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(Re)Designing for engagement in a project-based AP environmental science course

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ABSTRACT

This paper describes a three-year, design-based research project to redesign a year-long, project-based advanced placement environmental science course to better support student engagement and the development of environmental citizen identities. In the initial implementation, students' increased understanding of environmental problems paradoxically led to disengagement as students felt pessimistic and powerless. We describe design cycles across three implementation years and investigate the impact of design features on engagement and identity. Curricular design features (positioning students as change agents and widening projects' spheres of influence from local to global), alongside expansive framing for transfer, contributed to engagement and the development of practice-linked identities as environmental citizens. We discuss implications for designing courses for engagement and identification with disciplinary content.

KEYWORDS

Secondary education; science education; identity; curriculum; HLM; qualitative; case study

OVER A DECADE ago, Phyllis Blumenfeld and her colleagues (Blumenfeld, Kempler, & Krajcik, 2006) argued against assuming that project-based learning (PBL) would be inherently motivating and called for "making motivation an explicit concern" in designing PBL environments. Since then, few researchers have investigated ways to address this challenge. Although some design-based research in classroom settings has included engagement, motivation, identity, and transfer as important outcomes (Kaplan, Sinai, & Flum, 2014; Pugh, Bergstrom, Krob, & Heddy, 2017; Pugh & Bergin, 2005), this work is rare compared to research wherein the primary concern has been, perhaps naturally, to increase student learning. In the parent project from which our data come, for example, the original goal was to create entirely project-based advanced high school courses that led to deeper learning, as measured by a researcher-developed test, and the same or better learning on a standardized test, the Advanced Placement exam (Parker et al., 2013). Although we were largely successful, we found that students began disengaging from the content, taking an increasingly pessimistic view of their own role in sustaining the environment. In other words, students seemed to be learning that engaging in sustainable practices was futile.

The PBL AP Environmental Science (PBL-APES) course was designed around the concept of a challenge cycle (Bransford, Brown, & Cockling, 2000, Bransford et al., 2006), driven by a course "driving question": "What is the proper role of humans in maintaining the earth's sustainability?" Sustainability is an engaging, complex and controversial issue in which tensions among sometimes competing concerns (environmental, economic, social, and cultural) must be managed. It passes the "authentic problem" test put forth by Blumenfeld et al. (2006); others

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have demonstrated that students are more interested in learning controversial knowledge than settled knowledge (Blumenfeld et al., 1991; Nicholls & Nelson, 1992). But complexity and controversy can have unintended consequences. By the end of the initial implementation of the course, most students despaired of having any personal impact on what they increasingly understood was a very large and complex problem. Although they were learning the content of environmental science, they were also learning to disengage from the topic and any sense of personal responsibility. As others have pointed out, an unfortunate byproduct of students' increased knowledge about current environmental problems was a sense of "doom and gloom"[1] and a primarily passive identity in relation to major environmental problems (Kollmuss & Agyeman, 2002; Zeyer & Kelsey, 2013; Zeyer & Roth, 2013). In the design-based research reported here, our aim was to (1) identify which aspects of the initial course design interfered with (or failed to support) student engagement and the development of practice-linked identities as environmental citizens, (2) redesign the course on the basis of that analysis, and (3) assess the impact of the redesign on student engagement and identity development (as change in practice).

In this paper, we take a sociocultural perspective on engagement, viewing engagement as a form of participation in activity systems, combining both cognitive and affective components and arising through activity in relationship to evolving identities, goals, and norms (Greeno, 2006b; Hickey & Granade, 2004; Nolen, Ward, & Horn, 2011; Plaut & Markus, 2005; Roth, 2011). This paper describes a design-based research project to redesign the PBL-APES course to increase student engagement. Design-based research is iterative, with cycles of design, implementation, evaluation, and redesign (Dai, 2012). We begin by describing the initial design and then report on how we redesigned for engagement, supporting the development of *environmental citizen identities*. An environmental citizen is one who assumes that their decisions in the world have an impact on sustainability and who uses his or her understanding of environmental science to make reasoned choices. We take a situative view of learning and engagement, linking identity with knowing and employing particular practices (Hand & Gresalfi, 2015). Thus, being an environmental citizen is a "practice-linked identity" (Nasir & Hand, 2008), which requires knowledge of relevant practices (e.g. recycling, environmental activism, analysis of daily routines for their impact on the environment), an understanding of their function in a society, and a willingness to consider employing them. In iteratively redesigning the curriculum, we focused on expanding the curriculum beyond a focus on content to a focus on developing these identities. To assess the impact of our design, we collected data on whether students' everyday environmental practices had changed and on whether they could use the practices of environmental science in novel complex scenarios encountered in everyday life and in a culminating course test, described later in the manuscript. We also analyzed students' reported engagement and interest in course activities. We viewed both engagement and interest as indicators of students' values toward the environment and how students were attuned to environmental issues in the world. We sought to increase both engagement and take-up of scientifically-informed environmental practices by emphasizing students' agentic involvement in making decisions that affect the environment and emphasizing expansive framing for transfer of environmental knowledge and practices to expanding spheres of influence.

Theoretical framework

The ways that youth are asked to participate in different contexts and communities influence their engagement, the types of identities they are allowed to adopt, and ultimately, the types of people that they become (Boaler & Greeno, 2000; Cobb, Gresalfi, & Hodge, 2009; Cornelius & Herrenkohl, 2004; Wortham, 2006). Taking a situative approach, we assumed a tightly linked relationship between learning, engagement, and the process of identity development (Hand & Gresalfi, 2015) as students learn practices that expand their capabilities to participate in social

contexts in and out of school (Roth, 2011). This approach conceives of *identity* as a fluid and contextualized sense of self that is constructed through ways in which an individual is positioned and positions him- or herself in social practice (Hand & Gresalfi, 2015, Horn, Nolen, & Ward, 2012; Nasir, 2012; Nasir & Hand, 2008; Nolen & Ward, 2008). From this perspective, identities develop through participation in particular communities of practice (Brickhouse & Potter, 2001; Wenger, 1998) and take into account the social, cultural, and historical contexts within which one's identity is authored (Holland, Lachicotte, Skinner, & Cain, 1998). Identities in specific contexts start as roughly formed, but over time, through repeated practice and positioning, those identities will "thicken," becoming stable, impacting how an individual interacts with others and with disciplinary content and ideas (Holland & Lave, 2001; Wortham, 2006). In contrast to a single unit of instruction, lasting a few weeks or a few months, a year-long course may provide sufficient time to thicken developing environmental citizen identities.

Practice-linked environmental identities

To understand the connections between students' engagement in project-based environmental science activities, their take-up of environmental citizen practices, and their sense of their own roles 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 (p. 147)." Practice-linked identities are more likely to develop in learning contexts in which three conditions are met: "(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. 148). While many learning environments provide access to the domain, the latter two conditions are often absent.

Developing practice-linked identities as people who have the tools, agency, and responsibility to address issues of sustainability entails particular problems. Kempton and Holland (2003) describe three phases of environmental identity development that echo Nasir and Hand's notion of practice-linked identity: (1) becoming aware of environmental problems, (2) seeing oneself as an actor within the environment, and (3) learning how to engage in environmental practice. While the initial design of the PBL-APES course provided access to domain skills and concepts, it was not clear that students felt they had integral roles nor that they felt there was sufficient opportunity for self-expression and making valued contributions. Therefore, we analyzed the curriculum and students' and teachers' reports of their experiences with the projects for these elements.

Expansive framing for transfer

Taking up practice-linked identities as environmental citizens entails recontextualization or the transfer of practices learned in the environmental science course to students' lives outside of school. For our PBL-APES redesign effort to support students' identity development as environmental citizens, we were not only interested in the ways that practice-linked identities were developed in the class but also if and how those identities were recontextualized outside of the classroom, in students' lives. To the extent that identities were practice linked, we reasoned, the appearance of learned practices outside of the classroom context would indicate that they were being incorporated into students' identities as environmental citizens.

Traditional approaches to transfer have focused on either cognitive structures and types of knowledge or on the similarity between the contexts of use. This first approach examines how flexible knowledge structures and metacognitive knowledge increase the possibility of transfer

(Pugh & Bergin, 2005). The second perspective has looked at the extent to which project contexts were similar to those students encountered outside of school; knowledge (practices) learned in class should be transferrable. More recent views of transfer have challenged this second account (Goldstone & Day, 2012; Greeno, 2006a), expanding on the notion of perceived utility of learned content in new contexts.

Expansive framing for transfer (Engle, 2006; Engle, Lam, Meyer, & Nix, 2012; Engle, Nguyen, & Mendelson, 2011) entails creating a context for learning in which students expect that their prior knowledge is valued and applicable to the current context, that newly acquired knowledge can be adapted and applied in the future, and that they have valued and active roles in the learning environment. Framing these links forward and backward in time and across contexts expands the opportunities for transfer. In the context of the classroom, expansive framing for transfer allows for the creation of hybrid spaces (Calabrese Barton & Tan, 2009), wherein students blend discourses, practices, and identities from their in-school and out-of-school lives.

