, they would be inclined to act to reduce risk and harm.

We changed the condition of curricular silence by developing a course called "HIV, Biology, and Society," created and taught by talented educator Monica Devanas. Interest in the course was overwhelming; if I recall correctly, more than 600 students tried to enroll at its first offering. We finally admitted 450 or so. The students, mostly non-STEM majors who had put off taking required courses in science as long as possible, loved the course. We also created a whole set of what we called "wrap-around" courses, short courses in fields of student interest through which they could enter the foreign territory of biology (these ranged from journalism to Africana studies, poetry to criminal justice and teacher education). Thousands of students have been enrolled in the years since.[3]

I provided the money to get the course started and to have it professionally assessed and evaluated because I had hoped for particular results. The results I hoped for turned out not to be the results we achieved. Behavior didn't change much. We now know why—the subject of another article, but the short explanation is: you rarely get what you don't teach. Learning really did change, though. Indeed, the gains in learning were significant.

Why? Because of a few things, I think: one, the students were interested, they had a stake in what they were learning, and they had a need to know. That stake made the learning "sticky" to use Malcolm Gladwell's notion (Greenberg 1994; Gladwell 2000). The knowledge stayed around a while longer than a minute after the test. Second, the story of HIV—its emerging narrative—was one that gave students a framework, an intellectual skeleton, you could say, on which to "hang," organize, or fix the elements of biology, virology, immunology, epidemiology, and sociology they were learning as they confronted the trans-disciplinary phenomenon of HIV. Not only was HIV multidisciplinary trouble of the sort that they would see develop as a complex, capacious, civic question with political and personal consequences, but it was a story whose ending no one, neither teacher nor student, knew. We did know, however, that it was something we needed to follow, both personally and as citizens in a democracy.

Regarding their relationship to the science we hoped they would learn, the students in the AIDS course were what cognitive theorists call "novice" learners. Novices, that is, as opposed to so-called "expert" learners. Novices process traditional learning differently from experts (Bransford et al. 2000; Etkina and Mestre 2008).

But when novices are called upon to do real investigations of things that matter, they begin to function more like expert researchers do. By pursuing research interests and performing as scholars, novices are following a story, question, or interest and then going where the investigation leads them. They are not trapped in abstractions like those that temporarily ensnare students in a traditional introductory course. (I am thinking of the courses that, from the students' perspective may look like high hurdle races, but turn out to be academic bridges to nowhere.) The students in our AIDS course didn't have to ask "what do I need to learn this science for?" The course, itself, answered that question.

We saw that this way of teaching science worked not just at Rutgers, but nationally as well, after we established the CDC-sponsored Program for Health and Higher Education at AACU. It was through PHHE that I met Karen Oates, who had created one of the first HIV courses in the nation that was anything like what we had done at Rutgers. Karen later became my co–principal investigator in founding SENCER.

From HIV Prevention to STEM Education Reform

Karen and I discovered that we had an approach to science education that worked because it focused on matters that were real, relevant, interesting, and indeed vital to personal and civic welfare. The approach embodied what was known about how students learn. And it helped academic leaders achieve two elusive goals: improving the science part of the general education curriculum and assisting institutions in meeting their missions to educate students for civic engagement.

We were invited to make a proposal to a new program—the CCLI (Course Curriculum and Laboratory Improvement) "national dissemination" track—that the National Science Foundation was launching. We were also challenged by a National Science Foundation (NSF) program officer, Myles Boylan, to show that what seemed to be working on a matter of public health centered in bio-science—HIV—could work with other STEM-connected matters of civic consequence. With the help of a generous planning grant from NSF, we were able to respond to the challenge of diversifying our portfolio of both civic challenges and disciplinary applications.

3 I describe the genealogy and other dimensions of the project in more detail in Burns (2002).

SENCER has been made possible by the support that NSF entrusted to us. We see our role as working in support of NSF's mission. That mission embraces not just the advancement of scientific knowledge for the public good, but also advancement of the public's understanding of science for the good of our economy, our welfare and our democracy.

Why do these investments by NSF and others matter? Because at no time have there been more opportunities for more college students to pursue study in the STEM fields, and yet few students are making that choice. At the same time, our capacity for understanding and conscientiously dealing with issues we face as a nation requires the skills and habits of mind developed in STEM study. Beyond that, many of the most vexing problems we face are themselves products of advances in science, engineering, mathematics and technology. (For example, we have a stem cell debate because we have identified what a stem cell is; we wrestle with cyber privacy issues because we have invented cyberspace).

A lot is at stake: We now have institutions too big to fail, systems too complex to fail, and yet we experience failure with what feels like increasing frequency.[4] There seems to be more to do every day to meet the challenges that complexity and modernity have thrust before us, let alone the legacies of problems that we have inherited from the pre-modern era.

SENCER was created to give faculty, academic leaders, and students opportunities and resources to develop, teach, assess, and improve courses that teach *through* such complex, capacious civic questions *to* the basic science, or other canonical learning (be it in physics or economics or English literature) desired. In so doing, we hope to improve learning and stimulate civic engagement, in its broad variety of manifestations.

"The world is not parsed out like a college curriculum."[5] The best SENCER topics are so complex and so embody the idea of multidisciplinary trouble that they require the intellectual power of a variety of disciplines for their full elucidation and exploration. They break traditional boundaries and make the case for interdisciplinary inquiry, global learning, critical thinking, collaboration, and continuous attention and exertion. Even though the courses are often taught as introductory excursions in learning or capstone projects, as Robert Full has observed, they look like advanced research because their intellectual challenges resemble those being tackled by high-end research (see, for example, Full 2007) . They are essentially interdisciplinary, so they are more like the world itself than a typical undergraduate curriculum. In the words of one of our leadership fellows, this is "what a valid liberal arts education should include." (McKenzie 2008)

While SENCER is a name we invented that is not as old as my daughters, it is not exactly a new idea, whatever a new idea might be in the twenty-first century![6] The SENCER approach has deep intellectual roots: in Aristotle, the enlightenment thinkers, the land grant and extension movements, the pragmatism of William James, in constructivist approaches to learning and knowledge production, and in the work of modern cognitive scientists and learning specialists like John Bransford and Rick Duschl, both of whom have advised the SENCER program.

NSF support and the ingenuity and enterprise of faculty and students around the country and in other parts of the world[7] have enabled us to develop model courses and programs on the broadest range of topics in virtually all STEM disciplines. These have changed the story of undergraduate STEM education from the "definitions Daddy" content-laden and easily forgotten introductory courses that, in the words of one anonymous observer from one of our programs, encourage students to "dress up for parties they don't intend to attend and probably will never be invited to." SENCER courses, in their best manifestations, provide students and teachers to authentic experiences in discovering what science and mathematics have to tell us about what we need to do about some of the biggest issues that we will face, as individuals and

4 The May 16, 2011, *New York Times* reports on the lax oversight of Japanese nuclear power plants, for example.

5 Woody Mckenzie (2008), a SENCER Leadership Fellow from Lynchburg College, wrote: "SENCER is essentially an outlet for me to validate my own ideas of what a valid liberal arts education should include in the information age. More emphasis should be placed on interdisciplinary courses. The world is not parsed out like a college curriculum."

6 Janet Emig (1983, 166) writes "I have fully described the notion that the presence of an explicit or at least tacit intellectual tradition is requisite for a full and self-respecting inquiry paradigm, as acknowledgement of that tradition is requisite for any self-respecting paradigm inhabitant… The reason the only decent and scholarly ploy is to know and to acknowledge one's sources is that, at this very late date in human intellectual history, it is deeply unlikely that at least those of us who work in the humanities—that non-cumulative endeavor—will have a wholly original idea."

7 As of January 2011, more than 1,800 representatives from 8 percent of all accredited two- and four-year U.S. colleges and universities have participated in SENCER Summer Institutes and the DC Symposia. These 393 institutions represent forty-six U.S. states and all major Carnegie classifications and thirteen countries outside of the United States. Leaders from many more institutions have attended other SENCER-sponsored workshops.

members of a democratic society.[8] They also help students learn the limitations of science[9] and explore the connections between science, public policy, and personal and civic responsibilities.

Science Education and Democratic Education

Good science education supports good democratic education and *vice versa*. The relationships between scientific and democratic practices is too large a topic for this article,[10] so let us consider just one common element between the approach to STEM education we take in SENCER and a cardinal element in democratic practice.

"Interest" is a driving force in the SENCER ideals, as central to our pedagogy as it is to democratic process. How does interest work in learning? Here is William James (1899), the great American pragmatist philosopher and a founder of what we call psychology, on interest, from a book called *Talks to Teachers* published near the end of the nineteenth century:

> Any object not interesting in itself may become interesting through becoming associated with an object in which an interest already exists. The two associated objects grow, as it were, together; the interesting portion sheds its quality over the whole; and thus things not interesting in their own right borrow an interest which becomes as real and as strong as that of any natively interesting thing. . . .
>
> The most natively interesting object to a man is his own personal self and its fortunes. We accordingly see that the moment a thing becomes connected with the fortunes of the self, it forthwith becomes an interesting thing (94). . . .
>
> From all these facts there emerges a very simple abstract program for the teacher to follow in keeping the attention of the child: Begin with the line of his native interests, and offer him objects that have some immediate connection with these. . . . Next, step by step, connect with these first objects and experiences the later objects and ideas which you wish to instill. Associate the new with the old in some natural and telling way, so that the interest, being shed along from point to point, finally suffuses the entire system of objects of thought (96).

James (1899) concludes:

> The difference between an interesting and a tedious teacher consists in little more than the inventiveness by which the one is able to mediate these associations and connections (96).

When he writes "the most natively interesting object to a man is his own personal self and its fortunes," James is offering us a glimpse of not just of how to teach and how to reach students or one another, but of how to make a fundamentally democratic claim. What James is describing recalls Locke and Jefferson in reminding us of our inalienable rights—rights that democracies secure to individuals and that, when exercised in concert with other citizens, constitute what de Tocqueville observed and what political scientists have identified as "pluralism," itself something that begins in association.[11]

8 See the SENCER web site, www.sencer.net, for a complete list of SENCER model courses and search access to our digital library, hosed at Carleton College's Science Education Resource Center (SERC).

9 See the SENCER ideals at http://www.SENCER.net/About/pdfs/SENCERIdeals.pdf

10 Though we do not think of him as a democratic theorist, I cannot resist calling attention to Edmund Burke's famous observation that expresses the essential point I hope to be making: "The science of constructing a commonwealth, or renovating it, or reforming it, is, like every other experimental science, not to be taught a priori." (Burke 1871, 311). For more on democratic theory and some authors to whom I am indebted for my thinking, see, for example: Dewey (1929), Gutman (1987), Barber (1984), Thompson (1970), Connolly (2002), and O'Neill (2002).

11 That "special interest group" is now largely a term of derision is just one more unfortunate perversion of democratic ideals. See, for example, Dahl (2005) for a classical discussion of pluralism, a concept that has sparked lively debates and whose contemporary literature is especially relevant to those developing civic engagement projects. The Toqueville reference is, of course, to *Democracy in America*, where he writes: "Thus the most democratic country on the face of the earth is that in which men have, in our time, carried to the highest perfection the art of pursuing in common the object of their common desires and have applied this new science to the greatest number of purposes. Is this the result of accident, or is there in reality any necessary connection between the principle of association and that of equality? Aristocratic communities always contain, among a multitude of persons who by themselves are powerless, a small number of powerful and wealthy citizens, each of whom can achieve great undertakings single-handed. In aristocratic societies men do not need to combine in order to act, because they are strongly held together. Every wealthy and powerful citizen constitutes the head of a permanent and compulsory association, composed of all those who are dependent upon him or whom he makes subservient to the execution of his designs. Among democratic nations, on the contrary, all the citizens are independent and feeble; they can do hardly anything by themselves, and none of them can oblige his fellow men to lend him their assistance. They all, therefore, become powerless if they do not learn voluntarily

In democracy and in learning it is an act of generosity—and a savvy political strategy, as well—to genuinely engage a person's self interest, as s/he perceives it, and then to move to an exploration and consideration of other common or group interests. After all, democracy is a scheme that respects a person's interests and at the same time provides a system for permitting those interests to influence the work of democratic institutions.

The practices of scholarship—especially the research practices we employ in science and in scientifically inflected inquiry—correspond to many of the key elements in what I will call democratic practice.[12] Bringing these practices together in the study of matters of civic consequence in college courses, civic engagement activities, and/or authentic research constitutes a mutually reinforcing gesture and strategy.

