

Designing for Engagement in Environmental Science: Becoming "Environmental Citizens"

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Abstract: We report Design-Based Implementation Research (DBIR) on a year-long project-based AP Environmental Science curriculum in 11 classrooms in two urban districts. We report its impact on students' engagement, practice-linked identities as environmental citizens and performance on a complex transfer task. Results from the initial design-redesign phase in a suburban district were replicated. Implementation data provided new information about how two design features (positioning students as change agents in their own lives and gradually widening from local to global issues) contributed to engagement and identity development.

Major Issues Addressed

Environmental Science courses naturally fall at the boundary between science and citizenship. Students learn not only the scientific concepts and processes needed to understand the world around them, they learn their roles and responsibilities as citizens in the ongoing interaction between humans and that environment – their “practice-linked identities (Nasir & Hand, 2008).” An unfortunate byproduct of students’ increased knowledge about current environmental problems might be a sense of “doom and gloom.” In making sense of issues of sustainability and human impact on the environment, students may learn to be passive, coming to believe that environmental problems are so big that an individual can have no meaningful impact. In a project-based curriculum, this could lead to student disengagement with real-world and simulated activities that are the spine of the course (Parker, et al, 2013). We designed and tested an experimental, project-based, Advanced Placement Environmental Science (APES) course focused on increasing engagement with scientifically-informed practices by (1) emphasizing students' agency in making decisions that affect the environment and (2) supporting the development of practice-linked identities as environmental citizens. In this PBL curriculum, projects are the spine of the course, meant to provide a context and purpose for all learning activities. After a two-year design-test-redesign-test cycle in a suburban school (Goodell et al 2014), we used DBIR to study the implementation of the curriculum in 11 classrooms in two urban districts and its impact on students' practice-linked identities as environmental citizens, self-reported interest in environmental issues, and performance on a transfer task requiring hypothesis generation, requesting additional information, supporting/refuting hypotheses and proposing solutions to a real-world environmental problem.

Theoretical Framework

Practice-Linked Identities

To understand the connections between students' engagement in project-based environmental science activities and their sense of their role in addressing environmental issues in the world, we turned to Nasir and Hand's (2008) concept of "practice-linked identities." Nasir and Hand define practice-linked identities as "the identities that people come to take on, construct, and embrace that are linked to participation in particular social and cultural practices" in which there is a "sense of connection between the self and the practice" (p. 147). The kind of project-based learning embodied in the APES curriculum is intended to provide opportunities for students to learn how specific practices can have positive or negative effects on the environment. By expansively framing content as transferrable to out-of-school contexts, the designers hoped students would identify with or take up those practices in their daily decision-making (Engle et al., 2012). Considering the environmental impact of everyday decisions and using science to inform one's opinions and actions as a citizen in a democracy we call "environmental citizenship." To the extent that students took up practices and used concepts from the course in this way, we considered them to have begun to develop practice-linked identities as environmental citizens.

Nasir and Hand (2008) describe three dimensions of learning contexts that might support the development of practice-linked identities: "(a) access to the domain as a whole, as well as to specific skills and concepts within it; (b) integral roles and accountability for carrying out those roles; and (c) opportunities to engage in self-expression, to make a unique contribution, and to feel valued and competent in the setting." (p. 248). Contexts that supply all three dimensions would be expected to support higher levels of student engagement as students begin to identify with the practice of particular contexts. Students in the PBL-APES course participated in real-world or simulation projects. As designed, the project-based APES course could provide access to the domains of environmental science and environmental citizenship through framing

environmental science concepts and principles in the context of complex real-world (reduce your family's ecological impact) or simulated real-world (design a sustainable farm, participate in a global energy summit) projects. Students were also clearly assigned roles in each project, and evidence from the year two redesign suggested they saw these roles as "integral" and "accountable" to the project context. The first cycle, Eco-Footprint, cast students in the role of collecting data at home and making proposals to their own families, providing what Barton and Tan have called "hybrid spaces" and opportunity to integrate home and environmental-science related identities and discourses (see also Tzou et al, 2010). In each project, students had latitude to make decisions and express personal interests and choice, and interview data provided evidence that students felt "valued and competent in the setting." Survey data from year two also supported the connection between engagement in the project tasks and end of year interest in the environment, after accounting for initial interest in environmental science. Interview data suggested students had (further) developed their identities as "environmental citizens," able to suggest more specific solutions to problems, reporting more specific instances of transfer to life out of school, and reporting less pessimism and more agency in addressing environmental problems than students in year 1 (Goodell et al, 2014).