The approach to project-based learning used in the PBL-APES course is consistent with the notion of expansive framing for transfer. Students were introduced to content, skills, and practices in early projects that were revisited and built on in subsequent projects. This "looping" of ideas was the reason for developing the projects as *cycles* during which students were expected to continuously transfer previously learned knowledge into the current cycle and to transfer newly learned knowledge into future cycles, leading to more flexible transfer by providing reasons to learn from a variety of sources and experiences (Parker et al., 2013; Schwartz & Bransford, 1998). Another design feature, "engagement first," occurred through students being assigned roles at the beginning of each project cycle (e.g., sustainable farmer, natural resource manager) as the goal of the project was described. In these roles, students authored ideas and responded to ideas within the context of the projects (Engle et al., 2012). Rather than using projects as a way to linearly *apply* already-learned knowledge, students learned with the expectation that the knowledge would be continually useful in engaging with the current and future projects. Additionally, the projects focused on real-world scenarios and problems, allowing students opportunities to imagine the value and use of what they were learning to the world outside the classroom. In this way, the course projects were framed as having real-world relevance. Continuous participation in projects was expected to provide recurring opportunities for students to engage in the dimensions supporting practice-linked identities, 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 students to seek out additional information and opportunities to use their environmental science knowledge in other contexts (Renninger, Bacharach, & Posey, 2008).

Project overview

The parent project (The Knowledge in Action Project) was a multiyear, multicourse, collaborative design-based research project initiated by a well-resourced suburban school district. In collaboration with university researchers, the project was designed to examine whether fully project-based Advanced Placement courses could be successfully developed. The project was positioned as important in the district's embrace of broadening access to AP and to PBL as an approach. In addition to teacher collaborators and the research team, the original design team also included the district science coordinator and a university biology professor.

The work was an attempt to combat a persistent problem of AP practice: too much content "covered" with too little depth (Parker et al., 2013), "overstuffing" courses to "deliver" information to an extent equivalent to college-level introductory courses (National Research Council, 2002; Parker et al., 2013). According to a 2002 report by the National Research Council, students attempting to learn the breadth of content in AP courses failed to achieve deep conceptual understanding and cognitive skills. Following that report, the National Research Council recommended

Figure 1. The course poster for the project-based APES course in Year 1.

that AP courses be redesigned to better support student learning (Parker, Mosborg, Bransford, Vye, Wilkerson, & Abbott, 2011, National Research Council, 2002).

Initial design

The initial design of PBL-APES was based on the "challenge cycle" approach to PBL (Bransford et al., 2000, 2006). The course was structured around a driving question (e.g., "What is the proper role of humans in maintaining Earth's sustainability?"), and each project challenged students to find answers to that question in a different authentic context. The design principles were (1) rigorous projects as the spine of the course; (2) quasirepetitive project cycles wherein each builds on the other, yielding deeper understanding (called "looping" by the teachers); (3) "engagement first" in project roles that create a need to know; (4) teachers as codesigners, and (5) an eye to scalability. At the start of each of the six units (or "cycles"), students were placed in roles and given a complex project to accomplish over the course of several weeks. The structure of the course and its cycles are shown in Figure 1.

The first implementation of the year-long course prompted students to use their knowledge of science and citizenship to make informed recommendations about policies and practices that affect the environment. Each cycle was a simulation of adult expert practice in sustainability and environmental science, often in the role of a consultant, intended to promote student learning of APES content through immersion in adult practices. For example, students played the roles of scientist-advisors (in Biodiversity Hotspots) or "green" event planners (Eco Footprint). Projects were loosely ordered to ensure that foundational ideas (e.g., ecosystems, biodiversity, and tensions

among environmental, economic, and social-cultural concerns) were taught early in the course. Important concepts were then revisited in subsequent cycles, in a "quasirepetitive" process the teachers referred to as "looping."

Our role in the research

Design-based research is emergent; data collected and analyzed inform design changes and new data are collected as those changes are evaluated. The authors joined the parent project in the middle of the first year of PBL-APES implementation to provide expertise on student engagement. In conversations with teachers on the design team, it became apparent that engagement was decreasing rather than increasing over the duration of the course. These discussions led to initial re-design efforts that extended over the following summer. Data collection, analysis, and design activities overlapped as we tried to make major changes to the course before the beginning of a new school year. During the second implementation year, teachers began teaching the new course while still working on later units; analysis of Year 1 data continued as we collected an expanded set of implementation data from Year 2. The research team fed our initial findings back into the design work as they emerged. The following summer, the course was fine-tuned to increase an initially local focus as we brought new school partners into the project. Data were again collected in implementation Year 3 with those new partners and were subsequently analyzed. As is the case when doing research in collaboration with school and district partners, new problems of practice and unforeseen challenges to research design and data collection arose. In one of the two urban districts, personnel issues and pushback from some parents and teachers resulted in partial implementation of the curriculum for three teachers. We used that circumstance to examine the impact of the overall structure of the curriculum.

Overview of research

Design-based research is emergent and iterative, and data collection, analysis, and redesign activities overlap, making reporting somewhat messy. Because we addressed different research questions and had different participants at different points in the study, we have adopted the more canonical presentation of the multistudy report. Study 1 is a qualitative case study of students' and teacher's responses to the initial course design (Year 1), the redesign and its implementation (Year 2), and students' and teacher's responses to the redesigned course. Studies 2 and 3 explore the redesign in more depth, drawing on data from the second (Study 2) and third (Study 3) implementation years. Table 1 shows the research question(s) addressed by each study.

Study 1

In the first study, we report an in-depth case study of one teacher and her three classes of PBL-APES over two design iterations, using teacher and student interview data. The focal teacher participated in both the initial design of the course and the redesign. In our analysis, we compared student responses to the curriculum and their reports of taking up new practices in design years 1 and 2. We examined, in Year 1, the issues that led to course redesign and, in Year 2, how students responded to redesigned elements of the course. New design principles were developed to support student engagement and development of environmental citizen identities: positioning students as change agents, re-ordering projects to create expanding spheres of influence, and emphasizing expansive framing for transfer.

Table 1. Research questions and associated analyses.

Research Question	Related Analyses
What aspects of the initial course design interfered with student engagement and development of environmental citizen identities?	Study 1: Case study of a single teacher across two design versions (Years 1 & 2)
How did design changes impact student engagement and development of environmental citizen identities?	Study 1: Case study of a single teacher across two design versions
Do survey results support the theorized mechanisms of change?	Study 2: Quantitative analysis of factors related to environmental citizen identity and engagement
Can results of Studies 1 and 2 be replicated with a new sample?	Study 3: Interview transcript analysis HLM of Environmental Citizen Identity and predictor variables
Does engagement predict ability to transfer to an unfamiliar task?	Study 3: HLM analysis
Was level of implementation (full versus partial) related to identity development and ability to transfer?	Study 3: Interview transcript analysis comparing partial versus full implementation HLM

Study 2

Our second study looks across a wider set of classrooms to see whether measures of perceived agentic involvement were significantly related to students' development of environmental citizen identity. We used survey data from two districts implementing the redesigned PBL-APES course to test our theoretical model of the processes involved in student engagement and the development of Environmental Citizen Identity.

Study 3

In the third study, we further explored the mechanism of change, examining the role of the course architecture in providing opportunities for environmental identities to thicken. In addition to survey and interview data, we analyzed data from the Complex Scenario Test (CST), which was designed to measure students' abilities to transfer what they had learned into novel and challenging environmental scenarios. Considering that when identities change there are also changes in social practice (Dreier, 2009; Holland et al., 1998), we take the CST data as further evidence of whether students had learned practices of environmental sciences and could implement them in and out of school.

Study 1: Case study

Participants and context

This case study focuses on one teacher in a collaborating school district and her students. The teacher was a member of the original design team and assisted in the course redesign. At the beginning of the project she had 10 years of teaching experience, including 7 years of teaching a non-project-based version of APES. The focal teacher's school was the most racially and economically diverse high school in the district. In Year 1, 48 students had given consent to participate in the study from three sections taught by the focal teacher (25 identified themselves as male, 21 as female; 35 students identified as white, 10 as Asian, 2 as Hispanic/Latino, and 1 as multiracial/ethnic; 35 spoke English as their native language). In Year 2 of the study, 61 students from three sections were consented (36 male, 23 female; 33 White, 12 Asian, 6 Hispanic/Latino, 5 African American, 3 multiracial/ethnic; 21 identified English as their native language and 21 did not disclose that information; 18 qualified for free or reduced-price lunch).

Data sources

Overview

For the case study, the primary sources of data were interviews (individual interviews of teachers and students and group interviews of students) and teacher-researcher design meetings, supplemented by classroom video recordings. In analyzing interview data, we looked for two kinds of evidence of the development of particular environmental citizen identities: students' ability to articulate their roles in maintaining the environment and evidence that they were or were not transferring what they had learned to other contexts. Interviews were semistructured; prompts are shown in Appendix A.