On the fiftieth anniversary of C.P. Snow's "Two Cultures" (1959) lecture that lamented the separation of scientific and non-scientific competencies among educated people, Congressman Rush Holt (2009), a physicist by training, had this to say:

> The United States has had, over the centuries, really until roughly fifty years ago, a very scientific bend. It was not a coincidence that [the writers of] the Constitution called themselves in many cases, "natural philosophers." Back then, that was the equivalent of our word scientist today.
>
> The founders were thinking like scientists; they were asking questions so they could be answered empirically and verifiably. That's what science is. It is a system for asking questions so you can answer those questions empirically and in a way that others can verify your empirical tests for those answers.
>
> Every shopkeeper, every farmer, every factory owner throughout American history has had this scientific tradition. It was common for Americans to think about how things work and how they could be made better and made to work better.[13]

He observed:

> We're at a time now where, if I talk to most of my colleagues in Congress, most of your colleagues at the college or university, or any American on the street, however well educated, however able, however smart, they will likely say, "Oh, science, oh no, I'm not a scientist. I can't understand that, that's not for me."
>
> And thus we are deprived of the scientific way of thinking. The scientific way of thinking is important not just for developing new technologies, but for creating the kind of self-critical, self-correcting, evolving society we need to create. The whole balance of powers in our constitution, the whole idea of openness that we embrace as a democracy, these are very scientific in nature.

Now when Holt was speaking at a Capitol Hill event sponsored by NCSCE's National Center, he was a scientist/politician speaking as a scientist and a political theorist. But what he is describing about "method" isn't just the method of scientists. Historians don't just guess, or say whatever first comes to mind. Scholars of literature don't hide evidence that would undermine something they'd like to say. All good scholarship entails being self-critical and self-correcting. So I want to use "science" in the "natural philosophy" way that Holt

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to help one another. If men living in democratic countries had no right and no inclination to associate for political purposes, their independence would be in great jeopardy, but they might long preserve their wealth and their cultivation: whereas if they never acquired the habit of forming associations in ordinary life, civilization itself would be endangered. A people among whom individuals lost the power of achieving great things single-handed, without acquiring the means of producing them by united exertions, would soon relapse into barbarism." (Tocqueville 1997, ch. 5).

12 This is a point that often gets lost on folks who equate democracy with voting and science with truth finding. One might fix speed limits though voting (though we generally do not), but we would never "determine" the speed of light by holding an election. This is not as simple as I have made it, however, as we witness with some frequency, contestants in civic questions "toting up" the numbers of scientists, members of the National Academies, and/or Nobel laureates who believe one way or another.

13 Again de Tocqueville, writing in 1840, has something to add to Holt's analysis and our understanding: "In America the purely practical part of science is admirably understood, and careful attention is paid to the theoretical portion which is immediately requisite to application. On this head the Americans always display a clear, free, original, and inventive power of mind. But hardly anyone in the United States devotes himself to the essentially theoretical and abstract portion of human knowledge. In this respect the Americans carry to excess a tendency that is, I think, discernible, though in a less degree, among all democratic nations. Nothing is more necessary to the culture of the higher sciences or of the more elevated departments of science than meditation; and nothing is less suited to meditation than the structure of democratic society." (Tocqueville 1997, ch. 10) I suppose you could say that the National Science Foundation was created specifically to create that opportunity for "meditation" represented by investments in "basic" research.

suggests, as a way of speaking about a system of inquiry and a set of political and moral practices.

We can carry Holt's ideas a bit further if we speak about the intellectual and moral practices embraced within the STEM fields and research, generally. We can say that science is value-neutral, though that is a much-debated claim. That debate needn't concern us here. Whether neutral or not, science certainly embraces a particular value system, as does democracy. Both are processes to deal with realities that are changing or being changed through observation or perturbation, itself. Both have rules and standards for conduct. At their best (perhaps in their idealized states), both are deliberative processes that rely on honesty and integrity and eschew suppression of evidence, especially evidence that contradicts the desires of practitioners and proponents (we could use more of this in our democracy). Both see results and findings as provisional.

Democracy's work is provisional, temporary, the best we can do at this time. It is public. So is the work of science. In being held it up to peer and public scrutiny, our work gets critiqued, sometimes venerated, sometimes trashed, sometimes both venerated and trashed. The work of scholarship and the work of democracy is messy, tedious, unpredictable, often onerous. Teaching is even harder. The ingenuity that James credits with making for good teaching takes lots of energy and a bit of daring, too. Democracy, too, asks more from each of us in order for it to work. But as my mother used to say, "it's just work, so get busy."

It is work we do need to do, however, if we are to learn and if we are to advance knowledge and create a civil society that prizes liberty, stays fresh, and promotes something we can call a public good. It is work that our SENCER colleagues and students have embarked on campuses and in communities. This work has paid dividends to those who are doing it and to those of us who have reconnected STEM education and civic engagement. In part two of this essay, I will discuss some of the lessons we have learned in doing this work and I will suggest conditions that, if present, augur well for the success of future reform efforts.

About the Author

Wm. David Burns is the founder and principal investigator of SENCER, the NSF-supported national dissemination project. He is also executive director of the National Center for Science and Civic Engagement and professor of general studies at the Harrisburg University of Science and Technology. Prior to establishing the National Center, he served as senior policy director for the Association of American Colleges and Universities (AACU). During his nine years with AACU, he established the CDC-sponsored Program for Health and Higher Education and created the Sumner Symposia dedicated to exploring the power that students have to improve the health of colleges and communities. David is the principal author and editor of *Learning for Our Common Health* and, among other publications, the article, "Knowledge to Make Our Democracy."

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TEACHING & LEARNING

Improving Students' Attitude Toward Science Through Blended Learning

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Why Science is Important for Non-Science Majors

Regardless of one's major or profession, science plays an enormous role in everyone's life. From discovering cures for diseases, to creating innovative technologies, to teaching us how to think critically, science has become an indispensable feature of modern society. Controversial issues such as global warming, evolution, vaccination, HIV/AIDS, and the right to one's own DNA information are only a few of the issues being debated. Biology in particular has generated its share of controversies, including evolution, cloning and genetic engineering, global warming, premature species extinction, animal rights and animal suffering, human overpopulation, and the right to determine the timing and means of one's own death, to name a few (Leonard 2010).

Scientific discoveries shape the way we view the world and influence our decisions. Indeed, as reported in *Discover* (2010, 1) magazine, the scientific discoveries in the last thirty years have "touched nearly every aspect of our daily lives." Science teaches people how to think critically about not just scientific subjects, but all subjects. As Schafersman (1994; 1997) explains, the scientific method has proven to be "the most reliable and successful method of thinking that "results in the acquisition of reliable knowledge" (1997, ¶ 2), and therefore scientific thinking can and should be used in other human endeavors. People use the methods and principles of scientific thinking in everyday life, such as "when studying history or literature, investigating societies or governments, seeking solutions to problems of economics or philosophy, or just trying to answer personal questions about oneself or the meaning of existence" (Schafersman, 1994; 1997, ¶ 4). In short, whether we are aware of it or not, science is an integral part of our lives—even if we are non-science majors.

However, despite the fact that science informs our thoughts and behaviors, many people do not seem to place a high value on science. Studies report that the general public (that is, non-science majors) does not generally have positive feelings toward science and scientists (Rogers and Ford, 1997). These findings are unfortunate because such attitudes may have negative effects on the entire society. Since non-science majors are potential lawyers, presidents and managers of companies, politicians, and civic leaders, they will influence how research and development funds are spent, how scientific discoveries and technological innovations are implemented, and how scientific evidence is used in courts and other social organizations. An appreciation of science may provide a positive influence on these decisions (Rogers and Ford, 1997).

In addition, a positive attitude toward science may improve students' academic performance in not only science classes, but in other classes as well. Why should this be so? Science is a way of knowing and understanding through the exercise of reason, a construction of the mind based on actual observation to explain natural phenomena. Science, by choice, "is limited to questions that can be approached by the use of reason, questions that can be answered by the discovery of objective knowledge and the elucidation of natural laws of causation" (Futuyma 1983, 170). The practice of the discovery of objective knowledge involves observation of events (or the acquisition of data), followed by inference regarding possible causes (forming alternative hypotheses), and, finally, testing to select the best explanations (Cherif et al. 2001; Moore 1993). The mental discipline and rational approach of "the scientific method" have been successfully adopted in many other disciplines, such as business, law, the social sciences, and others.

It is therefore in the interests of society, and the responsibility of educators, to improve students' attitudes toward science, and to prepare students to live in a highly scientific and technological society. The future of our society will be determined by citizens who are able to understand and help shape the complex influences of science and technology on our world (Ungar 2010).

Why Negative Attitudes Toward Science Exist

Some students have developed negative stereotypes of science and scientists, whom they view as "nerds" or "mad scientists." Others describe scientists as "hard," "old," "frightening," and "colorless" (Rogers and Ford 1997). Several reasons have been suggested for these negative attitudes including students' undesirable experiences in previous science courses and with instructors, lack of needed skills to learn and apply scientific concepts, lack of motivation to work hard in science classes, home backgrounds, school and classroom environments, biases of peer groups, the media's portrayal of scientists, and students' perceptions of rewards associated with learning, to name a few (Rogers and Ford 1997). Science anxiety, the fear of science learning, and apprehension toward scientists and science-related activities are also results of these factors (Rogers and Ford 1997).

The way science is taught, both at the high school and college level, also plays a major role in shaping students' attitudes toward science. According to a study by Cherif and Wideen (1992), which addresses the question of whether a problem exists for science students moving from high school to the university, students are being presented with selected aspects of scientific dogma at the high school and university levels rather than being taught the innovative and visionary character of science and the value that such knowledge has to the educational process. Some of the students in this study reported that they were confused because the information they learned in college contradicted the information they gained in their high school science classes. As the study concluded, this dogmatic approach to teaching science, coupled with the drastic cultural changes that students undergo as they transition from high school to college, affect students' attitudes toward and performance in college-level science courses.

Though the development of desirable attitudes toward science is not the primary goal of introductory science courses, instructors usually recognize that attitude formation is one of the important aspects of instruction (Cherif and Wideen 1992; Garcia and McFeeley 1978). There is growing evidence that students who possess positive attitudes toward science will perform better academically. Russell and Hollander (1975), who created the Biology Attitude Scale—a tool designed specifically to measure students' attitudes toward biology—support this claim. "The tool was developed on the assumption that an important consequence of instruction is a positive change in the student's attitude toward the subject, and the authors argue the importance of focusing on attitudes by stating that there usually exists a positive correlation between attitudes and achievement" (Russell and Hollander 1975).

Most instructors, however, focus primarily on increasing the students' knowledge of the subject rather than increasing their favorable attitudes toward it. Many instructors assume that students will naturally acquire positive attitudes toward science as they learn more about it. However, a study by Garcia and McFeeley (1978) found that the positive attitudes of students toward biology in eighteen introductory biology courses at East Texas State University decreased by the end of the term. This necessarily raises the questions of how to improve students' attitudes toward science, and whether the way we teach science plays a significant role in this challenge. In short, it is not only what we teach but also how we teach that are important considerations in how to improve student success (Moore 1989).

How to Improve Attitudes Toward Science

Introductory science courses, such as biology, chemistry, and earth science, are usually required at the college level. It is important to keep in mind that non-science majors take science courses in college largely because they need to satisfy their liberal arts requirements, and not necessarily because they have a passionate interest in learning science. It is therefore not surprising that many students in these introductory science classes attend irregularly and do not take advantage of the extra help offered (e.g., meeting with the professor outside of class, going to tutorial and learning centers, doing extra credit). Studies show that students who attend all or most classes perform better academically, and good attendance is associated with high motivation. In other words, the most successful students are usually the most highly motivated; they are most likely to come to class, do extra-credit work, and attend help sessions (Moore 2006). A highly motivated student is usually one with a positive attitude toward the subject s/he is learning. Therefore, in order to improve students' attitudes toward science, faculty must motivate students, which they can do through their teaching styles and by showing them the relevance of the learning topics to their everyday lives. In addition, they must create the learning environment that helps motivate students not only to come to classes but also want to learn and enjoy learning.

Etkina and Mestre (2004) suggest that instructors of introductory science classes try to motivate their students by asking them to consider the preconceptions about science-related topics that they bring to the class. In a biology class, for example, teachers can ask students the following questions: "What do you know about HIV and about how AIDS is transmitted? What do you think is the reason that some cancers are curable and others are not? What do you think about genetic engineering, about cloning, about stem-cell research—are these good or bad things, and under what circumstances" (Etkina and Mestre 2004, 18). Questions like these will demonstrate to students that there are others in the class who have similar views and concerns, that there is a diversity of views in the class, and that they cannot all be scientifically correct. This divergence of views leads naturally to discussions about the process of doing science (experimentation, evidence-based model building, hypothetical-deductive reasoning), the application of scientific discoveries, and the impact of science on society (Etkina and Mestre 2004). The resulting discussions can also help instructors move away from a dogmatic approach to the teaching of science—to a more engaging and interesting approach that encourages critical thinking rather than just fact accumulation.

Furthermore, using controversial issues to introduce topics and concepts in biology classes helps to "raise questions that deserve answers and also generate interest among students, and interest can improve motivation to learn biology" (Leonard 2010, 407). In addition, making the learning and the teaching of the topics more relevant to students' lives helps them see the value of science and in turn motivates them to develop a better attitude toward science and science education.