Expansive Framing for Transfer and the Development of Interest

The approach to project-based learning used in the APES course is consistent with what Engle and her colleagues have called "expansive framing" to promote transfer (Engle, 2006; Engle et al., 2012; Engle, Nguyen, & Mendelson, 2011). By assigning roles in projects at the beginning of each cycle (e.g., sustainable farmer, natural resource manager), rather than using projects as a way to *apply* learned knowledge, students should learn with the expectation that the knowledge will be useful in the (at least immediate) future. To the extent that students found the projects to be authentic, that is, that they reflected the ways that real people in the world used the concepts and practices they were learning, the projects also should also increase the extent to which students see future value for transfer, increasing engagement and interest. Continuous participation in projects was expected to trigger and sustain student interest in the content, providing an opportunity for students to develop a more stable identification with and interest in environmental issues. This, in turn, could be expected to lead to students seeking out additional information and opportunities to use their environmental science knowledge in other contexts (Renninger, Bacharach, & Posey, 2008).

Context

Design-Based Implementation Research

As we moved our curriculum from a well-resourced suburban district to urban, poverty-impacted districts, we were concerned with a variety of contextual and institutional characteristics that could impact implementation. In our larger project, we have adopted a DBIR approach to understanding and innovating around issues of scaling (Penuel, Fishman, Cheng & Sabelli, 2011). In this brief report, we focus primarily on the effects of implementation differences, but it is important to note that the reasons for those differences represent persistent problems of practice to which the APES curriculum might be adapted, or which districts need to address in some way if implementation in urban contexts is to be successful. For example, the districts in this study differed in the availability of time to regularly meet across sites to discuss and plan implementation. District 1 had little or no history of such collaboration and researcher-organized meetings were not successful in establishing it. District 2 had provided released time and consistent district-level encouragement to collaborate monthly. Constraints of scheduling (block vs. modified block) and differential access to computers and other resources required curriculum flexibility. Other common issues complicated implementation, including teacher and administrator turnover, student absences, and differences in historic achievement levels and expectations for students. The analyses presented here were made possible by the impact of these issues on implementation.

Initial Design and Theoretical Framework

The project-based, Advanced Placement Environmental Science (APES) course provided students with opportunities to prepare for adaptive transfer through multiple, quasi-repetitive opportunities to learn and apply scientific concepts and processes in the context of real-life projects and simulations (Parker et al., 2011; 2013 Schwartz & Bransford, 1998). All instruction occurred in the context of 6 multi-week simulation projects that provided reasons for learning from a variety of sources and experiences, and that attempted to cast students in roles as active problem-solvers in settings beyond the classroom (e.g., as "green" event planners, as environmental consultants, as representatives of various countries). This expansive framing (Engle, Lam, Meyer, & Nix, 2012), was not sufficient to overcome students' push-back based on the enormity of environmental problems and their own lack of power in addressing them. Year 1 feedback from students and teachers led to a significant redesign of the curriculum focused on two main fronts. *First*, we re-ordered the project cycles to help students develop active practice-linked identities by beginning with a local, real-world project (reducing their family's Eco-footprint) and then gradually broadening their perspective across 5 project

cycles, ending with a Global Energy Summit simulation. *Second*, we redesigned several project cycles to enhance the expansive framing of tasks and instruction to improve adaptive transfer to out-of-school settings (Engle et al, 2012). This redesign resulted in students being more likely to report an increased sense of personal responsibility for the environment and adoption of specific sustainable practices, along with demonstrating increased specificity in proposed solutions to environmental problems. This suggests that the design modifications (changing the order of cycles to start with students as agents in their own families, redesigning cycles to emphasize agency and frame for transfer) had an impact on the extent to which suburban students developed practice-linked identities as environmental citizens. Student interview data suggested that beginning with the Eco-Footprint cycle was particularly important in helping students see the importance and environmental impact of their own decisions and practices. The curriculum was modified slightly in year 3 to emphasize the gradual widening of spheres of influence. The third-year project cycles as designed were, in order, Eco-Footprint, My Community Ecology (as state resource managers), Food Systems (as sustainable farm designers), Ocean in Action (as citizens debating the introduction of aquaculture to their island ecosystem), and Negotiation of Nations (representing countries in environmental negotiations).