Fishbowl interviews

To understand students' perceptions of the course, we conducted individual and group interviews. In group or "fishbowl" interviews, each class section was interviewed during the class period at the end of each school year. Groups of 4 or 5 students were "in the fishbowl" at any one time and answered questions from the interviewer or responded to others' answers. Audience members could participate by raising their hand. After about 10 minutes, new students replaced those in the fishbowl for the next segment. This was repeated until the end of the class period. All attending students participated, with verbal responses from approximately 80% of each class; only data from consenting students was analyzed. Fishbowl questions centered around perspectives on the course and their personal responsibility for sustainability. Fishbowl interviews were videorecorded and transcribed for analysis.

Individual interviews

In addition to group interviews, four students in Year 1 and four students in Year 2 were selected for individual interviews, chosen from across the teacher's course sections. We sought a balance of gender, grade level, and racial diversity. Students were interviewed after the first unit ("cycle") and at the end of each year, enabling us to look for changes in students' attitudes and understandings over time (Patton, 2002). The teacher and lead curriculum designer were interviewed and design team meetings were videotaped.

Data analysis

Interview transcripts formed the main corpus for the qualitative analysis, supplemented by video records of fishbowls and design team meetings. Our coding strategy was iterative and collaborative. To capture predicted links between identity, engagement, and transfer, we used theoretical constructs (Engle et al., 2012; Nasir & Hand, 2008) to examine self-reports of students and teachers. We used a combination of grounded theory (Strauss & Corbin, 1998) and theoretical constructs to create codes and coding categories for the case study. We began with an initial coding scheme based on these concepts for studying identity development, looking across years for evidence of practice-linked identities, including reports of connecting school with out-of-school contexts, reports of transfer to daily practices, specific solutions proposed to people outside of the classroom, and students' rationales for using or rejecting sustainable practices. Evidence of transfer included the specificity of any proposed solutions to environmental problems, reports of changed practices actually enacted in students' daily lives, and perceived relevance of course activities. We reasoned that more-specific solutions and examples of changed practices and greater perceived relevance in Year 2 data would suggest that the revisions supported initial development of environmental citizen identities. The data from the first year were coded collaboratively by the research team. Once the first year's data had been fully coded, we coded half of

the second year's data set using the same codes. New patterns in the Year 2 data required additional codes. The second half of the Year 2 interviews were then coded independently by members of the research team (2–3 coders per transcript). Transcripts were then reviewed as a group. When there were disagreements, they were resolved by the group as a whole. Next, Year 1 data were reanalyzed to see if any of the new codes could be applied. This process was repeated until theoretical saturation was reached. The comparison of patterns in the data, using this final set of codes, forms the basis for the findings reported next and confirms the initial observations on which the redesign was premised. Final codes and code categories are shown in Appendix B.

Findings from Year 1: Original PBL-APES

Agency

Systematic analysis of student and teacher interview data from the first year confirmed the existence of the problems initially identified by the design team as negatively affecting student engagement and interest in environmental issues. Analysis of the data found that *agency* (or its lack) was seen by teacher and students as critical to engagement in environmental science, both in terms of agency within the project and in relation to environmental problems in the world. The focal teacher reported that students were not engaging as deeply in the projects as she had hoped, and that their lack of agency was evident early in the year. "I realized they really didn't have any freedom to make big decisions … [they need] to be creative, to do something, to take their own direction … without being so constricting that they all end up with the same thing" (Teacher 123, May 10, 2011, individual interview). It was clear that the teacher felt that students lacked opportunities for self-expression in the practice, one of Nasir and Hand's (2008) key dimensions for supporting development of a practice-linked identity. While students had agency within project choices, they did not have opportunities to author ideas and make substantive decisions as emphasized in expansive framing for transfer (Engle et al., 2012) impacting their potential to develop environmental citizen identities.

Lack of agency in relation to solving environmental problems in the real world appeared to be an even bigger impediment to engagement. Students expressed in their individual interviews that they felt powerless to make positive changes to the environment, clearly feeling the lack of opportunity to make a valued contribution. For example, one student reported fatalistically, "It's just going to keep getting worse and worse" (Student 553, Period 4, June 10, 2011, individual interview). In the group fishbowl interviews, 30% of students' comments were explicit expressions of depression about their ability to have an impact. Students discussed societal obstacles to enacting sustainable practices when unsustainable practices were believed to be the norm. "We live in a society where we don't stress a lot of sustainability … So, like, you want to be on Earth's side, but you don't know if that's practical." After a discussion typical of this year's fishbowls, in which students stressed the depressing nature of the curriculum's content, a student complained about the lack of viable practices learned in the course. "I wish we could be more positive, like here are some things that you can do and be able to live with, then I think it will actually make a difference. Otherwise, if everyone is doing all these [unsustainable] things, what is the difference if I'm doing it too?" (May 10, 2011, fishbowl interview).

Agency and practice

Agency requires access to practice. Although the project cycles provided a simulated context in which environmental science practices were required, we found evidence in the interview data that students were not taking up disciplinary practices for use in the wider world. Throughout individual and group interviews, students were repeatedly prompted for possible specific solutions to environmental problems addressed in the curriculum. Yet the students were consistently vague,

offering solutions that *should* be enacted but were not currently in place. Of 28 proposed solutions in the two fishbowl interviews, 18 instances were coded as vague. For example, one student stated, "I think it is interesting about all of the energy sources, and some are not renewable and will eventually run out. It has made me think, like, I should probably use less of it, try to conserve it." (May 10, 2011, fishbowl interview). Other students described reasons that solutions to environmental problems were not feasible, as in this claim, "Everyone is going to drive their cars. So, like, there are little things that you can change but there are certain things that you can't change" (May 10, 2011, fishbowl interview).

Authenticity, value, and recontextualization (transfer) of practices

Proponents of PBL emphasize the authenticity of projects, the relationship of the problem or project to the real world and its practices (Krajcik & Blumenfeld, 2006). Disciplinary expertise is needed to design authentic PBL in science, but for students, authenticity may also be a function of the project's relevance to their own lives and values outside of school. We found that in addition to students not taking up disciplinary practices, students did not perceive an opportunity to learn *useful* practices. In the teacher interviews, fishbowl interviews, and individual student interviews, we asked for critiques or suggestions to improve specific project cycles. Most of the critiques focused on perceived relevance to students' lives outside of school and perceived authentic use of environmental science practices, indicating that, while intended, framing outside of the course and into the real world was not as successful as intended. For example, one student negatively commented on Eco Footprint as it was initially designed (plan an event using sustainable practices), "One of the projects I probably disliked the most was having to plan the wedding … I didn't see the connection to that and anything I could take away from that and to the future" (May 10, 2011, fishbowl interview). The teacher also reported that students struggled with connecting environmental science concepts with their lives, their identities in the world, revealing a need for additional framing for transfer. Practices and concepts are unlikely to be taken up when they are seen as irrelevant to navigating the world more effectively, when they don't align with one's identity or address important problems.

Contrast case: The environmental warrior

To the extent that students see projects as authentic to their lives and values, practices learned in those projects should be construed as potentially valuable and more likely to be taken up and recontextualized. This possibility is illustrated by the only interviewee who *did* seem to take up environmental science practices as relevant to her identity: a student who considered herself an "Environmental Warrior." This student came into the course with an existing proenvironment identity. She had considerable prior knowledge of environmental problems and solutions and was able to make connections between the curriculum and out-of-school contexts, successfully transferring her environmental knowledge across contexts. She reported using the learning in class to develop solutions with the "Environmental Warriors Club," of which she was a member. Her prior knowledge and existing environmental identity helped her expansively frame her own opportunities to learn valued concepts and practices. She expected her prior knowledge to be relevant and was able to create connections to course activities and their application in current and future contexts.

> EW: I've written letters to the President about fishing practices that we have… Once you get into international waters there's no restriction whatsoever. We're overfishing so much, it's bad for the fish.
>
> Researcher: Did you start that before this class?

> EW: No, the fishing thing, that started after I realized that was a problem. I didn't even know that was going on (Environmental Warrior, May 12, 2011, individual interview).

This student stood out as a contrasting case of engagement and identification because she saw the relevance of most course activities to her current identity as an environmental warrior. Her responses supported the design changes intended to strengthen connections between the course and students' out-of-school lives.

Course redesign

Feedback from students and teachers at the end of the first year suggested that some students had constructed passive identities regarding the environment. As one student put it, "It was so depressing that you thought that there was no hope, so why would you care? … I wish that we could [learn] some things that you can do and be able to live with." Such feedback indicated the need to more deeply consider the ways students used course content to interact with their daily lives. In other words, how could we redesign the course to support the development of identities as agents whose practices have impacts on the environment?

Following a week-long debriefing, at which teacher collaborators were provided an outline for redesigned cycles, the curriculum materials were redesigned. The redesign followed three new, related design principles created to address the challenges identified in the environmental science course: (1) position students as change agents throughout the course, (2) arrange cycles in expanding spheres of influence, and (3) emphasize expansive framing for transfer.