Hybrid Courses as a Way to Student Improvement

In an attempt to motivate students and improve their attitudes toward science, one important opportunity, at a time when technology plays such a prominent role in our lives, is for instructors to redesign their traditional courses using a hybrid model. Blended (hybrid) learning is defined as "a coherent design approach that openly assesses and integrates the strengths of face-to-face and online learning to address worthwhile educational goals. . . . [Furthermore, it] is fundamentally different and is not simply an addition to the dominant approach" (Garrison and Vaughan 2008, x). In this sense, hybrid or blended instruction is the integration of some of the conveniences of online learning with the traditional face-to-face instruction in the learning process (Humphries 2009; Rovai and Jordan 2004; Colis and Moonen 2001). While both onsite and online learning can accomplish course and program objectives, in a blended system, these modes of learning are combined in order to enhance the learning and teaching experience for both students and faculty. Using computer-based technologies and web-based course delivery, instructors use the hybrid model to redesign some lecture or lab content into new online learning activities, such as case studies, tutorials, self-testing exercises, simulations, online group collaborations, and threaded discussions (Garnham and Kaleta 2002). Blended learning systematically incorporates the use of asynchronous teaching (facilitated by computer-based technologies) into the traditional onsite teaching in order to maximize both teaching and learning opportunities (Hrastinski 2008). Although integrating technology into the classroom in small steps is part of a natural evolution of teaching and learning, a blended learning system includes a committed, sustained, and well thought-out implementation plan, combining appropriate technology with traditional classroom interaction, so that it leads to better outcomes for students (Garrison and Vaughan 2008; Mayers et al. 2006; Bonk and Graham 2006).

Early evidence suggests that hybrid courses may indeed lead to better student performance on exams, better student perceptions of and attitudes toward the course, and higher attendance rates (Riffell and Merrill 2005). Hybrid courses may be especially appealing for college introductory science courses because they typically contain, in addition to lecture: a laboratory component, problem-focused threaded discussion, and group work. While the lecture portion of these introductory science classes might be very large (100–400-plus students), in some colleges and universities, the laboratory class is much smaller (about thirty students), and lab exercises are more interactive, group-oriented, and targeted toward problem solving. A study conducted by Riffell and Merrill (2005) aimed to determine if the more interactive and problem-solving nature of Web-based materials better prepares students for labs and enhance their performance. They found that the hybrid lecture format (two hours lecture plus one online homework assignment weekly) was at least as effective in preparing students to do well in the laboratory course as a more traditional course format (three hours of lecture per week). They also found that the hybrid course format appeared to help all minority groups in their student population perform better in the laboratory. These findings have significant implications since they suggest that incorporating online problems into science courses may be a valuable tool for narrowing the performance gap of minority students (Riffell and Merrill 2005). This study, along with many others, suggests that web-based learning combined with traditional face-to-face learning may serve as a good way to get students more involved and motivated in introductory science classes.

Hybrid Courses and the Constructivist Approach to Teaching

In seeking to improve student performance, satisfaction, and retention, teachers should consider adopting a constructivist approach to teaching. According to the theories of constructivism, learning is an active and constructive process; learners not only construct knowledge, but the knowledge they already possess affects their ability to gain new knowledge (Etkina and Mestre 2004). Constructivism thus has important implications for the teaching and learning of science. As stated earlier, one of the potential reasons for students having negative attitudes toward science has to do with their previous experiences. The study conducted by Cherif and Wideen (1992) found that students complained that what they were taught in their college science classes sometimes contradicted what they had been taught in high school. Constructivism recognizes that knowledge previously acquired by the learner will affect how s/he interprets what a subsequent instructor is attempting to teach (Etkina and Mestre 2004). If something contradicts what has been previously taught and learned, the new contradictory information may be disregarded. Therefore, an instructor should probe the knowledge that students have previously constructed in order to make appropriate instructional choices with respect to the content to be learned. The instructor should evaluate the sufficiency and accuracy of students' prior knowledge and decide if this background knowledge conflicts with what is being taught. If a conflict is apparent, the instructor should guide learners in reconstructing their knowledge using, for example, guided inquiry in a relevant context (Etkina and Mestre 2004). To ignore learners' prior knowledge and beliefs makes it highly probable that the message intended by the instructor will not be the message understood by the student (Etkina and Mestre 2004). A good understanding of the content being taught is essential for building motivation and a positive attitude. In addition, providing the opportunity and the learning environment for the students to reconstruct their own conceptual knowledge and understanding leads to a lasting improvement in students' attitudes toward learning and to greater chances of success in their studies and lives.

Teaching Biology Through the Blended Learning: Personal Experience

Recently, I redesigned and taught one my biology courses at Harold Washington College (HWC) in both hybrid and traditional delivery formats using the same textbook, learning materials, labs, quizzes, exams, and so on in both sections. The course is Bio 114, which is one of the most popular introductory science courses. It is a survey course intended for students majoring in non-science degrees. As stated in the college catalogue, Bio114 is a course emphasizing scientific inquiry through selected concepts of biology, such as organization, function, heredity, evolution, and ecology. The course also discusses biological issues with personal and sociological implications, enabling students to make informed decisions. This course is offered every semester and is four credit hours. In a face-to-face (traditional) format, students meet twice a week: one class meeting for lecture and one class meeting for laboratory. After two-and-a-half years of research and collecting data, I offered Bio114 in a hybrid/blended format during the Spring 2010 semester—this was the very first time this course was taught through the hybrid delivery model at HWC. The course met once a week with 60 percent of the class onsite and 40 percent online. The online components of the course include reading the lecture and lab materials, conducting virtual labs as practice and preparation for actual laboratories on campus, taking quizzes, participating in a threaded discussion, and research group projects. The onsite class meetings covered class lectures, exams, as well as actual laboratory work on campus. Assessing the success of the course was accomplished by teaching the same course content in both hybrid and traditional formats, conducting concept-based pre- and post-tests, surveying the students in Bio 114 at the end of the semester, and examining the overall grades of students in both the hybrid and the traditional Bio 114 classes.

The effectiveness of the hybrid Bio 114 course was assessed by measures of student success in terms of student performance, satisfaction, and retention—in comparison to the same measures for the traditional onsite version of the course. Based on these criteria, the students who completed the hybrid section of Bio 114 reported higher rates of satisfaction with the course than their traditional course counterparts: 91 percent felt they were helped and encouraged to learn and 100 percent would recommend the course to other students; while in the traditional class, 83 percent felt they were helped and encouraged to learn and 90 percent would recommend the course to others. Students of the hybrid section also performed better overall than students in the traditional section. Furthermore, analysis of the results for comparable questions from the students' class evaluation, which was administrated directly by the college, supported the findings of the study. The overall findings thus bore out the hypothesis that not only can non-science majors perform as well as the traditional class but may actually achieve higher success rates in taking Bio 114 in a hybrid delivery format than by taking the same course in a traditional onsite format.

Discussion

Scientific discoveries and scientific thinking influence our decisions and behaviors, regardless of our profession or major. Yet, despite the undeniably important role science plays in our lives, studies show that many people do not hold positive attitudes toward science. It has therefore become the responsibility of educators to help shape the attitudes toward science among students so that these students leave their classes with a positive view of the discipline. Non-science majors are potential lawyers, managers, and government officials, and they may influence not only how research funds are spent but also how science discoveries and technology can be applied in society. A positive attitude toward science may influence these important decisions. Finally, a positive attitude toward science may contribute to students performing better academically in all subjects and encourage them to think critically about scientific and non-scientific issues that arise throughout their lives. The design of our courses, namely the type of delivery model we use, becomes important then because the delivery model influences the content being taught and the level of student involvement with the content.

There is much research that supports the potential value of blended instruction. Osguthorpe and Graham (2003) found that blended instruction methods improved pedagogy, increased access to knowledge, fostered social interaction, increased the amount of teacher presence during learning, improved cost effectiveness, and enhanced ease of revision. Similarly, Chung and Davis (1995) reported that blended instruction provided learners with greater control over the pace of learning, instructional flow, selection of resources, and time management (Lim and Morris 2009). According to a study from South Texas College, hybrid learning can produce better outcomes than those that are delivered exclusively on the Web or in the classroom. Their data showed that, overall, 82 percent of students of hybrid courses were successful, compared to 72 percent in classroom courses and 60 percent in distance courses (Kolowich 2009).

There are several advantages to blended learning compared with completely online learning or traditional face-to-face learning. While completely online learning might create a sense of isolation among students, blended learning provides the effectiveness and socialization opportunities of the classroom. Students who would be reluctant to contribute in a face-to-face setting are more likely to contribute in an online dialogue and would perform better in a blended learning environment. An advantage of blended instruction in biology courses in particular is that it helps students, especially minority students, perform better in labs. Biology labs are becoming increasingly computer-dependent, and blended instruction provides the technical training to prepare students for these labs, thus increasing confidence and performance levels of all students.

Technology has the potential to enhance instruction as well as student engagement and learning. Blended instruction makes pedagogically significant use of the Internet and other technological tools while reducing seat time (time spent in the classroom). The National Education Technology Plan 2010 recognizes the role that technology plays in improving student success and states that "the challenge for our education system is to leverage the learning sciences and modern technology to create engaging, relevant, and personalized learning experiences for all learners that mirror students' daily lives and the reality of their futures" (U.S. Department of Education 2010, v–vi). A blended instructional approach answers this call for a learning system that utilizes technology to create an engaging and student-centered environment.

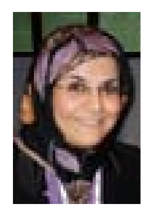
The hybrid delivery format has proven to be very effective in improving students' academic performance. Every month, there are major articles and/or government reports about the significant contribution of hybrid learning to student success and institutional improvement. Therefore, I believe that science departments should begin to systematically offer hybrid courses, starting with introductory courses. A broader selection of hybrid courses would also allow further comparative studies of student success in such courses against traditional models.

Finally, blended instruction does not only offer significant learning advantages for students, but also for faculty and institutions in optimizing access, learning, suitability, elasticity, and resources. However, faculty attitude toward hybrid and online learning delivery, which influences how they teach the course and how students learn, is shaped by the type of departmental and institutional support faculty receive. The need for faculty support in teaching hybrid and online courses has been reported in a number of studies (cf., Humphries 2009 2008; Morote et al. 2007; Rahmani and Daugherty 2007). The greatest reported need is support and training in best practices in hybrid and online instruction as well as consistency and fairness in allocation of time and schedules, assigning classrooms, labs, and computer rooms. Morote et al. (2007) identified four main categories of support that greatly influence faculty decision to develop and implement hybrid and online courses. These categories include technology, pedagogy, institutional policies, and faculty-centered issues. In the area of technology, for example, reliability of technology, technical support, hardware/software availability, and connectivity are the biggest concerns among many faculty who are teaching and/or thinking about teaching hybrid and online courses. In a study conducted among tenured and nontenured faculty at higher education institutions in New York, the researchers conclude that these four factors (technology, pedagogy, faculty-centered issues, and institutional policies) have the same influence on faculty decisions on teaching hybrid and/or online courses regardless of tenure status (Roman et al. 2008).

Summary and Conclusions

Taking a conservative position, we can conclude that hybrid instruction is at least as good as the traditional methodology. Hybrid instruction has the added advantage of being more efficient in its use of space (a real consideration to community colleges, which are space constrained), more flexible for working adults (who need to travel to campus less), and more conducive to the sharing of best practices among faculty in a department. In addition to student's success, these benefits provide some of the strongest reasons for the city colleges in urban settings, such as HWC in downtown Chicago, to support future efforts with hybrid learning across departments.

About the Author



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POINT OF VIEW

The Hybrid Experience

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As a student pursuing a degree in English, I was not looking forward to any science classes that I would be required to take. It's not that I don't like science. On the contrary, I have always been interested in the workings of the world and the universe around me. I've just never been very quick to learning and understanding the material presented in science classes. I've always felt like science classes demand that I memorize some words that I cannot attach meaning to, and then they "evaluate" my understanding of said words via a test of some kind. In this manner, if I can relate one word to another on a test, then I have a shot at passing. Unfortunately, there has never been any real learning taking place; simply regurgitation. As aforementioned, I do enjoy learning about all kinds of sciences. The previous winter, tired of literature and unable to produce any writing of my own, I turned to pop-science books for something different. One book was *The Flamingo's Smile* by Stephen Jay Gould (1985). The other book was *In Search of Schrödinger's Cat* by John Gribbin (1984). Although I certainly was not able to understand, or even follow in some cases, everything that these books attempted to teach me, I nevertheless found them extremely fascinating and helpful. The question begs asking: How was I able to learn from these books what I was unable to learn in the classroom? There's something to be said for the authors' styles and their abilities to effectively communicate complicated ideas to the layman, but more than the writing itself, I believe that I was able to learn from these books because I was able to select which essays or passages interested me the most and skip the diagrams, charts, et cetera that were not helpful to me. Simply put, I chose which material was most conducive to my particular learning style. Harold Washington College's first hybrid biology class offers its students a variety of materials from which to learn, allowing its students to decide for themselves which materials work best for their particular learning styles.