Implementation in Urban Schools

Suburban students in a relatively "green" region of the US might have brought significant prior knowledge and sustainable values into the course. The teacher, a curriculum co-designer, might have been particularly effective in implementation, especially in year 2. In the third year, the expansion to two urban districts provided an opportunity to test the robustness of the curriculum while investigating local differences in context and implementation that could affect its success. One new district was in the same "green" region, where it might be easier to establish hybrid spaces because of the similar concepts and values of in- and out-of-school contexts. The second was in the middle of the US, in an area of concentrated and long-standing economic difficulty. Both districts served a mix of students but included significant numbers of immigrant families and similarly high rates of free-or-reduced lunch qualification. Teachers differed in the extent to which they remained committed to implementation of the whole curriculum, resulting in differences in the number of cycles (curricular units) taught and the extent to which teachers curtailed project-based learning and supplemented with lecture-based presentations of information. All teachers were new to the curriculum, although some teachers in both districts had experience teaching environmental science or environmental studies courses.

Research Questions

Scaling

We were interested in whether the curriculum design was robust when implementation was expanded to districts that differed from the design environment. Specifically, did urban students develop practice-linked identities as environmental citizens as indicated by their reports of specific practices adopted and a positive rather than pessimistic outlook for citizen action? In addition to collecting interview data on students' self-reported environmental practices, we also assessed end-of-course *Environmental Citizen Identity* with items including interest in environmental issues, feeling that they knew enough to make good environmental decisions and a belief that "people like me" can make a difference. We also investigated processes theoretically involved in the development of practice-linked environmental identities. The extent to which students had opportunities for integral roles and accountability and opportunities for self-expression was measured by class mean levels of *Agentic Involvement*, a scale with items indicating engagement in the project tasks ("I actively participated") and the perception of an integral role in the group's learning ("I usually felt like I contributed to our learning"). Scores on the end-of-course transfer task, an indicator that students had had access to the discipline and *could* use the practices of environmental science to address a complex environmental problem, were examined for links to two engagement measures, Agentic Involvement and Flow (reported concentration, losing track of time), given initial interest in environmental issues (*Initial Environmental Interest*).

Implementation

Two main design changes were of interest: (1) engaging students at the beginning the year with a real-world project aimed at informing and influencing family members, and (2) sustaining engagement and a sense of agency by positioning students as decision-makers in larger and larger spheres of influence over the course of the year-long curriculum. Although all classes implemented the first cycle, only about half implemented all or most of the curriculum. Comparing students in these two groups of classes provided a means of examining whether the curriculum-length design change was necessary or whether similar results could be obtained by "jump-starting" engagement and identification by implementing the Eco-Footprint cycle alone.

Substantiation

Methods

Participants

We analyzed data from the classrooms of four teachers in three schools with a total of six APES sections from District 1 recruited to teach the experimental curriculum. All five APES teachers (five sections, five schools) from District 2 participated. District 2 adopted the experimental APES curriculum as a district with the consent of the teachers. Data from 217 students who completed pre- and post-course surveys were analyzed.

Data Collection

Students completed surveys at the beginning and end of the school year. Scales included Initial Environmental Interest (Fall), and Agentic Involvement, Flow, and Environmental Citizen Identity (Spring). Students also completed a written transfer task, the Complex Scenario Test (CST), which presented a real-world ecological problem (e.g., flooding in Cambodia) and asked students to generate hypotheses, request additional information, support or refute hypotheses, and propose and justify solutions. Semi-structured interviews were conducted with approximately 10% of the students to gather self-reports of transfer, along with other experiences in the course.

