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-wide 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 Lor — 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.](image)
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.

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 2.](image_url) Preschoolers viewing a display of their work at Family Science Event.

![FIGURE 3.](image_url) 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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References