When I first enrolled in the biology hybrid class, I had very few expectations. Since I had never taken a hybrid class before, any expectation was drawn from the stories of other students' hybrid class experiences. However, the majority of those stories pertained to hybrid math classes, so I was aware that my experience would differ greatly. I assumed that I would need to spend more time reviewing the material at home to make up for the reduced face-to-face classroom time. Since biology is not my strong suit, I also assumed that I would need to meticulously go over every piece of information at my disposal in order to maintain my near perfect GPA. I did not assume that the class would be easier simply because meeting times were reduced by half of the traditional face-to-face biology class. Before the semester began, and into the first few weeks, I reminded myself to work diligently but to remain flexible in case my preconceived assumptions were wrong.

As it turned out, and for my benefit, only one of my assumptions was inaccurate. The class did not demand that I meticulously examine every bit of information presented to me. A wide range of learning materials was given to the students from Professor Movahedzadeh. A short list of these materials included the classic textbook, lecture notes, lecture power point presentations, animations of various processes, and a variety of additional materials obtainable through the course's online component, Mastering Biology. Besides the textbook, all of these materials were readily available online. At first, I studied every source with the belief that I would be tested on every piece of information. It was not long before I realized that each source contained the same information, though presented in varying ways. I began to discard materials that were of no use to me as per my learning style. For instance, the animations were meaningless to me. The exact same information written in the lecture notes or in the textbook was exceedingly more beneficial than the animations. As the class progressed, I found I learned best by reading the lecture note before class, where the professor would review the notes and clarify any confusing aspects of the lesson. Then I would review the lecture notes and the power points again while studying for a quiz or exam. While all other materials were not particularly helpful to me, there were other students in the class who claimed that the materials were helpful to them. It follows that a student's success is entirely dependent on the variety of learning materials that the instructor provides for the class so that each student may experiment with learning methods until a successful formula is reached.

Although I have found the hybrid class intellectually stimulating and yes, educational, it should be noted that a hybrid class is not for every student. Any hybrid class demands that its students be active. A student cannot simply show up to class and expect a passing grade at the end of the semester. If a student does not take the initiative to learn the material outside of the class, then the student has little chance of passing. Students of hybrid classes need to be self-sufficient. They must know exactly how they learn best, and they must be able to immediately recognize problem areas in order to correct them. Above all else, students of hybrid classes must have an inner drive to learn. Students who enroll in a hybrid class should do so because they have a real interest in expanding their knowledge of the world. Since so much time learning is spent outside of the classroom, a student who is genuinely interested in learning will find a hybrid class much more stimulating than one who is only after a grade. How much motivation can a disinterested student muster? For the disinterested students, the traditional face-to-face class that demands only regurgitation is better suited for their level of commitment. For students with a desire to learn about biology, a hybrid class may be well suited for their needs.

A hybrid biology course offers flexibility for its students. On the first day of class, many students echoed the same reason for enrolling, that is, the class fit their schedules. Many students—particularly at a community college with a wide range of nontraditional students—must work, have children, or face any number of obstacles that prevent them from taking a traditional, face-to-face class. I am currently a full-time student at Harold Washington College. I am also employed by the school as a tutor, and I am the president of the school's Creative Writing Club. In addition to my school-related activities, I am a writer for an internet comedy website, and I must find time every week for my own, more serious writing. Needless to say, I am very busy. Enrolling in a class that only met once a week was the only feasible way that I could take biology this semester. My situation is not unique. Students enrolled in a hybrid class typically do so because they cannot logistically spend the extra time to meet more than once per week.

The only significant problem area concerning hybrid classes is with the technology these classes require. In Jackson and Helms' study (2008), the majority of complaints were in regard to technological issues. When either a teacher or a student does not understand how to interact with the technology, problems will naturally arise. However, one cannot seriously consider this a permanent problem as it will naturally dissolve in time as the technologies required become more familiar to all parties.

I would argue that any student with an active desire to learn can succeed in a biology hybrid course. With all the materials a student could ever need at his or her disposal, success is entirely dependent on the student, as opposed to the limited class time. As the population continues to grow and each year brings record numbers of students to colleges, hybrid courses of all kinds seem to be the most logical and cost-effective solution to limited classroom space. Most important, the hybrid experience has the potential to teach students material that will be retained after the semester ends, as opposed to the aforementioned regurgitation of material only for a test's sake. Since many students may prosper more in hybrid courses than they would in traditional face-to-face courses, schools should attempt to create as many hybrid classes in as many subjects as possible.

About the Author

Eric Wozniak (ewozniak@ccc.edu) is a non science major undergrad from Harold Washington College in Chicago, IL. He took Bio114 in the biology department in a hybrid format. It was his first experience in taking a class in a blended learning. He is pursuing a degree in English/creative writing.

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Lessons from the Past

Economic and Technological Impacts of U.S. Energy Policy

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Introduction

> In 1979, in the middle of an energy crisis, Jimmy Carter had solar panels installed on the roof of the White House. . . . "A generation from now," said President Carter, "this solar heater can either be a curiosity, a museum piece, an example of a road not taken, or it can be a small part of one of the greatest and most exciting adventures ever undertaken by the American people, harnessing the power of the sun to enrich our lives as we move from our crippling dependence on foreign oil." . . . Ronald Reagan had the panels taken down." (Herbert 2010).

In this article, data will be presented which show that the United States' dependence on foreign oil has resulted in repeated cycles of economic recession following peaks in crude oil prices. In response, when crude oil prices are high, additional government funding is allocated to alternative energy research. However, when oil prices decline, funding for alternate energy research is drastically reduced. Data will also be presented which show that when less money is allocated to research on alternative energy, fewer related patents are granted. As a result, expertise and critical information obtained during cycles of high funding are likely lost during periods of lower funding, putting our country at a strategic disadvantage. U.S. energy policy could thus be described as short-sighted, focused simply on maintaining an ample supply of oil at a low cost to consumers. There is little long-term vision for preparing against uncertain future oil supplies from politically unstable regions, and thus protecting the U.S. economy against these cycles of recession. The challenge is how to sustain research and development initiatives to develop alternative energy sources, breaking the cycle of sporadic effort.

The most recent recession and current economic slump have had a devastating effect on employment rates, prosperity, and well-being. In addition to the economic ramifications, continued U.S. reliance on petroleum products for energy has resulted in increasing concentrations of carbon dioxide in the atmosphere, generally believed to lead to climate change (IPCC 2010 and NRC 2001). Increasing atmospheric carbon dioxide concentrations in the atmosphere are being exacerbated by China's unprecedented economic growth. Due to both the burning of fossil fuels and cement production, China passed the United States as the world's largest carbon dioxide emitter in 2006 (Heinhorst 2010). Climate change and other man-made pollution have the potential to negatively affect not only future economic growth but also health.

The information in this article can be used as a platform for classroom discussions on energy, environmental science and to promote civic engagement. The approach used is in alignment with the National Science Foundation supported SENCER (Science Engagement for New Civic Engagements and Responsibilities) project with goals to:

1. Involve more students in science, technology, engineering and mathematics (STEM) courses
2. Help students connect STEM learning to their other studies
3. "Strengthen students' understanding of science and their capacity for responsible work and citizenship." (SENCER Ideals 2010)

An additional aim of this work, beyond the SENCER goals, is to present multidisciplinary materials that could be used to foster classroom discussions in not only STEM subjects, but that would also be relevant to liberal arts classes such as economics and global politics as well. It is hoped that this material will engage students who may not have initially been interested in science, in the application of science policy to real world problems. This could possibly create more enthusiasm for taking STEM classes in the future.

Historical Perspective

The federal government first became involved in energy research and development after the development of nuclear power in the late 1940s, financing large-scale civilian research and development (Federal Financial Interventions [FFI] 2007, 30). In 1954, Atomic Energy Commission chief Lewis Strauss even predicted that one day civilian nuclear reactors would produce electricity "too cheap to meter" (Eisler 2009).

In 1973 the Organization of Petroleum Exporting Countries (OPEC) initiated an oil embargo, greatly restricting supplies and quadrupling the cost of oil. Later in that decade, in 1979, oil supplies were again disrupted, resulting in another significant increase in the cost of oil. Research on alternative sources of energy accelerated in the 1970s as a direct result of these oil crises in 1973 and 1979, with the greatest effort focused on nuclear energy and converting coal to liquid fuels. Improving the Fischer-Tropsch synthesis, a process for converting the nation's large reserves of coal to liquid fuels, received increasing attention as a strategy for achieving energy self-sufficiency. The process was developed in coal-rich but petroleum poor Germany in the 1920s, and was used by both Germany and Japan in World War II to produce synthetic fuels. Since 1955, the process has also been used in coal-rich South Africa by SASOL Ltd. (Suid Afrikaanse Steenkool en Olie [this is Afrikaans for South African Coal and Oil]) to convert coal and natural gas to liquid fuels and chemicals. However, once energy prices decreased in the 1980s, interest waned and research dollars dried up; momentum to develop alternative fuels was largely lost. This pattern is seen in the private sector as well. Over the period 1977–1980, when gasoline prices were high, General Motors produced the Electrovette, a battery-powered Chevette concept car. When gas prices collapsed, the project was abandoned. With the recent rapid rise in gasoline prices, attention has returned to developing alternative energy sources. Chevrolet recently introduced the Volt, an electricity powered car, in an attempt to capture demand for cars fueled by cheaper alternative energy compared to gasoline (Tingwall 2011). Another lost opportunity is concentrating solar power technology. The harnessing of solar power was first introduced by Frank Shuman in 1912. After the oil crises of the 1970s, the U.S. Department of Energy (DOE) collaborated with Luz International to build nine plants from 1985–1991 in the Mojave Desert, California. Following a period of relatively cheap oil in the 1990s, however, another large scale solar plant was not built again until 2007 (Tullo 2010). There was thus a period of nearly twenty years when the opportunity for the United States to expand alternative energy sources and reduce its dependency on imported oil was lost.

Current evidence strongly suggests that the consumption of fossil fuels is a major contributor to climate change due to greenhouse gas emissions, which could result in potentially devastating economic losses. As a consequence, research on alternative energy sources has increasingly focused on renewable energy such as sunlight, wind, biomass, and geothermal energy. Due to the expense and risks associated with the storage and disposal of nuclear waste, as well as high-profile nuclear disasters such as Chernobyl, Three Mile Island and most recently the Fukushima Daiich nuclear power plant in Japan, there is staunch opposition to the expansion of nuclear power. Similarly, interest in converting the nation's vast reserves of coal to liquid fuels has waned. Coal is also a nonrenewable fossil fuel and its use as a fuel adds to CO_2 emissions. There are also health and safety risks for coal miners as well as environmental damage and pollution associated with mining coal.

In 2009, the United States was consuming an estimated 18,690,000 barrels of oil per day, more than the entire European Union, and more than twice as much as China, which used an estimated 8,200,000 barrels per day. These numbers show the continued reliance of the U.S. economy on fossil fuels (CIA World Fact Book 2010). However, a bright spot is

TABLE 1. U.S. Energy Consumption by Energy Source (2002–2006) in Quadrillion BTUs (EIA 2007b)

Energy Source	2002	2003	2004	2005	2006
Total[a]	**97.927**	**98.280**	**100.413**	**100.756**	**99.960**
Fossil Fuels	83.994	84.386	86.191	86.451	85.307
Coal	21.904	22.321	22.466	22.785	22.511
Coal Coke Net Imports	0.061	0.051	0.138	0.044	0.061
Natural Gas[b]	23.628	22.967	22.993	22.886	22.518
Petroleum[c]	38.401	39.047	40.594	40.735	40.217
Electricity Net Imports	0.072	0.022	0.039	0.084	0.060
Nuclear Electric Power	8.143	7.959	8.222	8.160	8.208
Renewable Energy	5.893	6.151	6.261	6.404	6.844
Biomass[d]	2.706	2.817	3.023	3.114	3.277
Biofuels	0.309	0.414	0.513	0.594	0.758
Waste	0.402	0.401	0.389	0.403	0.404
Wood Derived Fuels	1.995	2.002	2.121	2.116	2.114
Geothermal Energy	0.328	0.331	0.341	0.343	0.349
Hydroelectric Conventional	2.689	2.825	2.690	2.703	2.890
Solar/ PV Energy	0.064	0.064	0.064	0.066	0.070
Wind Energy	0.105	0.115	0.142	0.178	0.258

[a] Ethanol blended into motor gasoline is included in both "Petroleum" and "Biomass." [b] Includes supplemental gaseous fuels. [c] Petroleum products supplied, including natural gas plant liquids and crude oil burned as fuel. [d] Biomass includes: biofuels, waste (landfill gas, MSW (Municipal Solid Waste) biogenic, and other biomass), wood and wood-derived fuels. Data for 2006 is preliminary.