Results

Scaling

Analysis of the end of year interviews replicated year 2 (suburban) results, indicating that many students were developing practice-linked identities as environmental citizens. Most students interviewed (69%) provided both specific descriptions of changed personal practices and expressed a belief in their own agency and responsibility in contributing to sustainability. The following example combines these characteristics:

So just, like I said before, like, you know, I just changed. It changed me as a person... learning the facts and how many gallons of water get wasted a day and how it's possible that we have another Tragedy of the Commons. I was like, "You guys can't be showering for like 40 minutes each. And don't leave the water running." So that was really helpful as well. We definitely recycle now a lot. And we have a little separate thing for compost as well (Student 2970).

Survey data were used to test the relationship between being in a class with higher mean levels of Agentic Involvement and individual interest in the environment at the end of the course. The HLM analysis is summarized in Table 1.

Table 1. Effects of classroom-level Agentic Involvement on end-of-year Environmental Identity

Fixed Effect	Coefficient	Standard error	t-ratio	Approx. d.f.	p-value
For INTRCPT1, β_0					
INTRCPT2, γ_{00}	3.667756	0.038887	94.318	21	<0.001
AGENTICI, γ_{01}	0.549041	0.092206	5.955	21	<0.001
INTRCPT2, γ_{10}	0.231301	0.053339	4.336	136	<0.001

Implementation

Several analyses compared full implementation (at least 4 of 5 cycles) with partial implementation (Eco-Footprint plus 1-2 additional complete cycles). Evidence of impact on practice-linked identities as environmental citizens was more limited in partial-implementation classrooms. All of the students who could not provide specific transfer examples or expressed a pessimistic, non-agentic position in post-course interviews were in classes where the curriculum was only partially implemented. Five of the six full-implementation classes were taught by teachers in District 2, where teachers planned and adapted as a group through the year. This is likely to have supported commitment to a challenging new set of teaching tools.

Full implementation appeared to support engagement and interest more effectively than partial implementation. HLM analysis of survey data, with beginning of year interest as a covariate, revealed that partial-implementation classrooms had lower reported levels of Agentic Involvement, Flow, and end-of-year Environmental Citizen Identity (all $p < .001$). Since all classes implemented Eco-Footprint, these findings suggest that an initial experience being positioned as environmental change agents, though powerful, was not sufficient. Positioning students as agentic in gradually widening of spheres of influence over the course of APES appeared to provide the support necessary to increase practice-linked identification with environmental

issues. Finally, reported engagement was positively related to scores on the Complex Scenario Test across the entire sample. Specifically, HLM analyses found that Agentic Involvement predicted CST scores for Hypothesis Generation, Supporting/Refuting Hypotheses, and Proposing Solutions (all $p < .001$). Flow (task immersion) positively predicted scores for Hypothesis Generation and Proposing Solutions (both $p < .05$). These results suggest that, in addition to supporting identification with environmental citizenship, engagement in project tasks promoted student learning of the practices of environmental science.

Limitations

With the exception of the CST scores, the data reported here come primarily from students' self-reports. Video observation data in several of the project classes indicates that while many students were consistently engaged in project tasks, they may need additional supports in order to engage in the knowledge practices of environmental science. The connections between engagement and performance on the CST may indicate deeper learning for engaged students, but could also mean that engaged students were more likely to exert effort on the CST. These and other issues of implementation are the subject of ongoing research in the larger project.

Relevance to Conference Theme

The study reported here embodies the conference theme is "Learning and Becoming in Practice." In the project-based APES curriculum development project, providing spaces for students to develop as environmental citizens and as environmental scientists has been a key aim. The data presented in this brief paper suggest that the curriculum and its implementation did have an impact on students' practice-linked identities as environmental citizens. Students had opportunities to engage in the practice of both environmental science and citizenship through the project. The developmental structure of the curriculum, moving from real-world hybrid spaces focused on students' personal and family environmental practices through increasingly broader frames of reference, seemed an important contributor to the curriculum's impact. The evidence suggests that student engagement and identity development occurred alongside the knowledge practice of environmental scientists. By purposefully positioning students as decision-makers throughout the curriculum and by focusing on ways to address difficult environmental problems, we were able to reduce the disidentification, pessimism and resistance to deep engagement often seen in environmental science courses.

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