Positioning students as change agents

To position students with integral roles as change agents and to provide access to the discipline, the first project cycle (Eco Footprint) was changed from a simulation project ("green" planning for a large event) to a real one involving students' own families. In the redesigned Eco Footprint, students were required to conduct detailed audits of their families' water consumption, electricity use, and waste production. After analyzing the ecological impact or "footprint" of their families' current practices, students drafted and presented to their families a proposal for specific ways to reduce that footprint using social, economic, and ecological reasons to convince their family members to change their daily practices. This cycle provided what Calabrese Barton and Tan (2009) have called "hybrid spaces" and opportunity to integrate home and environmental-science related identities and discourses (see also Tzou, Scalone, & Bell, 2010). In this way, students were positioned as actual agents with the potential to change their families' environmental practices and as persons who had the authority for self-expression in the practices of environmental citizenship. In the process, the course content was expansively framed as having relevance and value to the world beyond the classroom.

Expanding spheres of influence

After Eco Footprint, the project cycles were arranged to progressively expand students' real or simulated spheres of influence from local (i.e., designing a sustainable farm, writing a children's book to teach children about ecology) to global action (using knowledge of ocean systems to make decisions about siting industries, participating in geopolitical environmental negotiations). This expanding-spheres design (see Figure 2) provided access to understanding larger problems in the domain of environmental science while maintaining student agency through integral roles in projects and opportunities for self-expression. The expanding spheres expanded not only in environmental focus but student agency to address the environmental challenges. By purposefully positioning students within the course and giving them iterative opportunities to agentically act

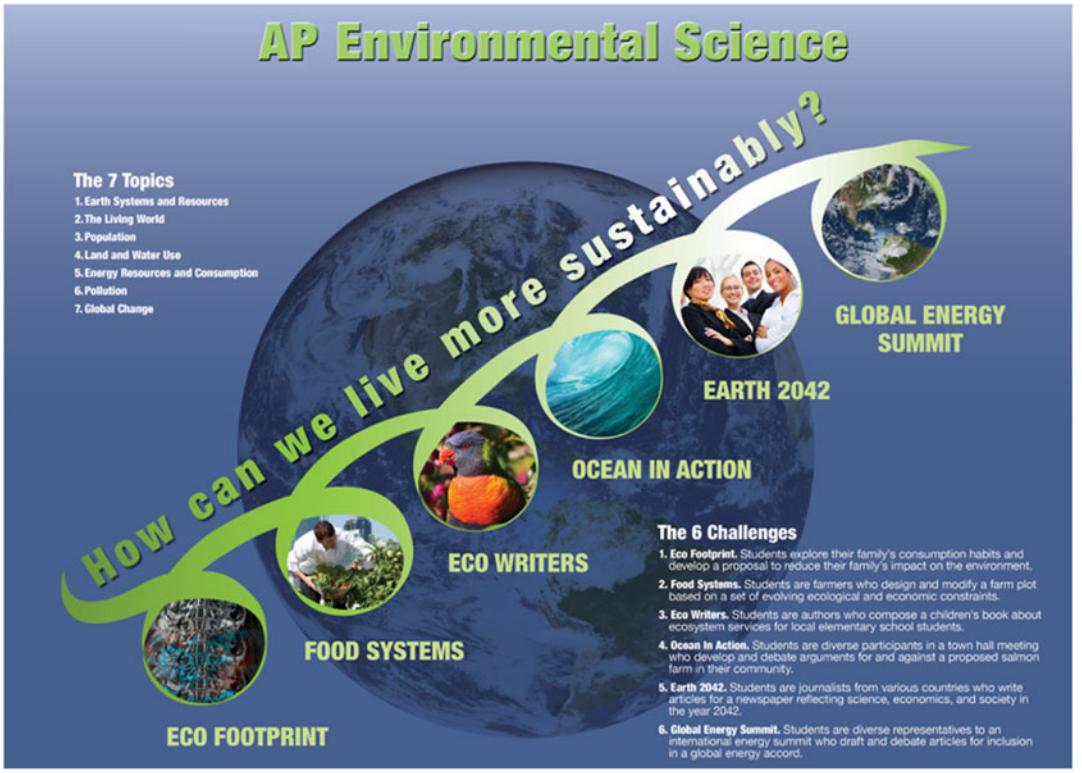

Figure 2. The course poster for the project-based APES course in Year 2.

with environmental science practices, we posited that their identities as environmental citizens would thicken.

Expansive framing for transfer

The third design principle was instructional rather than curricular. In a challenge cycle design, such as the one implemented in PBL-APES, learning is framed as serving the purpose of expanding students' capabilities to address the project and its designed problems. Looping provides repeated opportunities for transfer within the course. In the redesigned course, teachers were encouraged to more expansively frame for transfer beyond the course in terms of content, practices, and roles. The course redesign provided a structure for expansive framing, but teachers were responsible for emphasizing the relevance of practices and roles in the course to students' roles outside of school as citizens of the environment. Collaborative professional development sessions with the Year 2 teachers emphasized both the coherence of the redesigned project sequence and how teachers might specifically frame activities to promote transfer in and out of the classroom. Through expansive framing and starting the course with a project that created a hybrid space (Calabrese Barton & Tan, 2009) between students' in-school and out-of-school lives and then expanding spheres of influence, teachers were encouraged to emphasize to students that disciplinary practices were relevant and useful in their everyday lives outside of school, now and in the future, contributing to the development of practice-linked identities.

Taken together, we hoped that the curricular and instructional changes would help students see their role in enacting specific environmental practices and mitigate against the feelings of "gloom and doom" observed in the initial implementation.

Case study findings from Year 2: Redesigned PBL-APES

Take-up and transfer of environmental science practices

Comparing initial interviews with students immediately after the completion of the first cycle across the two years, provided an initial assessment of the changes. In Year 1, the first cycle was "Biodiversity Hotspots," in which students were consultants to imaginary groups seeking to protect biodiverse ecosystems across the planet. Students had reported difficulty in relating to remote areas and in understanding their role as consultants. In Year 2, the first cycle was the redesigned Eco Footprint focused on students' families' practices. Interviews suggested that the cycle's new activities, focusing on expansively framing the course content as having relevance to students' everyday lives, had created a hybrid space between school and home in which students could explore the personal relevance of sustainable practices learned in class, creating a space to support students' environmental citizen identities. Consistent with the theoretical basis for the curriculum changes, students interviewed at this point reported specific instances of transfer from school learning to home practice. The following response was representative of students in the redesigned course talking about specific solutions to environmental problems:

> [The teacher] gave us a whole list of electrical appliances that we might use, and so we put in how long each day they're used or plugged in. And then we put it in this Excel sheet and got the math of how many kilowatt hours are being used from that, and then we printed it out and made a pie graph. I immediately showed that to my mom and she was amazed and right off the bat we just started changing the way that we use stuff, and started to unplug stuff when we weren't using them (Student 1391, October 31, 2011, individual interview).

Student responses indicated that they made connections between school and home with the expectation that they would use their learning outside the classroom, evidence that they considered their learning as relevant to their lives. "I can totally see how that relates to me, and how that impacts my life because I can see, 'Oh! This is how much gas I use. This is how much I don't walk …' So, I can really relate to it" (Student 1217, November 14, 2011, individual interview).

The new Eco Footprint cycle positioned students to recognize connections between school and home, which can lead to deeper transfer, scientific understanding, and identification with environmental science practices (Calabrese Barton & Tan, 2009). Students were framed as active participants and authors of the sustainable practices in their lives (Engle et al., 2012). Although some students' families already engaged in some environmentally conscious practices, the curriculum's activities encouraged transfer by asking students to examine impacts of simple changes across a range of connected settings. This focus on Earth as a network of interacting systems encouraged the students to consider their roles in these systems, which may have enabled them to realize the spreading effects of simple changes in their daily practices. To highlight systems, students were required to evaluate the ecological, economic, and social impacts of behaviors in their proposals. This type of analysis was intended to deepen student learning, which can lead to adaptation of that knowledge when needed for application to new problems (Calabrese Barton & Tan, 2009, Engle et al., 2012), helping support students' developing environmental citizen identities.

Development of practice-linked identities

All of the students interviewed following the Eco Footprint cycle reported new practices that were not only proposed to their families, but implemented in their daily lives. These changes stemmed from the underlying principle that small personal changes had an impact on sustaining the Earth. As students prepared to move into subsequent cycles, in which the scope of environmental problems became progressively larger, all of the focal students expressed a belief that what they had learned thus far and what they were preparing to learn had implications for how they would live in the future, beyond high school and as adults, indicating initial development of

practice-linked environmental identities (Nasir & Hand, 2008). One student in an individual interview reported, "[This class] will definitely change the style of living when I'm off on my own … I know that if, like I ever have a kid someday, the first thing I'm gonna teach him is recycling" (Student 1051, October 31, 2011, individual interview). This stated intention to transfer the learning from class suggests that she perceived the knowledge as having present and future value and that she was learning in preparation for transfer (Engle et al., 2012).

Course architecture: Thickening environmental citizen identities

After positioning students as environmental change agents at the beginning of the course, the other revisions to project cycles were designed to provide further opportunities to develop practice-linked environmental identities, even as the scope of the projects expanded to include increasingly large environmental systems. One student described continuing to influence his family:

> Oceans in Action has also helped me realize, "Oh, we're actually really screwing things up. We now have mercury and like deadly levels of it, and if we eat too much we're going to get screwed up, too!" So, I told my parents about it, and they were really fish lovers, and they're kind of scared now. They're like, "Wow! It's because of us that we're basically killing ourselves slowly now." And my parents are a lot more aware, and I say, "If you can walk, let's do it. Let's not drive" (Student 1217, June 15, 2012, individual interview).