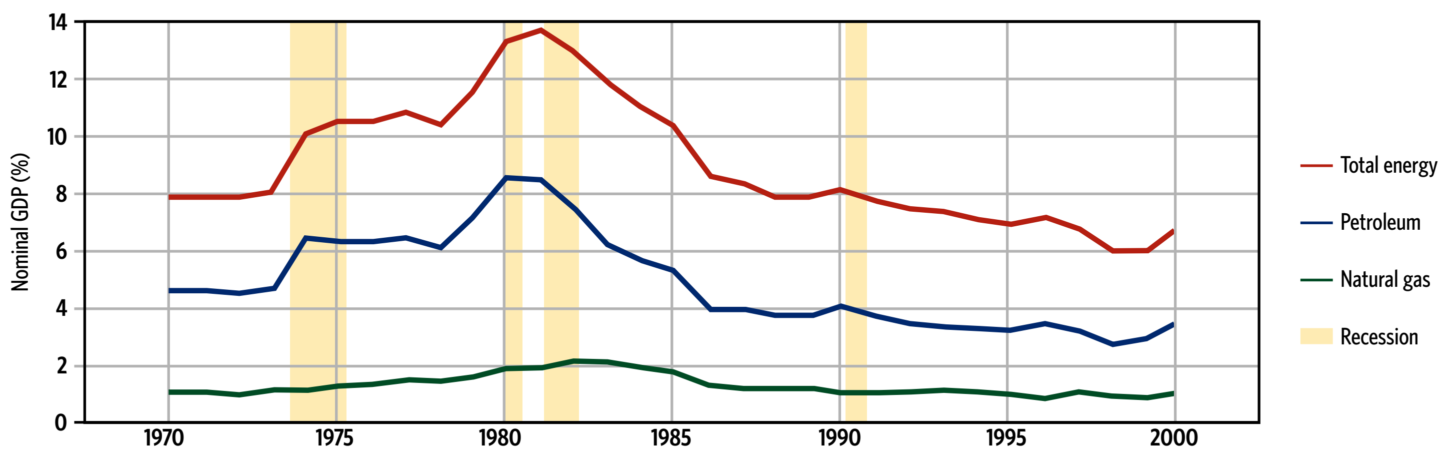

FIGURE 1 Energy Expenditure Share of the Economy (EIA 2001, Fig. 1)

the slowly increasing percentage of alternative energy use after years of increasing reliance on imports, as shown in Table 1.

Economic Impacts

The relationship between the percent of the nominal gross domestic product (GDP) and energy expenditures (total, petroleum and natural gas) is shown in Figure 1.

Dates of economic recession associated with increases in oil prices are shown in the shaded regions: November 1973–March 1975 due to the Arab oil embargo, and January–July 1980 and July 1981–November 1982 after the Iranian Revolution (National Bureau of Economic Research [NBER] 2000). Lines were drawn in by the authors. There was also a recession from July 1990–March 1991, when a small bump in petroleum prices occurred. Not shown are recessions from March 2001–November 2001 and the most recent recession, December

2007–June 2009. The figure shows that during the oil crisis of the 1970s, oil expenditure constituted a larger portion of the GDP. This has consequences on economic growth. There are spillover effects to the rest of the economy from higher oil prices such as higher costs of production, higher inflation, and higher rates of unemployment. All of these factors then contribute to lower economic growth and recession.

Federal Energy Research and Development Budget

The data provided in the Appendix (FFI 2007, 40) were released by the Energy Information Administration (EIA), the independent statistical and analytical agency within the DOE. As discussed above, higher prices lead to lower or negative growth and therefore recession. To reduce the volatility of the U.S. economy because of its dependence on oil, upon his election in 1976, President Jimmy Carter dedicated unprecedented funding to developing alternative energy in order to make the United States energy self-sufficient. After his defeat in 1980 and the election of President Ronald Reagan in 1980, greater stability in oil producing regions lead to a decline in oil prices through most of the next two decades. President Reagan was a follower of classical economic theory that advocated a limited role for government intervention in the economy. The practical application of this theory resulted in a reduction in government spending in the 1980s; therefore, the funding of alternative energy started by President Carter was drastically cut. Funding levels decreased from \$6.5 billion in 1978 to \$1.2 billion in 1987 (in 2007 dollars). Spending increased under the first President George H.W. Bush, took a dip, then slowly increased under President Clinton in the 1990s, averaging \$1.9 billion to \$2.5 billion. (EIA 2007a, ch. 3, pg. 1)

A plot of the total annual DOE research-and-development (R&D) expenditures (in million 2007 dollars) from 1978 to 2007, summarizing the trends just discussed, is shown in Figure 2, (data given in the Appendix). Figure 2 clearly shows a sharp dip in funding in the early 1980s and a gradual overall increase since the mid-1990s. Funding levels still have not returned to their peak levels of the late 1970s.

Patents

The number of patents provides a measure of the outcomes of the innovation process. In the energy sector, R&D spending and the numbers of new patents are closely linked. (See

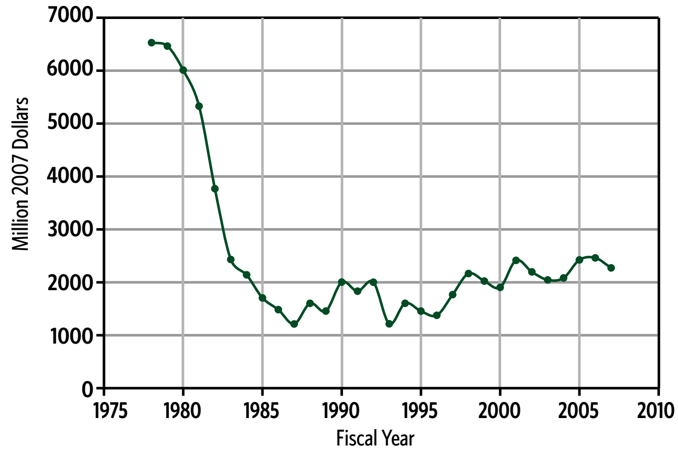

FIGURE 2 Summary for DOE R&D expenditures, 1978–2007 (million 2007 dollars)

Figures 3–7.) Alternative energy patents rose from 102 in 1976 to a high of 228 in 1981, then declined to a low of 54 in 1994 (Margolis and Kammen 1999). The number of successful U.S. patent applications (by year of application to remove any time lag between application and approval) and public research and development investment was compared (Kammen and Nemet 2005). These records of successful U.S. patent applications were used as a proxy for the intensity of innovative activity. A strong trend between public R&D and patents across a variety of energy technologies was found. For example, in the areas where R&D decreased such as wind technology, nuclear fusion, and photovoltaics there has been a trend of declining patents. As can be seen in Figure 5, nuclear fission provides a counter-example to the trend of the relationship between R&D expenditure and patents observed with the other types of energy sources. There is some evidence to suggest that the benefits of R&D may not be realized until two to three decades after the initial investment (Anderson and Bird 1992).

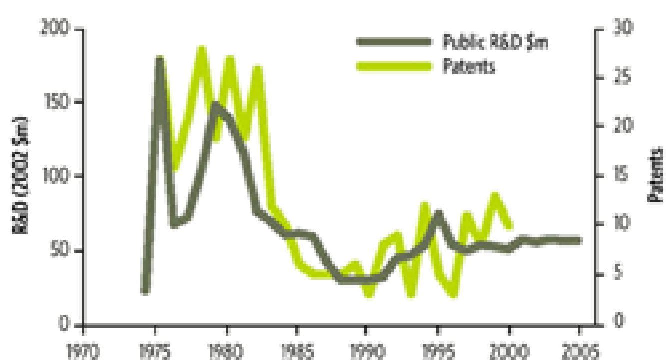

FIGURE 3 Wind R&D and Patent Applications (Kammen and Nemet 2005)

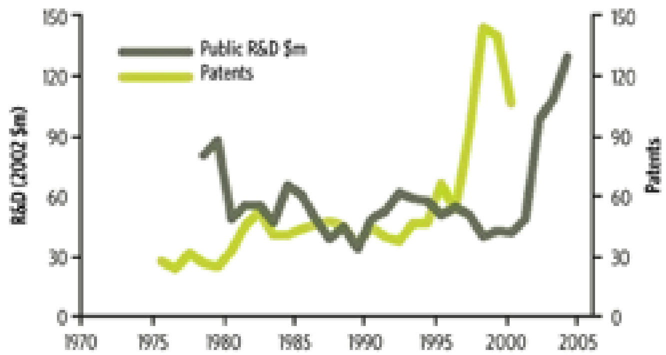

FIGURE 4 Fuel Cell R&D and Patent Applications (Kammen and Nemet 2005)

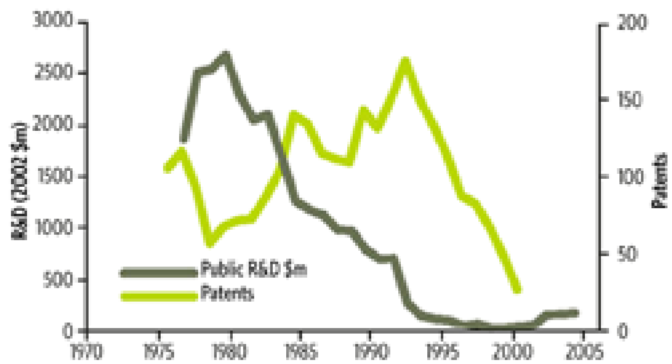

FIGURE 5 Nuclear Fission R&D and Patent Applications (Kammen and Nemet 2005)

Thus, the increase in the number of patents in nuclear fission over this period may be a response to the greater investment in nuclear technology during the oil crisis of the 1970s. It can also be seen that there is a relationship between current events, energy policy and innovation. Note that U.S. public research and development spending on nuclear fission dropped after the Three Mile Island disaster in 1979. A dip in U.S. patent applications can be seen beginning in 1986 after the Chernobyl disaster followed by an increase in 1990, coinciding with the first Iraqi War and an increase in oil prices. Continued European and Japanese interest in nuclear fission for energy in the 1980s and early 1990s may also explain why the relationship between nuclear fission and patents differs from the others. This example highlights the complexity of the relationships between energy, technology, and economics. It should be noted that the investment costs in these different technologies will be different which may impact on technological innovation. For example, it is a lot less costly to develop a wind

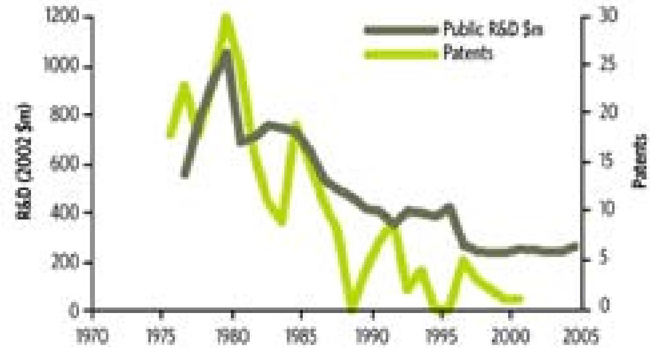

FIGURE 6 Nuclear Fusion R&D and Patent Applications (Kammen and Nemet 2005)

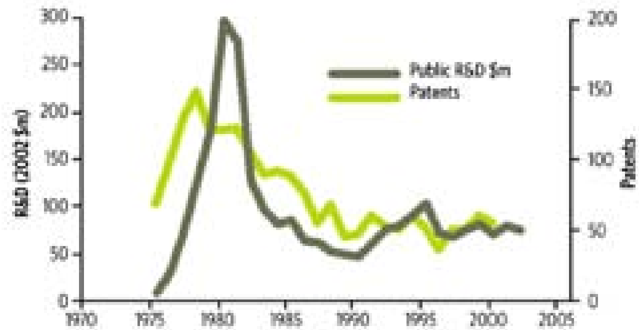

FIGURE 7 Photovoltaics R&D and Patent Applications (Kammen and Nemet 2005)

turbine than invest in nuclear technology. Conversely, where R&D expenditure has increased for fuel cells, there has been a trend of an increase in patents. The following figures are evidence that providing funds for R&D is essential to ensuring technological innovation in the energy sector.

Hope for the Future

On a worldwide scale, Europe, Asia, and the United States are currently investing in renewable energy. Globally about 19 percent of energy consumption is now from renewable sources. The World Intellectual Property Organization (WIPO) is one of the sixteen specialized agencies of the United Nations. WIPO was created in 1967 to promote creativity and the protection of intellectual property throughout the world. Patent information on renewable alternate energy, collected by the WIPO, and provided in their report, "Patent-base Technology Analysis Report—Alternate Energy Technology" (WIPO 2006) is provided in Figure 8. The left-hand side of the y-axis

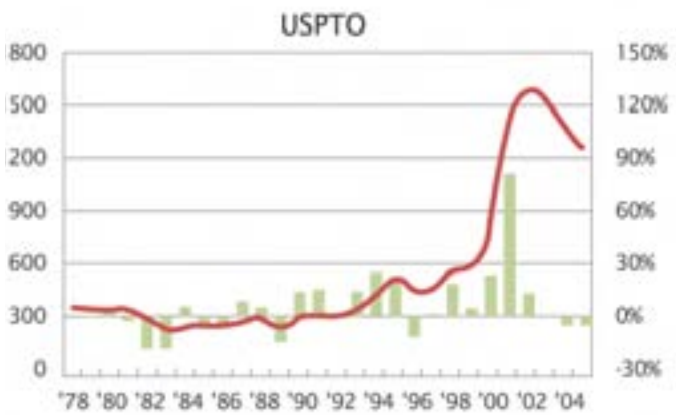

FIGURE 8 USPTO Data on Renewable Energy Patent Applications by Year, 1978–2004

is the total number of patents. The right-hand side of the y-axis is the growth rate in the number of patents. The bars show the annual growth rate. From this figure, we can see that patents for renewable alternative energy are growing.

Conclusion

Rapid economic growth in emerging economies such as China and India has intensified world demand for fossil fuel. This increased demand has lead to rising prices. As discussed, rising energy prices have been associated with lower growth and recessions in the past. To avoid economic volatility, it is essential that there is investment in the use of viable renewable energy sources. Besides the economic benefits, renewable energy sources can contribute significantly to a reduction in greenhouse gas emissions. Another advantage over fossil fuels, which are concentrated in a few regions of the world, is the wider availability of many renewable energy sources such as biomass, the wind, the sun, geothermal energy, waterfalls and waves to create hydroelectricity.

The U.S. economy is faced with the challenge of maintaining a commitment to research and development funding during the current economic downturn. Research shows that a decline in investment leads to a decline in patents and therefore technological innovation.

It has been shown that the United States' commitment to supporting funding for alternative energy is intermittent, and declines during periods of stability in energy costs. In closing, ponder whether history is repeating itself. President Barack Obama as a sign of his commitment to promoting sustainable energy has commissioned the installation of solar panels and solar water heaters on the White House roof (Fifield 2010).

Application to the Classroom

The material covered in this article can be used to foster classroom discussion on the relationship between geopolitics, government policy, and scientific research. The questions below could be asked in a social science class such as an applied macroeconomic class or a humanities course such as 20th century history. For example, classroom discussion can be used to help students understand the link between oil prices and economic growth. After students understand this link, students can discuss how economic policy can be used to promote the development and use of alternative energy sources. This classroom project has been applied to an undergraduate economics course for students at the University of Aberdeen, Scotland. Many of the students enjoyed seeing the link between economic theory and real world applications These questions could also be asked in STEM subjects such as environmental science, general chemistry or introductory chemical engineering courses. For the STEM classes (including social sciences) there are further extensions on the material which are discussed below.

1. What alternative energy source might have the quickest impact on the use of oil in the United States? How does the "not in my back yard" (NIMBY) reaction impact implementation? Can you recall any current events where the NIMBY reaction impeded or stopped installation of alternative energy sources such as wind turbines, etc.? What are some of the environmental impacts of alternative energy sources?
2. What type of policies should the United States implement to encourage alternative energy sources? What could be the motivation of U.S. policy to continue to fund alternative energy sources and for citizens to accept their installation?
3. What type of activities could the average citizen engage in to reduce dependence on fossil fuels?
4. How would you propose that the United States end the cycle of recessions when oil prices peak? What are your feelings on tapping into the United States' strategic oil reserves to mitigate increasing fossil fuel costs?
5. What effect would a strong alternative energy policy have on U.S. relations with oil-producing countries? What about economic relations with other countries that are dependent on oil for energy?
6. What political, global effect would be felt if U.S. energy sources were at least 50 percent non-fossil fuel based? What parts of the U.S. economy might be affected?

A further extension of this topic is student research on alternative energy choices; discover strengths, weaknesses and impediments to implementation for the different types of alternative energy. Students could then report their findings in a classroom setting and/or write a research paper. Students could also research the strengths and weaknesses of using coal to produce electricity, "fracking" to recover natural gas, etc. If these assignments are done by groups of students, this type of exercise will promote team work, information literacy and oral and written communication skills.

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APPENDIX Summary of U.S. DOE R&D Expenditures, 1978–2007 (million 2007 dollars)

Fiscal Year	Renewable Energy	Energy Coal	Other Fossil	Nuclear	End Use	Clean Coal Technology	Total
1978	1046	1709	275	2938	561	0	6529
1979	1302	1685	322	2614	541	0	6464
1980	1367	1657	203	2373	413	0	6011
1981	1196	1464	184	2018	377	0	5329
1982	588	975	97	1954	155	0	3769
1983	454	497	68	1313	99	0	2432
1984	346	500	80	1110	106	0	2142
1985	328	523	71	702	81	0	1705
1986	270	504	63	586	61	0	1484
1987	224	430	55	450	55	0	1213
1988	253	502	63	422	55	309	1603
1989	159	383	75	492	64	284	1457
1990	155	435	78	494	47	796	2004
1991	233	439	105	463	60	543	1833
1992	277	513	95	500	54	563	2,002
1993	282	331	122	419	61	0	1,216
1994	355	231	222	441	64	291	1,604
1995	416	224	238	471	61	47	1,456
1996	314	335	208	289	45	185	1,377
1997	289	258	202	980	42	–3	1,768
1998	300	182	192	1,218	398	–124	2,166
1999	344	174	218	900	438	–49	2,024
2000	326	172	244	742	595	–173	1,905
2001	468	400	150	643	634	120	2,415
2002	317	486	144	570	632	48	2,197
2003	319	482	123	570	603	–52	2,045
2004	298	535	105	754	498	–106	2,083
2005	376	511	81	1,124	502	–168	2,424
2006	356	530	64	1,062	470	–20	2,462
2007	444	470	0	946	414	0	2,273
Total	13,392	17,537	4,147	29,558	8,186	2,491	75,302

PROJECT REPORT

SENCER-ISE

Establishing Connections between Formal and Informal Science Educators to Advance STEM Learning through Civic Engagement

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and

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Introduction

On Sunday afternoon, March 6, 2011, more than fifty educators from the formal education (or higher education) and informal science education worlds gathered at the Liberty Science Center in Jersey City, New Jersey, to engage in two days of discussion about how both communities could work together to advance STEM learning through the broad focus of civic engagement. The SENCER-ISE conference* was funded by grants from the National Science Foundation (NSF) and the Noyce Foundation to the National Center for Science and Civic Engagement (NCSCE), the home of SENCER (Science Education for New Civic Engagements and Responsibilities). Two NSF divisions, Research in Learning in Formal and Informal Settings, where the Informal Science Education (ISE) program is housed, and Undergraduate Education, combined efforts to support the initiative.

Although unable to attend the conference, ISE's Program Director Al DeSena sent remarks that were read at the opening of the conference. In them, he noted his personal view that "I don't think there is work more important in informal science education and in higher education than creating meaningful opportunities for learners of all ages to engage in activities at the interface of science and civic engagement." He also commented that the conference attendees had the opportunity to build on the work of previous collaborations among professionals in higher education and informal science education (DeSena 2011). DeSena's comments are included in SENCER (2011). Along with an Executive Summary and the authors' recollections, these proceedings provide a source of information for this review article about the activities of the conference.

The informal science educators who attended SENCER-ISE came primarily from science and natural history museums, science centers, science media and communication outlets, and science organizations such as the National Geographic

* SENCER-ISE: A Conference to Create Partnerships between Formal and Informal Science Educators to Advance STEM Learning through Civic Engagement. NSF grant number DRL1001795. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Society and the Association of Science-Technology Centers. The world of formal science higher education was represented by SENCER faculty, primarily by those who are co-directors of the SENCER Centers for Innovation located at two- and four-year institutions of higher education. The participants came from 19 states and the District of Columbia and also from Canada, Chile, and Israel.

How the individuals in the room found themselves together, what their discussions entailed, and how the connections between both communities can be strengthened will be the prime focus on this preliminary project report.

The idea to bring together a working group of individuals from both communities grew during this time period. With Alan Friedman's involvement, the National Center received the NSF grant and a supplementary grant from the Noyce Foundation to hold an invitational conference that would give both communities an opportunity to share methods and outcomes that each sector employs to implement the civic engagement approach to STEM learning. The conference was also seen as an important step in creating possible partnerships between formal and informal science educators and strengthening those that already exist.

The Path to SENCER-ISE

SENCER focuses on teaching and learning through real-world problems and provides an approach for faculty to teach science and mathematics courses through complex, capacious, and often unsolved problems of civic consequence. SENCER pedagogical strategies include learning that is active, inquiry-based, collaborative, and connected to research. SENCER courses can also include academically based service-learning projects and community-based research.

For a number of years before the conference, SENCER scholars had been exploring the relationship between the work of its faculty as formal science educators and the work of those involved in informal science education. Programs at regional meetings in 2008 and 2009 and at the 2010 D.C. Symposium saw presentations by Alan Friedman, nationally known expert in museum development and science communication, David Ucko, then Deputy Division Director of the NSF's Division of Research and Learning and now president of Museums+*and more*, and Al DeSena. All provided SENCER faculty overviews of the role of informal science educators in STEM learning. At the 2010 symposium, two Noyce Fellows (Phelan Fretz, Executive Director of the Echo Lake Aquarium and Science Center in Burlington, Vermont, and Stephanie Radcliffe, Executive Director of The Wild Center in Tupper Lake, New York), whose attendance was sponsored by the Noyce Foundation, met with SENCER faculty and undergraduate students about activities and career in informal science education venues. SENCER faculty also participated in a colloquium at the 2009 SENCER Summer Institute to explore the differences and commonalities between formal and informal science education.

The Connection between SENCER and Informal Science Education

At first glance, the formal and informal science education worlds seem far apart. Alan Friedman notes that "Informal Science Education (ISE) does not *deliver* education, like a school" but rather it provides opportunities for people to become fascinated with something they experience, and to then find themselves learning and becoming even more interested in whatever it was that caught their imagination. That is why ISE is also called *free-choice learning* that "complements rather than replaces or just continues formal education" (Friedman 2011). The website of the Center for Advancement of Informal Science Education (CAISE) notes that "informal science education supports people of all ages and all walks of life in exploring science, technology, engineering and mathematics" (CAISE 2009).

At the 2009 regional meeting at Franklin & Marshall College, which focused on how informal science education experiences could improve college readiness, David Ucko provided a succinct comparison of key aspects of formal and informal education, focusing on K–12 education for his comparison. His analysis is applicable to higher education as well. Table 1 (next page highlights some of the differences he addressed. Ucko presented data from the Center for Informal Learning and Schools showing the extent to which informal science education complements the formal side through out-of-school enrichment such as after-school programs, museums, the media and cyber learning and by providing classroom and teacher programs and resources. He also indicated that formal education can complement the informal side in part through developing assessment tools and providing professional development activities.

TABLE 1 The Modes of Learning: Formal and Informal Education

Formal Education	Informal Education
Compulsory	Voluntary
Curriculum-based	Personal Interest
Teacher-directed	Self-directed
Set Times	Anytime
Ages 5- 18	All ages, lifelong
Classrooms	Ubiquitous
Assessment	No tests or grades

The 2009 NRC report, *Learning Science in Informal Environments: People, Places, and Pursuits*, reinforces the belief that there are commonalities in learning goals between formal and informal science education. The report indicates that:

> Learning science in informal environments is a diverse enterprise and serves a broad range of intended outcomes. These include inspiring emotional reaction, reframing ideas, introducing new concepts, communicating the social and personal value of science, promoting deep experiences of natural phenomena, and showcasing cutting-edge scientific developments (Bell et al. 2009, 41).

The report also provided strands of learning or learning goals for informal science learning that include experiencing excitement, interest and motivation to learn about phenomena in the material and physical world; generating, understanding, and using concepts related to science; reflecting on science as a way of knowing and on the process of learning about science; participating in scientific activities or practices; and having participants think of themselves as both science learners and individuals who use science (Bell et al. 2009, 43). The six informal science education strands can be seen to follow from the four strands of scientific proficiency that were introduced in *Taking Science to School* (Duschl et al. 2007, 37).

The strands of learning for informal science education can be related to SENCER theory and practice, providing a justification for the idea that the two communities can join together to improve science learning. Although the fit is not seamless, the SENCER Ideals offer a framework for teaching and learning science that connects unresolved public issues with basic science. Thus learning can, for example:

- Start with matters of interest to students allowing them to put scientific knowledge and the scientific method to use;
- Begin with an intellectual project that is practical and engaged;
- Extract from immediate issues the larger lessons about scientific processes and methods; and
- Locate the responsibility of discovery in the work of the student (SENCER 2009).

The SENCER-ISE Conference

Through facilitated, interactive problem-solving discussions, participants were able to build upon mutual learning goals and interests. They began to theorize that partnerships between formal and informal science educators could, through a shared focus on issues of civic consequence, lead to greater civic engagement and the continued development of a science-enabled citizenry that can make science-based decisions about these issues.

The problem-solving process included discussions on both potential obstacles and possible strategies to address these obstacles. The question "What can we do together to advance our shared vision?" was central to the proceedings as participants worked in teams to learn more about each other's strengths and goals. It became apparent that most of the higher education participants saw civic engagement as a means towards achieving science learning and most of the informal science education participants looked at civic engagement as a valuable end in itself. Still, the commonality of interest in using civic issues to engage audiences (whether students in and out of school or adults in the community) was the glue that held the discussions together.

For part of the final morning, participants again worked in teams to develop ideas for potential collaborations. One "mock" project postulated the formation of a Climate Change Corps (CCC) that would develop science content through a partnership between formal and informal institutions. This project would involve creating toolkits and providing training and would include a student leadership component, based upon the National Center's GLISTEN (Great Lakes Innovative Stewardship through Education Network) project. The CCC would provide sub-grants to develop the toolkits and also involve community members from different regions who could share their personal experiences related to climate change.