Interview data from the end of the redesign year suggest that students continued to show signs of developing environmental citizen identities. The student responses indicated that gradually expanding from personal to global spheres of influence may have ameliorated the sense that environmental problems were too big to change. One student was able to connect what she knew about local pollution to pollution in China, based on her participation in Global Energy Summit (the final cycle). "Seventy five percent of the people there have a respiratory problem because of the smog. And if we just keep … polluting, we're going to end up like China. Or we could keep it up, go green, and keep our world alive" (Student 1051, June 13, 2012, individual interview). This comment suggests that the student saw herself as having agency in relation to a large abstract environmental problem.

Comments made during the fishbowl interviews indicated that students were, in general, more likely to self-identify as being concerned with making environmental decisions in their daily lives and were able to cite specific examples of past or future transfer. The fishbowl discussion covered many topics about the class as a whole. Of students who were asked about practices in their daily lives, about 45% cited specific changes. About 30% of students who were asked about their favorite cycle mentioned changes in practice, citing the relevance of the Eco Footprint cycle to their own decision making. Of the remaining students in the class, 25% who did not describe specific changes, said the information in the class was deepening their understanding of the impact they and others were having on the environment.

Even at the end of the school year, students invoked the learning from Eco Footprint for its connection with students' personal lives. For example, "I thought it was really cool to like personalize it to like what your exact effect on the environment was" (May 29, 2012, fishbowl interview). Students also spoke more optimistically about solutions when discussing global problems. In contrast with the first year, in which students felt they had not learned viable solutions, only one utterance in the second-year fishbowls indicated apathy, depression, or no perceived relevance.

The focal teacher reflected positively on the implementation of the redesigned course. "It was better. I'm not hearing depressed students all the time, like I was last year, so I think those changes really made a difference" (Teacher 123, June 13, 2012, individual interview). Other teachers responded in a similar manner. The course, by nature of the research project, continued to be redesigned, including building on the local-to-global architecture findings by designing a new second cycle (My Community Ecology) to replace Eco Writers. This case study suggests that the

design modifications (reordering the cycles to begin with students as change agents in their families and redesigning cycles to emphasize agency and framing for transfer) had an impact on the extent that students developed practice-linked identities as environmental citizens.

Study 2: Cross-site survey

In addition to the qualitative case study, we wished to examine across a broader sample how students' perceptions of their PBL-APES class related to their environmental citizen identities. Therefore, in the second year we used survey measures to capture some of the themes identified in the case study to further test our theoretical model of designing for engagement.

Although expansive framing was "baked into" the redesigned curriculum through suggested introductions to each cycle and curriculum materials and activities, it is likely that implementation of these framing features varied across teachers and that the influence of time constraints and a looming AP test at year's end might influence teachers' willingness or ability to spend the time needed for students to engage the content more deeply. Surveying across the implementation classrooms allowed insights into variations by classroom.

Participants

Participants were 311 students enrolled in PBL-APES across 18 classrooms in two districts: the suburban district in which the curriculum was initially designed and an urban public charter network in another state. Among the participants, 138 were male, 169 female, and 4 were undisclosed. One hundred twenty-nine students identified as White, 61 as Asian, 40 as African American, 40 as Hispanic/Latino, 32 as multiracial/ethnic, 3 as Native American, 2 as Other/Pacific Islander, and 4 undisclosed. One hundred thirteen of the 311 students qualified for free or reduced-price lunch, with four students' status unknown. Thirty-five percent of the students identified English as their native language and 41% did not indicate a native language.

Measures

As part of the larger project's beginning- and end-of-year surveys, we included scales to measure initial interest, engagement in course activities, perceptions of the teacher's focus on (deep) learning, and the extent that students identified as being environmental citizens. Students responded to items on a 5-point Likert scale with 1= *strongly disagree* and 5 = *strongly agree*; items within each scale were averaged to produce a mean score for each scale for each student. Surveys were administered by a member of the research team. Fall surveys were collected in the first week of school; spring surveys were collected in May. Survey items and internal consistency reliability coefficients are shown in Appendix C.

Initial interest

Initial Interest items were based on the work of Hidi and Renninger (2006) and assessed individual interest in environmental issues at the beginning of the course (e.g., "(I am taking this class because) I am interested in this subject"). We viewed interest as a component of developing environmental citizen identities, in that interests influence what students value and how they attune to the world.

Engagement

Self-reported engagement was assessed in two forms. General engagement was measured with items assessing *Flow* (e.g., "Time passed really quickly"), adapted from the work of Csikszentmihalyi and Larson (1984). *Agentic Involvement* was as scale developed to capture students' feelings of being agentically involved in the PBL-APES activities, a perception that was theoretically linked to the thickening of practice-linked agentic identities and that emerged from our case study. Items measured the extent to which students perceived opportunities for integral roles and accountability and opportunities for self-expression 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"). A third scale, *Learning Focus,* adapted from previous research in science classrooms (Nolen, 2003) assessed perceptions that the teacher's classroom practices supported agentic involvement (e.g., "The teacher encouraged us to think for ourselves").

Environmental Citizen Identity

For this scale, students rated the extent to which they were interested in environmental issues, knew enough to make good environmental decisions, and believed that "people like me" could "make a difference."

Analysis and results

To account for variation between implementation classrooms, we used hierarchical linear modeling (HLM) to test the combined and independent contributions of Initial Interest, Agentic Involvement, Flow, and Learning Focus to variance in end-of-course Environmental Citizen Identity. Initial interest in environmental issues was presumed to predict end-of-course environmental citizenship identity due to the relationship between interest and identification. Therefore, we examined whether engagement measured by Agentic Involvement and Flow along with perceptions of the classroom's Learning Focus accounted for additional variance.

When students are taught in classrooms, the observations on students within a classroom are not independent observations. To correctly calculate estimates of the variability we used hierarchical linear models (Raudenbush & Bryk, 2002) that take the effects of clustering into account. Our continuous measures met the assumptions of normally distributed residuals and our binomial outcomes are modeled appropriately in HLM using the logit link function.

In the first set of models, we assessed the role of individual predictors on individuals' end-of-year Environmental Citizen Identity, given individuals' beginning-of-year initial environmental interest and accounting for nesting.

Level 1 Model:

$$Environmental\ Citizen\ Identity_{ij} = \beta_{0j} + \beta_{1j} * \left(Initial\ Interest_{ij}\right) + \beta_{2j} * \left(Agentic\ Involvement_{ij}\right) + \beta_{3j} * \left(Learning\ Focus_{ij}\right) + \beta_{4j} * \left(Flow_{ij}\right) + r_{ij}$$

Level 2 Model

$$\begin{aligned} \beta_{0j} &= \gamma_{00} + u_{0j} \\ \beta_{1j} &= \gamma_{10} \\ \beta_{2j} &= \gamma_{20} \\ \beta_{3j} &= \gamma_{30} \\ \beta_{4j} &= \gamma_{40} \end{aligned}$$

Individual levels of Agentic Involvement ($t_{(230)} = 3.29$, $p < .001$), Flow ($t_{(230)} = 9.64$, $p < .001$), and perceived classroom Learning Focus ($t_{(230)} = 4.44$, $p < .001$), explained significant variance in end-of-year. To test whether classroom levels of Agentic Involvement added to the predictive

Table 2. HLM Model and final estimation of effects, Year 2.

Level 1 Model:

$$Environmental\ Citizen\ Identity_{ij} = \beta_{0j} + \beta_{1j} * \left(Initial\ Interest_{ij}\right) + \beta_{2j} * \left(Agentic\ Involvement_{ij}\right) + \beta_{3j} * \left(Learning\ Focus_{ij}\right) + \beta_{4j} * \left(Flow_{ij}\right) + r_{ij}$$

Level 2 Model

$$\beta_{0j} = \gamma_{00} + \gamma_{01} * \left(Class\ Mean\ Agentic\ Involvement_{j}\right) + u_{0j}$$
$$\beta_{1j} = \gamma_{10}$$
$$\beta_{2j} = \gamma_{20}$$
$$\beta_{3j} = \gamma_{30}$$
$$\beta_{4j} = \gamma_{40}$$

Fixed Effect	Coefficient	Standard error	*t*-ratio	Approx. *df*	*p* value
Environmental Citizen Identity, γ_{00}	3.43	0.027	125.49	15	<0.001
Class Mean Agentic Involvement, γ_{01}	0.59	0.16	3.77	15	0.002
Individual Initial Interest, γ_{10}	0.13	0.03	3.76	230	<0.001
Individual Agentic Involvement, γ_{20}	0.12	0.04	3.29	230	0.001
Individual Perceived Learning Focus, γ_{30}	0.22	0.05	4.43	230	<0.001
Individual Flow, γ_{40}	0.35	0.04	9.63	230	<0.001

power of the individual measure, a model with Initial Environmental Interest, individual Agentic Involvement, perceived Learning Focus, Flow at Level 1, and the classroom mean of Agentic Involvement at Level 2 was constructed to predict end-of-year Environmental Citizen Identity.