Next Steps

By the end of the conference, an interconnected and parallel set of strategies emerged from the first step of listening to the communities to be served as displayed in Figure 1. (An expanded version of this diagram can be found in (SENCER 2011) and is based upon the diagram developed during the conference by Jonathan Bucki, the conference facilitator.

Participants agreed that this meeting was just the first step for the SENCER-ISE initiative and suggested further meetings with prematched partnerships at the regional level (i.e., informal and formal science educators who attend as already formed teams), either with some participants from the March conference or with new participants. The purpose of the follow-up meetings would be to develop workable structures for a diverse range of informal and higher education partnerships.

In the meantime, a document is being completed that is a synthesis of the discussions and is meant to serve as a resource for those who attended and for others in the field. This document, along with an Executive Summary, will be available both on line on the SENCER website and other locations and in hard copy, which can be ordered through the National Center's office. An evaluation report is also being completed.

A "Passport to Networking," which included information about the backgrounds and existing partnerships of the participants, enabled individuals to go beyond the usual formal introductions that occur at meetings. The "Passport" will be available on line so that participants can share their ongoing activities, along with an opportunity for participants and others to join a LinkedIn network about collaboration between informal and formal science educators.

Conclusion

A recent *Education Week* report, "Science Learning Outside the Classroom," noted, "as concern mounts that U.S. students lack sufficient understanding of science and related fields, it has become increasingly clear that schools can't tackle the challenge alone. This special report explores the field often called "informal science education," which is gaining broader recognition for its role in helping young people acquire scientific knowledge and skills. Opportunities abound outside the classroom to learn about science, and to inspire a passion for it. Zoos and science museums, robotics clubs, science competitions, and online games are just a few of the options to engage American youths. Education Week reporters examine what informal science education looks like in practice, and what we know about its impact, its potential, and the challenges it faces" (*Education Week* 2011). (The report contains articles on the role of science learning outside of school, NSF, and informal learning, and assessment.) Falk and Dierking (2010) state that "average Americans spend less than 5 percent of their life in classroom," and offer arguments and citations to support their conclusion that "most science is learned outside of school." The *Learning Science in Informal Environments* report (Bell et al. 2009), along with a companion volume, *Surrounded by Science* (Fenichel and Schweingruber 2010), are now widely referenced and have given informal science education a more solid framework than the field has ever had.

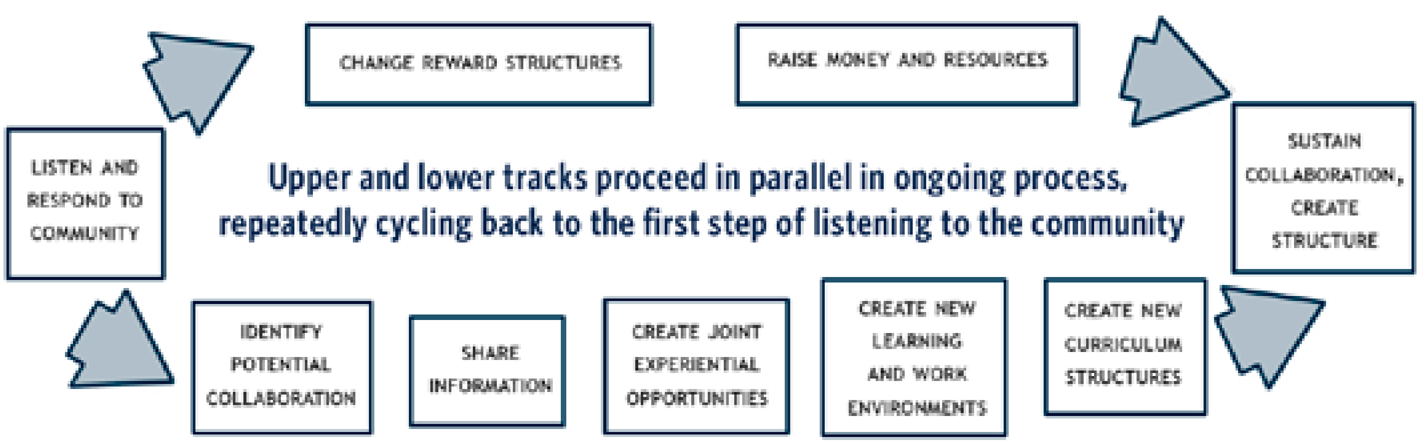

FIGURE 1. Emerging strategies for civic engagement (SENCER 2011, 2).

Given this growing body of evidence, it is important that both communities work together as equals to develop opportunities for all ages to understand and engage in science practices. Whether it is offering issue-based exhibits at a science museum or providing opportunities for individuals to participate in data collection as a citizen scientist, both communities have much to offer each other in educating students of all ages. SENCER-ISE is a crucial step in connecting initiatives between these communities.

Brief Interview with Alan Friedman

As this report is being published in a SENCER journal, we thought it would be interesting to pose some questions to Alan Friedman about informal science education.

Mappen: You have been involved with science museums for a good part of your career. How have these museums changed over that time period?

Friedman: When I started working in a science museum (the Lawrence Hall of Science at the University of California, Berkeley) in 1973, there were about twenty institutions like the Hall that called themselves "science-technology centers." They differed from traditional museums in that they had few if any permanent collections of artifacts that they studied, and instead they had hands-on interactive exhibitions. They were focused as much on the visitor experience as they were on the science they offered. Today there are over 350 such institutions in the US alone, and over 500 in other countries. Most of these institutions have, in the last couple of decades, become very serious about evaluating their impacts, and looking for more ways to engage visitors than the traditional exhibitions and theater presentations. Citizen Science Citizen Science (www.citizenscience.org) is an example of these new mechanisms for engagement, and the technique is becoming popular in both formal and informal science education. I've written about these trends recently (Friedman 2010).

Mappen: A 2008 CAISE study looked at the informal science education "landscape." How would you describe this landscape?

Friedman: I would estimate that informal science education is a billion dollar a year industry in the U.S., and that tens of thousands of people work in it. But they do not see themselves as a common body (Falk et al. 2008). Science journalists relate to other journalists, not to museum educators. TV producers feel that they are part of the media, not in the same business as zoos. Even in the museum field, for the most part the natural history museums do not have a lot to do with the science centers, living collections (zoos, aquaria, botanical gardens) have their own networks, and aerospace museums keep to themselves professionally. So there has not been nearly as much synergy as there could be if the various parts of this landscape could somehow be brought into closer contact. That is one of the goals of the Center for Advancement of Informal Science Education project (www.insci.org).

Mappen: What opportunities are there in science museums or other areas of informal science education for undergraduate students to complement their studies in science or mathematics courses?

Friedman: Most of us who have taught science at any level agree that when you try to teach a concept to others your own understanding is really tested and improved. So I think undergraduates who learn to communicate science to informal audiences, like museum visitors of all ages and backgrounds, have a unique experience that sharpens their own knowledge and communication skills. This is certainly the case for the hundreds of undergraduates who have served as paid floor staff at the New York Hall of Science, as supported by several longitudinal studies of program alumni.

Mappen: We know that some connection with formal science education has always been a feature with informal science education. Has this typically been at the K–12 level and how might that change?

Friedman: Museums have for decades worked closely with K–12 education, and the school field trip has become a nearly universal practice in museums worldwide. No such tradition exists for higher education and museums. Science museums often have university researchers on advisory boards, and in the past twenty years science museums have employed a modest number of undergraduates to serve as part-time floor staff (often called Explainers, a term coined at the Exploratorium in San Francisco). There are sometimes connections with university faculty in schools of education, because museums do a lot of in-service teacher professional development. But connections to undergraduate education are much rarer: The New York Hall of Science and the City College of New York have a joint program called CLUSTER, in which both the science center and the college are involved with pre-service teacher training (NYSCI 2011). But the SENCER-ISE project is looking to connect undergraduate higher education and informal science learning in a very different fashion. Engagement with practical, local, civic issues is equally distant from both the traditional higher education classroom and from the traditional informal science education modes of operation. The potential SENCER and ISE partners are both venturing into new territory, and each has significant, complementary resources to facilitate that engagement.

Mappen: On a more personal level, what first drew you to the science museum field?

Friedman: I was a visiting assistant professor in 1973 at the University of California, Berkeley, when I wandered into the Lawrence Hall of Science, one of the pioneering public science-technology centers. As a solid-state physicist, I was in a field with thousands of other researchers, hundreds of university and industry labs, and my chances of contributing in a big way seemed limited. But at the Lawrence Hall I discovered this other field, informal science education, where there were only a few dozen institutions, and a handful of recognized leaders. I also found that research and development into communicating science to the public was in its early stages, and there were many opportunities to influence the advancement of this nascent enterprise. So I convinced the Lawrence Hall to hire me part time for nine months. It quickly became full-time, stretched to twelve years, and I never looked back.

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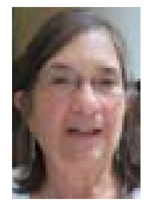

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Alan J. Friedman is a consultant in the areas of museum development and science communication. He has consulted for more than sixty institutions around the world. From 1984–2006, Friedman was the director and chief executive officer of the New York Hall of Science. He has also served as conseiller scientifique et muséologique for the Cité des Sciences et de l'Industrie, Paris, the biggest science museum in Europe. Additionally, he was the director of astronomy and physics for the Lawrence Hall of Science at the University of California, Berkeley. Friedman has served as a member of the National Assessment Governing Board since 2006 and currently is vice chair of the Board's Assessment Development Committee. He received a Ph.D. from Florida State University and a bachelor's degree from the Georgia Institute of Technology, both in physics. He served as Project Director for the SENCER-ISE.

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PROJECT REPORT

Transformative Learning and Teaching of Environmental Science, from College Sophomores to Urban Children

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Introduction

Improving PK–12 science education, especially in under-resourced urban schools, is a clear social need in the United States today. This is particularly important during the early primary years when young children are first exposed to formal science instruction. Such improvements have the potential to enhance scientific literacy for all students (PK–12), while also creating a more diverse and robust stream of potential STEM majors. Colleges have a role to play in helping our neighboring communities achieve such goals — and, in the process, educating our own students for civic engagement (Jacoby et al. 2009). To best educate for active citizenship, interdisciplinary work is needed, as recognizing, understanding and taking action on social concerns requires knowledge and skills from across the academy (Lucas 2009; Mooney 2010). As science and education faculty working together, we prepare our students to see the inequities common in the lives of the urban poor, and work toward addressing them. One such eye-opening moment for our largely well-off suburban college students is learning how few of these working class urban children have ever seen the ocean, despite living within twenty miles of the Atlantic Ocean (Mooney 2007). Another moment is when students learn that the city is heavily overburdened with waste sites: 347, more than four times the state average, with an average density of sixteen such sites per acre. As a low-income, high-minority area, this pattern is identified as one of environmental injustice.

SENCER has fostered collaboration between college and PK–12 science education (e.g., Othmer and Sealfon 2010; Kim and Szupnar 2010). As these and other experiences indicate, involving college students in teaching science to young children is fruitful, as the college students are more motivated to learn the science in order to teach it well. The enthusiasm and content knowledge college students bring to school children is valuable; however, opportunities are being missed for transforming both the learning of undergraduate and early elementary students in deeper, more lasting ways by failing to place enough emphasis on educational theory and practices.

The aim ought to be for college students to develop conceptual understanding of best practices in teaching and then learn to utilize these pedagogies in under-resourced PK–12 classrooms with supervision from both science and education faculty. For students planning careers in early childhood or elementary education, such an approach will likely have a broad impact on science teaching. Fink (2009) has found that teaching science with SENCER approaches to preservice teachers increases their disposition toward science and might well lead them to teach more science, and do so more effectively, when they are in-service teachers. Collaboration between education and science faculty to ensure that both the educational and the scientific content are given equal weight in such SENCER approaches can only increase the odds of success.

The curriculum we report upon here is one component of a long-term collaboration between an education professor, a science professor, and an urban pre-K–3 school. Our common goal was to improve the quantity and quality of science instruction in a local elementary school (the principal of which identified the need and welcomed our involvement). In addition, our goals for our college students were to motivate non-science majors pursuing careers in education to conceptually understand the science they are learning and to immerse pre-service teachers in best practices in pedagogy, as both learners and then as teachers.

To accomplish these goals, we created a three course Learning Community (LC) pairing ENV200, Principles of Environmental Science, with EDU312, Art, Music, and Movement for the Young Child. ENV200 is an introductory-level course that fulfills the college-wide requirement for natural science, as well as the state recommendation for elementary teaching licensure candidates to experience appropriate college level science content with laboratory experiences. EDU312 is a pedagogy course that introduces project-centered instruction (PCI), summarized below, as an approach to teaching young children. When taught as part of this LC, these two courses are scheduled back-to-back, often in the same classroom.

Our LC's third course, a team-taught integrative seminar, challenges students to use the pedagogical skills acquired in EDU312 to teach environmental science content acquired in ENV200 to children in prekindergarten through grade three. In order to translate the college-level science our students are learning in ENV200 to material developmentally appropriate for the young children, the college students are required to not only understand the detailed science they are being taught, they must also understand the 'big ideas' behind the science. This knowledge must then be matched to the developmental level and prior knowledge of their young students. To assist our students in accomplishing this task, the course meets one afternoon per week in a local PK–3 school, and in pairs, the students spend much of that time in their assigned classroom. College faculty are in the school building supervising the student teams each week as well as participating in whole class meetings to consider relevant theory, review the curricula being designed and executed, and plan the Family Science Event the students create and host at the end of the semester. Few, if any, of the students enrolled have prior college coursework in either science or pedagogy. Participation in our LC has changed over the three years it has been offered, increasing not only the class size from twenty-one to twenty-six students, but also the percentage of students who are teacher licensure candidates (from 65 to 92 percent).

Pedagogy Employed Across the Learning Community

There are probably as many definitions of PCI as there are scholars and practitioners who are involved with the pedagogy. In addition to being a complex, multifaceted concept, practitioners employ a variety of terms to name it, including the project approach (Katz 1994), project-based learning (Krajcik et al. 1999), and most notably *progettazione* in the schools of Reggio Emilia (Edwards et al. 2000).

Our concept of project-centered instruction as a pedagogical tool grew out of both project work (Katz and Chard 1989) and the work currently underway in the schools of Reggio Emilia. Key to both of these techniques is the reliance on an emergent curriculum model/approach, in which projects grow from student interests. With guidance from teachers, students then construct knowledge and skills through an extended inquiry process of active engagement with those real-world problems that pique their interest. The fundamental elements of PCI include the creation of projects utilizing real-world problems, an emergent curriculum design, and documentation as formative assessment. Our particular model of PCI is unique to our work (Anderson et al. 2010); however, such integrated teaching utilizing an emergent curriculum can be traced to Dewey's (1916) proposal that classroom curriculum be related to children's real-life experiences.

We employ PCI in our courses, and we require our students to employ PCI in their work with children. This is an explicit attempt to bridge the gap between research and practice by exposing college students to new instructional practices; both the students enrolled in the LC and the children they teach are actively engaged in PCI. As others have noted, experiencing a teaching methodology as a student leads to deeper understanding and better implementation of that methodology as a teacher (Akerman et al. 2009).

Logistics: School-based Collaboration

Our students are placed in an under-resourced Catholic school in a nearby working-class city. Though a private school, this school is not elite, having fewer resources than many of the local public schools. This fact, along with more flexible and responsive building administration, made this collaboration ideal for our project. As the curriculum standards mirror those of the public schools, the projects designed by our students are transferable to public early childhood and elementary settings.

The city is racially and ethnically diverse. Twelve percent of families and almost 20 percent of children under age eighteen living in poverty. U.S. Census data from 2000 reports 94,304 residents and a per capita income of $17,163. The estimated racial distribution of the city in 2006 was 50 percent white, 33 percent African American, and 18 percent other or multiracial. The student population of the school reflects this economic and racial diversity.

For the first three weeks the college students work in pairs observing and assisting the classroom teacher. They come to know the classroom structure and children's personalities and inquire about science topics of interest to the children. The college students are then challenged to bring together the children's interests with those of the curriculum standards and the classroom teacher to implement standards-based projects utilizing an emergent curriculum design. The students are typically overwhelmed by this task. As one student gently phrased it, "this lack of structure is uncomfortable." Another offered: "When I was first confronted with the idea of student-directed approach to learning I was extremely hesitant. I was used to being told what to do by a teacher."

Project curriculum is reviewed (by professors and peers) and revised on an ongoing basis throughout the semester. The classroom teachers allot class time to the college student teaching teams to implement their emerging projects. As the entire class (students and both professors) are present in the school on the same day, at the same time, ongoing support is provided to these first-semester sophomores through classroom observations, lesson plan reviews, reflective essays, and works-in-progress sessions (in which student teams present the design and emerging results of their project for review and feedback from the class).

The college students gradually begin to see the merits in the unfamiliar pedagogy: "It is far too easy to do exactly what one has been told, so easy in fact, that once the teacher has done so it is nearly impossible to form ideas on one's own." Another noted "we had an on-going project in the LC—integrating environmental science into an elementary school curriculum. While we created projects for elementary school–aged kids, we learned how to teach about environmental science for ourselves." Still another offered this reflection on her own learning: "In a 'normal' classroom there is a fear of proposing an answer or idea and being wrong. However in [PCI], I was encouraged to express my ideas, whether they were right or wrong, and examine and investigate them with peers to come to a better understanding and expand my knowledge."

College-level Science Learning

Students enrolled in the LC had very limited interest in science and little confidence in their scientific literacy. None were science majors or minors and enrolled in this Learning Community as a somewhat more palatable way to complete the college requirement of one natural science course. Most consider themselves weak in science and report "hating" science.

The science course content is typical of an introductory course in environmental science, including basic ecology and human approaches to energy production, water, agriculture, and waste management. In addition to learning and being assessed in all these areas, teams of students engaged in doing science, gathering and analyzing data on environmental health problems in the community in which they taught. The increased risks of exposure to environmental toxins, and the concomitant health problems of the urban poor such as increased rates of asthma and lead poisoning, are discussed in the course as environmental justice concerns—and this connection to ethics as well as to the lives of their young students prompts most students to do the science well.

Teams of students find and read the primary literature, then design research studies, collecting and analyzing data, drawing conclusions and presenting their results. This process is guided by the science faculty member, including several points of feedback and revision as well as supervision of the data collection and analysis. Topics students have investigated include lead (in soil, water, or paint); arsenic in the soil (at former tannery sites near the school and pressure-treated chromated copper arsenate [CCA] lumber playgrounds); particulates in the air; and, noise pollution. The college students are very motivated to understand the risks the children face, and consequently learn the complex science involved. (Thus far, fortunately, the results of these pilot studies have found few hazardous levels of toxins. Peeling lead paint was found on one metal railing abutting the schoolyard, and the building administration was informed.)

Given how overwhelming problems such as these can be, it is not developmentally appropriate to focus young children's projects on environmental health issues or other threats like climate change. Generally, the science taught to the children is focused on key concepts, often in ecology, that are in the grade-level science standards as well as embedded in the college-level science course. Employing PCI, our pre-service teachers must learn so much more ecology than they present to the children. It is Socratic and spontaneous in the classroom — teachers must be prepared to respond to student interests and questions. Success requires much more familiarity and facility with the science than teaching from a textbook or ready-made science kit, including the ability to recognize connections and opportunities for learning as they arise. As one student noted: "Seemingly the responsibility of choosing the course of learning is relieved of the teachers and given to students. However, as I experienced in the placement, the resulting responsibility of serving as a guide to the children's learning processes is even more difficult."

Sample Project: How Do Animals Live in Our City?

This question emerged from second-graders' experiences exploring the schoolyard alongside college students. Following emergent methodology, the process of answering the question was guided by the college student teaching team, ensuring needed content and skills were learned (standards-based) without limiting the children's creativity or narrowing the range of solutions to the problem. Within an emergent curriculum conceptual understanding is achieved, but the specific means by which that learning is accomplished and demonstrated varies depending upon the needs and interests of the students. The individual solutions, though focused on the same real-world problem, therefore differ.

The study — how do animals live in our city — began with extensive discussion and investigation of the schoolyard and the animals that call it home. Observational data was captured utilizing multiple representational forms, including numbers, pictures and words — an approach referred to as the "100 languages" of children (Edwards et al. 2000). Teams of second-graders quickly formed based upon their expressed interest in a "favorite local animal" (ant, squirrel, worm, bird). In order to guide their learning further — and capitalize on their interest in animal habitats, the college student teaching teams assisted the students in translating their two-dimensional representations into three-dimensional replicas (see Figure 1.)

Throughout the project the student teaching teams acted as recorders (documenters) for the children, helping them trace and revisit their words and actions and thereby making the learning visible. Documenting both the process and product of the children's project work allowed children to express, revisit, construct, and reconstruct their feelings, ideas and understandings. Pictures of children engaged in learning, their use of language and scientific vocabulary as they discuss their work, and the children's interpretation of their experiences through the visual arts are displayed as a graphic presentation of the dynamics of learning. This ongoing formative assessment of both the process and products of learning facilitates communication and the exchange of ideas in the classroom; helps parents know what their child is learning; and guides planning, as it serves as real-time assessment. Are the children

FIGURE 1. Second-graders creating habitat boxes.

coming to understand the concepts, or are misconceptions common? For example, are the children connecting the animals via food webs in their habitat projects—or have they neglected to account for food as essential to life and to recognize that food involves consuming other creatures? If the latter, another attempt at learning this concept in required.

Emerging Results

We are using a variety of data sources to assess the effectiveness of this collaboration including course-embedded documents (reflective essays, project proposals, team meeting notes, lesson plans) as well as post-course surveys. Analysis of the course-embedded documents is ongoing; we report here on the initial indications of positive impacts for the children and the college students.

Teachers and administration in the school building offer universally positively assessments of the collaboration as do parents who attend the Family Science Events at the end of each semester (see Figure 2). The time allotted to learning science goes up remarkably when we are in the building. The quality of the children's work and observations in the classroom confirm their success and level of engagement in science learning. Over the three years this LC has been offered, thirty-three classrooms (approximately 600 children total) have learned science via project-centered instruction implemented by our students, while the classroom teachers have been exposed to this pedagogy in a compelling way.

FIGURE 2. Preschoolers viewing a display of their work at Family Science Event.

The post-course surveys of our students are particularly revealing. As shown in Figure 3, compared to students enrolled in all other LCs at the college, our students reported some striking differences in attitude and experience. We compared three years of survey results. Post-course surveys are administered to all LC students at the end of each semester. A Likert scale is used (5 points, from Strongly Disagree to Strongly Agree) with ample space provided for written explanation/comment. (LC 254 n=68; all other LCs n=629). (All LCs at our college are sophomore general education requirements with small class sizes [twenty to twenty-six students], emphasizing integrative learning and employing active learning pedagogies [Mooney 2003].)

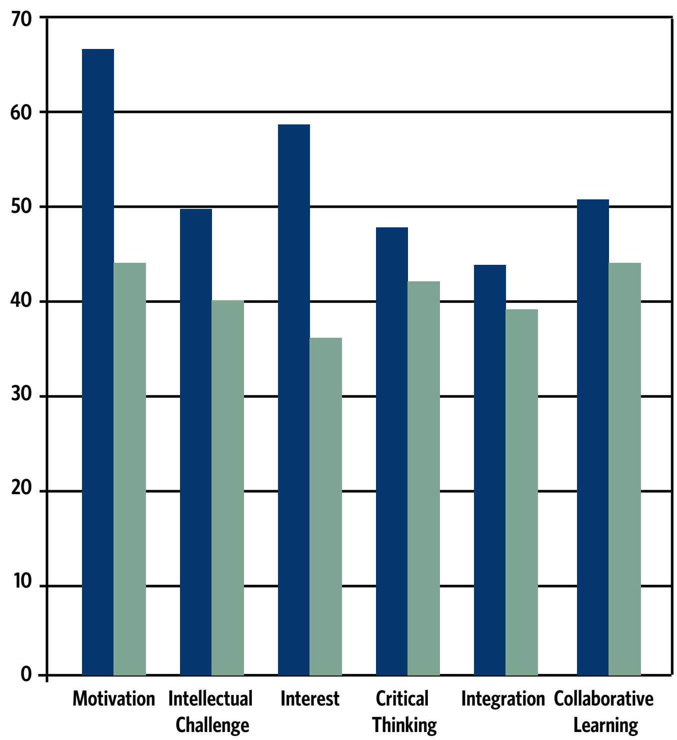

FIGURE 3. Percentage of students choosing "strongly agree" in LC254 versus all other LCs over the same three semesters (Fall 2006–2008). Learning community survey statements: Motivation, I was motivated to do my best work in this course; Intellectual Challenge, this course challenged me intellectually; Interest, this course increased my interest in the subject matter; Critical Thinking, this course helped me become a more critical thinker; Integrative Learning, this LC has led me to develop some skill in how to use knowledge from two disciplines together to better understand an issue or solve a problem; Collaborative Learning, being in this LC gave me the opportunity to learn from other students as well as faculty.

■ ■ ■

In addition to these findings, 37 percent of our students (twenty-five out of sixty-eight students) reported working seven or more hours a week on the course beyond class time, while only eighteen percent of their peers reported that level of time invested (118/633 students). This increased time investment likely contributed to the increased learning all across the board. Many students wrote that the connection to the children prompted them to this level of commitment; noting, for examples, "I did not want to be unprepared when teaching" and "I worked harder than I have for any class."

Future Directions

The next time this Learning Community is taught, we plan to incorporate a teacher self-efficacy survey, pre and post, to further evaluate our tentative conclusion that our students improve in science teaching confidence. Continued analysis of course-embedded materials will document to what extent skill in science teaching is actually enhanced. We also plan to follow those who become teachers after graduation to see whether this experience teaching science via a powerful pedagogy affects the quantity and quality of science teaching in their own classrooms.

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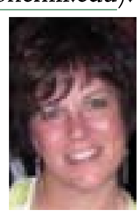

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