After adjusting for Initial Environmental Interest and individual predictors, students in classes with higher mean Agentic Involvement had higher Environmental Citizen Identity ratings. Put another way, classrooms that provided more opportunities for integral roles in environmental science activity had students who identified more as citizens of the environment, beyond the contribution of their individual perceptions. Similar results were obtained when class means of Learning Focus were used as a Level 2 predictor, indicating thatin classrooms with a higher shared perception, where when teachers focused on understanding, independent thinking, and problem-solving, students were more likely to identify as environmental citizens (Table 2).

Summary of results from studies 1 and 2: Impact of course redesign

The case study suggests that the design changes had the intended effect of increasing agency, engagement, and the development of practice-linked identities as environmental citizens. The survey study supports the theoretical rationale for the design: that students in classrooms with more opportunities for agentic involvement and where students are encouraged to take authorship of ideas and practices in the course are more likely to develop or thicken their practice-linked identities as environmental citizens. Positioning students as agentic in expanding spheres of influence, with an emphasis on expansive framing for the transfer of ideas, practices, and roles appeared to support engagement and identity development as predicted and mitigated against the perceptions of helplessness in the face of insurmountable environmental problems. Together, these findings provide support for the proposition that increasing students' opportunities for integral roles and self-expression in the practice of making science-informed decisions contributes to students' interest and, potentially, transfer to out-of-classroom contexts.

These results clearly bear on the efficacy of our first and third redesign principles, to position students as agentic in relation to environmental problems and emphasize expansive framing for

transfer. They do not reveal as much about the need for our second design principle, sequencing cycles so as to provide increasing spheres of influence in which to practice environmental citizenship. Study 3 takes advantage of unforeseen difficulties in implementation in Year 3 to addresses this issue, along with the robustness of the findings from Year 2, by investigating data from an expansion of the curriculum to additional urban districts.

Study 3: Replication and extension

The data from the redesign presented above showed that the first cycle of the curriculum, Eco Footprint, was particularly powerful in setting the stage for the take-up of environmental citizen identities. However, the data we collected could not tell us whether the course design principle of gradually expanding spheres of influence, from local to global, was influential in supporting development (thickening) of environmental citizen identities or whether our results might reflect learning from a smaller set of experiences (in Eco Footprint) in which our other two design principles were particularly powerful.

Following the first two years of the course, the parent project expanded curriculum implementation in two additional urban districts. Teachers in the two new districts were recruited to help the research team adapt the curriculum to best fit the students at their urban schools as they implemented it. During this study, 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? Interview data can capture students' reports of the adoption of practices and their use outside the classroom, one measure of the adaptive transfer we aimed to foster. The ever-widening spheres of influence model is also intended to support students' use of environmental science practices to address larger, unfamiliar environmental issues. Therefore, in Year 3 we augmented student self-reports of transfer by considering a transfer task requiring hypothesis generation, requesting additional information, supporting/refuting hypotheses and proposing solutions to a real-world environmental problem (flooding in Cambodia). Adding transfer task data to the self-report data in Study 1 provided an additional test of our conjectures.

The implementation of PBL-APES in the two urban districts ranged from partial to complete for a variety of reasons beyond the control of the researchers. Reasons ranged from time management issues for one teacher (inability to move through the curriculum at the designed pace) to two teachers' response to parents' concerns that the project-based course was not rigorous enough to prepare students for the AP test. Although all classes implemented the first cycle (Eco Footprint) and all students participated in AP environmental science for the entire year, only about half (6 of 11) implemented all or most of the PBL-APES curriculum. We capitalized on this unintended implementation difference to examine the question of whether the results obtained in Studies 1 and 2 might have been due to a powerful initial cycle (Eco Footprint) or to the expanding-spheres design of the course architecture. Comparing students in these two groups of classes provided potential to examine whether the curriculum-length design change contributed to the thickening students' identities (Holland & Lave, 2001; Wortham, 2006) or whether similar results could be obtained by "jump-starting" engagement and identification by implementing the Eco Footprint cycle alone.

Participants and contexts

Two urban school districts in two different regions of the United States participated in Study 3. We recruited four teachers from three of the 12 high schools in Urban District 1 to teach the experimental curriculum, for a total of six sections. Urban District 2 adopted the experimental

Table 3. District, schools, class sections, and level of implementation of teachers in Study 3.

District: School	Number of PBL-APES Class Sections	Level of Implementation
District 1: School 1	2	Partial
District 1: School 1	2	Partial
District 1: School 2	1	Partial
District 1: School 3	1	Full
District 2: School 1	1	Full
District 2: School 2	1	Full
District 2: School 3	1	Full
District 2: School 4	1	Full
District 2: School 5	1	Full

PBL-APES curriculum as a district with the consent of the teachers. All five APES teachers (five sections, one in each of five schools) from District 2 participated in the study. We collected survey data and transfer task data from 120 students in 11 classes and interviewed a subsample of 20 students early and late in the school year, split evenly between full-implementation and partial-implementation classrooms. Interviewed students were selected from volunteers using classroom observations, field notes, and student grades to get a range of students. Both districts served a mix of students but included significant numbers of immigrant families and similarly high rates of free and reduced-price lunch qualification. All teachers were new to the curriculum, although some teachers in both districts had experience teaching environmental science or environmental studies courses. Teachers in partial-implementation classes continued to teach AP environmental science for the full year but either "stepped away" from the PBL approach (four sections, two teachers in one school) or took much longer to proceed through the curriculum (one teacher). The class sections, teachers, schools, and level of implementation are shown in Table 3.

Data sources

Study 3 used multiple data sources and methods to address our research questions (see Table 1). To address whether response to the course was robust as we expanded implementation to new districts, we collected and analyzed interview data using the same individual and group interview approach as in Study 1. We then compared these data across implementation types (full versus partial) to address whether the full course architecture contributed to identity development beyond the impact of the initial cycles. Survey data were analyzed in a replication and extension of Study 2, in which we examined the relationship between engagement variables from Study 2 and performance on the transfer task, examining the role of full versus partial course implementation in supporting the development of environmental citizen identities.

Measures

Survey measures were the same as those used in Study 2. The transfer task was the Complex Scenario Test (CST), a measure of flexible transfer developed in the parent project, given in May. The CST presents a real-world ecological problem (e.g., catastrophic flooding in a specific region) and asks students to generate hypotheses, request additional information, support or refute hypotheses, and propose and justify solutions to the problem using the knowledge and skills learned in APES, other prior knowledge, and the information and data provided in the prompt. Students were given about 25 minutes to do each part. The scoring rubric asks raters to evaluate each of these tasks on three dimensions: content (accurate, detailed understanding of key content, particularly the interconnectedness of human and environmental systems), process (ability to apply scientific reasoning to the problem), and scope (the extent and complexity of the causes and consequences of the problem and potential solutions considered.

Technical properties of the CST across three years of administration in the parent study in various contexts are summarized here. Two raters (not members of the research team) score each CST, with an interrater agreement ranging from .88 to .91 for the three types of rubric across all parts of the test and all samples (for agreement within 1 rubric point). True scores are estimated by averaging the two ratings. If two raters are more than 1 point apart, a third rater scores that response independently and the two scores that are the same or adjacent are taken to represent true scores. Factor analyses of the scores across three years of use consistently found four factors with high internal consistency (alphas above .9), each representing a dimension of scientific thinking as prompted by the CST: generating hypotheses, requesting additional information, supporting or refuting hypotheses in light of results, and proposing evidence-supported solutions to environmental problems. For the present study, summary scores for each factor were created for each student.

Procedures

As in Study 2, surveys were administered by a member of the research team in the first week of school (fall) and in May (spring). In May, we also conducted fishbowl interviews, then returned to administer the transfer task (CST). Participation in fishbowl interviews and other group measures was similar in full- and partial-implementation classrooms. Individual student interviews, using similar prompts to those described in Study 1, were conducted at the end of the first cycle (November) and at the end of the course (May). We obtained both fall and spring interviews from 18 students across the 11 classrooms.

Qualitative analysis and findings

Analytical procedures

Analytical procedures were similar to those used in Study 1. Approximately five to seven interviews from Study 3 were coded by the entire team to calibrate. Subsequent interviews were coded independently by members of the research team (2–3 per transcript). The research team met regularly to discuss patterns and additional codes that needed to be added. We then compared classrooms, looking for patterns within and across classrooms that had implemented full or partial curriculum.

Replication of Study 1, Year 2

Analysis of the end-of-year interviews replicated Year 2 (suburban) results, indicating that many students were developing practice-linked identities as environmental citizens. Half of the students interviewed (50%) provided both specific descriptions of changed personal practices and expressed a belief in their own agency and responsibility in contributing to sustainability. In addition, 75% of the students expressed agentic beliefs and 60% of them expressed agentic beliefs and hopefulness. 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, May 31, 2013, individual interview)

The student reiterates the perception of identity change (It changed me as a person), the student's position as a change agent convincing family members (I was like, "You guys can't be showering for like 40 minutes … ") and lists multiple family practices that have changed as a result.

Table 4. Interview transcripts categorized according to four dimensions. F = full implementation; P = partial implementation. Numbers in brackets indicate counts.

		Apathetic		Agentic	
		Depressed	Hopeful	Depressed	Hopeful
Not Enacted	Vague	P (1)			F (1)
	Specific	P (3)			
Enacted	Vague			P (2)	P (1)
	Specific			P (1)	F (8)
					P (2)

Affective Dimension Definitions

Apathetic-Agentic: The extent that students talked about their influence in making a change with environmental issues. Apathetic student comments were about not being able to enact change, while Agentic student comments focused on the student as a change agent.

Depressed-Hopeful: The extent that students talked about their emotional view of environmental issues. Depressed student comments centered on environmental issues being too big to change. Hopeful comments focused on possible environmental change.

Transfer/Practice Dimension Definitions

Enacted-Not Enacted: This dimension looked at students bringing up specific environmental actions they took in their lives.

Vague-Specific: This dimension examined the environmental practices and solutions students mentioned. Vague solutions, such as "recycling more," did not mention specific actions they took; while Specific solutions pointed to particular enacted practices.

Full versus partial implementation

To compare students from full- versus partial-implementation classes, transcripts were categorized along two affective dimensions (Apathy-Agentic; Depressed-Hopeful) and two transfer/practice dimensions (Enacted-Not Enacted; Vague-Specific). Definitions of affective and transfer/practice dimensions and tabulated data are represented in Table 4). For example, student responses that focused on the value and positive impact of encouraging her family to use canvas bags would be coded "Responsibility," "Hopeful," "Enacted," and "Specific"; whereas student responses that focused on the importance of everyone caring for the environment but that did not mention specific actions would be coded "Responsibility," "Hopeful," "Not-Enacted," and "Vague." Coders were unaware of which classrooms transcripts came from. One student is not represented in Table 4 because the student's responses, while vague, were not clearly agentic, apathetic, hopeful, or depressed.

As shown in Table 4, evidence of impact on practice-linked identities as environmental citizens was more limited in partial-implementation classrooms. Most students across the two groups (partial and full implementation) showed evidence of some features of practice-linked identities as environmental citizens. Students from full-implementation classrooms were all agentic and hopeful; eight of the nine could also relate specific instances of transferring practices to contexts outside of school. Students from partial-implementation classrooms were less specific about enacted environmental practices and their responses were more distributed across the dimensions, with four expressing apathy and seven expressing a depressed affect (though three of these felt they had at least some agency).

Quantitative analysis

Replication

In Study 3 we used the same HLM approach to our survey data used in Study 2 to assess the impact of process variables (Agentic Involvement, Flow, and perceived Learning Focus) on Environmental Citizen Identity, with Initial Environmental Interest taken into account. The results replicated the earlier findings. As before, we were interested in both the effect of individual perceptions and the shared perceptions, as indicated by class mean levels. The analysis for class mean Agentic Involvement is summarized in Table 5; results were similar for class mean

Table 5. Final estimation of effects, HLM analysis Year 3.

Fixed Effect	Coefficient	Standard error	*t* ratio	Approx. *df*	*p* value
Environmental Citizen Identity, γ_{00}	3.79	0.027	125.49	9	<.001
Class Mean Agentic Involvement, γ_{01}	0.51	0.17	3.07	9	.002
Individual Initial Interest, γ_{10}	0.12	0.06	2.20	105	<.001
Individual Agentic Involvement, γ_{20}	0.17	0.06	3.06	105	.001
Individual Perceived Learning Focus, γ_{30}	0.22	0.08	2.73	105	<.001
Individual Flow, γ_{40}	0.24	0.04	5.61	105	<.001

Learning Focus. Both individual and class means contributed to end-of-year Environmental Citizen Identity for both variables.

Extension

Analysis of the relationships between CST scores and the survey data provided an additional test of the link between engagement and the ability to use practices from the course in a novel task, augmenting the self-reports of transfer. 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 (engagement) positively predicted scores for Hypothesis Generation and Proposing Solutions (both $p < .05$).[2] These results suggest that, in addition to supporting identification with environmental citizenship, engagement in project tasks promoted learning of environmental science practices.

Full versus partial implementation

Using the same approach as for the analyses of classroom processes and Environmental Citizen Identity described previously, a multilevel-HLM analysis, with beginning-of-year interest as a covariate and a dummy variable representing full versus partial implementation was conducted. The analysis revealed that students in partial-implementation classrooms reported lower levels of Agentic Involvement, Flow (a measure of engagement), and end-of-year Environmental Citizen Identity (all $p < .001$). Because all classes implemented Eco Footprint, these findings suggest that an initial experience being positioned as environmental change agents, though powerful, was not as powerful as a full-year implementation in supporting the thickening of students' identities nor in engaging students in course activities. Although Study 3 was not a randomized controlled trial or quasiexperiment, the results suggest that positioning students as agentic in gradually widening spheres of influence over the course of APES may have provided better support for practice-linked identification with larger environmental issues.

Summary of Study 3

Both qualitative and quantitative analyses in Study 3 suggest that PBL-APES had a positive impact on the development of practice-linked identities as environmental citizens and engagement in classroom activities in urban classrooms. These results were similar to those from Study 1, where we tested two different models of five cycles. However, Study 3 allowed us to examine whether or not the revised Eco Footprint cycle was enough to influence the changes in students' Environmental Citizen Identities. In Study 3, partial implementation appeared to be less effective in supporting student engagement and development of environmental citizen identities than full implementation. This finding, together with findings from Study 1, is consistent with our

conjecture that the increasing-spheres design may have supported students' identity development by providing sustained and broadening contexts in which to practice their environmental citizen identities and that it was not just the impact of a powerful first cycle (Eco Footprint). These results must be viewed with caution, however. Due to our capitalizing on the "natural experiment" of teachers' implementation levels, there may have been other differences that accounted for these results including differences between the two groups of classrooms and systematic differences between the teachers partially rather than fully implemented the design.

Limitations

Classroom-based research is frequently challenged by issues of generalizability. Our qualitative analysis for Study 1 focused on the students of a single teacher in a suburban school across the first two years of design implementation. Other aspects of the study, including the project-based course design, provide a particular context in which to understand students' development of environmental citizen identities. The quantitative analyses of survey data across multiple sites in Study 2 and 3 support the findings from the more localized qualitative analysis and suggest that the outcomes in the focal teacher's classrooms may not be unique. Although all single studies are limited, the set of three methodologically complementary studies here provide consistent evidence to support our claims.

Methodologically, in this paper, we used fishbowl interview data alongside other forms of collected data. While useful in getting many perspectives at one time, the fishbowl interviews may have led students to express views about the course and their developing identities that were similar to their peers' views. The replication inherent in design-based research and in balancing group interview with individual interview and survey data allowed us greater confidence in the generalizability of our findings. In most classes across Studies 1 and 3, about 80% of students spoke during a fishbowl. In three full-implementation classrooms, attendance was down for fishbowl interviews due to conflicting end-of-year events.

General discussion

In this multistudy effort, we used design-based research and theories of engagement, identity development, and transfer to develop and test an approach to design for student agency and the development of environmental citizen identities. Integrating these theories to analyze and revise the course was instrumental in understanding how different aspects of the activity system functioned together to promote student engagement and identity development. Our case study identified aspects of the initial course design that interfered with (or failed to support) student engagement and the development of practice-linked identities as environmental citizens. The analyses of students' survey data provided further evidence of the relationships among agency, engagement, and identification and their connection to transfer of environmental science learning. This provided a closer examination of two major change mechanisms: increased agency and the progression from local to global contexts over the course of a school year.

We used the data from teacher and student perspectives in the first implementation year to inform the subsequent revisions of the curriculum, collaborating with teachers and using the conceptual tools provided by the constructs of practice-linked identities (Nasir & Hand, 2008) and framing for transfer (Engle, 2006; Engle et al., 2011, 2012). The conceptual tools helped to direct attention to revisions that ultimately influenced students' practice-linked identities by increasing their access to the domain of environmental science, placing students in integral roles in each of the projects, and creating opportunities for self-expression in the practice. These changes reframed the projects, helping students find more connections among them and with other contexts, which increased the likelihood of transfer. Through this research project, then, we increased

our understanding of supporting engagement and identity development in science. Important in its own right, focusing on engagement and identity development as goals in course design facilitated the deeper learning that was the primary goal of the research project.

For both iterations of the redesigned course, we found that the Eco Footprint cycle was instrumental in positioning students as change agents. Concepts and activities from this cycle appeared with regularity in the postcourse interviews as touchstones, supporting later learning and providing important insights in the moment. It seems plausible that this cycle was powerful, in part, because it created a hybrid space in which both home and school contexts were clearly and purposefully intertwined (Calabrese Barton & Tan, 2009). By linking home and school contexts, students are positioned to see the ways school learning is relevant and can be applied to their daily lives. In contrast to the rest of the cycles, wherein the primary roles were in simulations, Eco Footprint provided an opportunity to see school science learning as relevant and powerful in motivating change in others. Students were not role-playing, they were (often) *actual* change agents in their families. Their scientifically grounded arguments and interpretations of household data became tools students could use to have an impact. This finding further supports recent literature on the importance of relevance for student learning and identity development (Kaplan et al., 2014; Pugh et al., 2017), allowing for greater agentic involvement.

With Eco Footprint as a starting place, students saw the individual impact they were making on the environment and were able to create specific action plans, seeing changes through data they collected. The agency and relevancy that began in the first project was built on as the projects increased in scope. This finding has implications for project-based course design in science and beyond. While simulations can enable participation in contexts beyond students' current capabilities or access (e.g., climate summits), they do not provide the opportunity for real impact on a local or personal level or for connecting learning to students' own personal and local lives. Starting with a real-world project and then moving into simulations that built on those authentic roles and practices, provided an opportunity for the benefits of both models to be leveraged for student learning, engagement, and identity development. Thoughtful ordering of projects may be able to build on the strengths of both approaches, as appeared to be the case in the PBL-APES course design.

Connecting the concepts of expansive framing for transfer and the development of practice-linked identities provided useful guidance for PBL course design, identifying processes by which students can learn, participate, and develop disciplinary practices in science courses that extend beyond the walls of the classroom. By connecting practice-linked identities to framing for transfer, we hoped to highlight for youth the ways that they could transfer their in-class practice-linked identities to their everyday lives. Understanding the broader meanings students see in their school work can make it possible to develop designs that are more likely to result in learning that students view as important and relevant, both personally and to the world (Calabrese Barton & Tan, 2010; Nicholls & Nelson, 1992).

The data presented suggest that the implementations of the revised curriculum had an impact on students' practice-linked identities as environmental citizens. Students had multiple opportunities to engage in the practice of both environmental science and citizenship through the projects, thickening those identities over time. We sought to increase student engagement and identity development by increasing student agency and also by positioning students and the curriculum so students saw the authenticity and value of what they were learning. Doing so, we sought to redesign the curriculum not only thinking of students as learners but also as individuals in the world. It mattered that students learned environmental science, but given the despair expressed in the first year, it also mattered how they saw themselves as actors within the world of environmental science. Our work provides a model for designing curriculum that is not only generically engaging, providing an authentic problem (Blumenfeld, Rogat, & Krajcik, 2006) but also directly tackles issues of motivation and identity development.

In contrast to many PBL studies that focus on individual units, studying a year-long PBL-APES curriculum allowed us to consider the longer-term impact of course design on identity

development. In thinking about students' development of disciplinary identities, it may be worthwhile to consider not only the opportunities or resources for identity development that are available but also the length of time that students have to build their identities through iteration, while also tackling different problems and trying on different roles.

Interest theorists have argued that sustained environmental support is necessary for individuals to develop stable interests that lead to reengagement and seeking out opportunities to interact with the object of interest (Hidi & Renninger, 2006; Nolen, 2007). Identity theorists have also discussed the importance of time as identities thicken through repeated positioning (Holland & Lave, 2001; Wortham, 2006). By purposefully positioning students as decision-makers throughout the curriculum and by iteratively focusing on ways to address increasingly difficult environmental problems, we have provided an example of how to largely avoid the disidentification, pessimism, and resistance to deep engagement seen in the initial implementation while still deepening students' understanding of environmental issues. Students' increasing understanding of and identification with their roles as citizens of the environment may provide both motivation and the means to participate in the world around them.

Notes

1. A phrase used by teachers in the study to describe students' perspectives after the first year of curriculum implementation.
2. For brevity, the complete tables for the results of these analyses are available from the last author.

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Appendix A

End of Year Student Interview Protocol

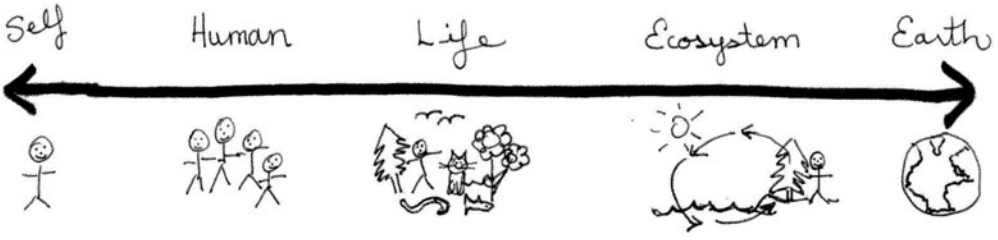
Thank you for agreeing to participate in this interview. We are interested in hearing about your experience in this class and getting your suggestions on how we can improve this course for other students in the future. Everything you share with us is confidential. This interview will be audio-recorded. You may ask me to stop recording at any time or to stop the interview at any time if you ever feel uncomfortable.

1. Can you give me a brief summary of what this class was about?
   a. Overall, how did you like the class?
   b. What stood out for you?
2. What were your expectations of this class?
   a. Were those expectations met?
3. (**TAKE OUT COURSE POSTER NOW**) Looking at the course poster here, can you tell me about which project cycles worked well for you and why? Which project cycles did you really get into and why?
   a. What cycle/s or parts of a cycle helped you to learn the most?
   b. What cycle/s did you find the most challenging? How was it challenging?
   c. Do you think the project cycles fit together in this order well? Did they make sense to you in this order?
   d. Were there things you learned in one cycle that you were able to use or build upon in other cycles?
4. Tell me a little bit about the roles you took on in these projects.
   a. What did you know about those roles? What helped you to take on those roles in the project?
   b. What did you think about the teamwork in the projects? What made working in a team easy or hard for you?
   c. Has your opinion about working in teams changed since the beginning of the year?
5. We've heard from some other students that sometimes it can feel like you're in "two worlds" at once in this class. Sometimes you're working on the project part of the class and then you switch to "another world" and work on the AP part of the class. Did you experience that feeling at all this year?
   a. IF NO → How did you see the projects as relating to the AP test?
   b. IF YES → Were there any project cycles in particular where you experienced that feeling more or less than other project cycles?
   c. Did the Learning Logs help you make connections between the projects and test prep at all?
6. What does "deep learning" mean to you?
   a. Did this course achieve that?

7. Was this course different from other courses you have taken? Tell me about what was different?
   a. Did this course require you to think, learn, or participate differently than other courses you've taken?
   b. Have you taken other AP courses? How does this course stack up against other AP courses in terms of the knowledge you've gained?
8. What are you taking away from this course experience that's of value to you personally?
   a. Has the course influenced the way you think or act in your life outside of school? How so?
   b. Have you had any conversations about things learned in this course with people outside of school? Tell me about those.
9. Tell me about the reading you did for this class.
   a. How much reading did you do? In class? For homework?
   b. Independent? With partners?
   c. How hard was the reading for you?
   d. When the reading was difficult, where did you get support?
   e. How often did you do the reading? Did you find it necessary to be successful in the class or could you get away with not doing it?
10. Tell me about the writing you did for this class.
   a. How much writing did you do? In class? For homework?
   b. Tell me about the kinds of writing assignments you had.
   c. How hard were the writing assignments for you?
   d. When the writing was difficult, where did you get support?
   e. How well do you think you were prepared for the writing assignments?
   f. How often did you do the writing assignments? Did you find them necessary to be successful in the class or could you get away with not doing them?
   g. Tell me a little bit about your experience with the Learning Logs.
11. How did the teacher impact your experience in this course?
   a. What advice would you give future teachers to make this course successful for students like you?
   b. What advice would you give future students to be successful in this course?
12. Did you take the AP exam? If no, why not?
   a. How well do you think this course prepared you for the AP exam?
   b. How well do you think you did on the AP test?
13. The *(project)* test that we administered in your class before you took the AP test asked you to apply the knowledge you've gained this year. How well do you think you did on the test?
   a. Was it hard or easy for you? What made it hard or easy?
   b. How prepared did you feel for the test? What helped to prepare you?
   c. If you took the AP test, which test would you say showed your knowledge better?
14. Describe any experiences you had in this course that may be helpful in preparing you for college or other career plans after high school.
   a. Did you learn anything new about yourself as a student in this course?
15. Is there anything else we haven't asked that you want to share with us about the course?

End of Year Student Fishbowl Protocol

1. This course had a master question (*How can we live more sustainably?*) This is an important question and one that many people have differing opinions on. What's your opinion? What do **you** think we *should* do or *can* do to live more sustainably? What is our responsibility toward the planet?
   a. *This activity requires students to stand up and line up somewhere in the room. First draw the picture below on the board (or use the associated slide if projector is available) and then explain it.*



   On the survey you gave your opinion on this, but let's talk about it a little bit more—If we think about different perspectives of our role on the planet as lying on a continuum from more self- or human-centered on one end to more ecosystem- or Earth-centered on the other end, where would you

place yourself right now? What part of the continuum best represents your personal perspective? *Have students physically get up and stand along a line in the classroom to best represent their views.*

b. Okay, where would you have placed yourself along this continuum before you took this course? *Have students shift to those places.*
c. Where do you think humans in general should be? *Have students shift to those places.*
d. *Have students sit back down. Ask some of them to talk a little bit more about:*
   i. What was it that you experienced or learned in this class that shifted your views?
   ii. *If most of the class moved to one end of the continuum when asked where humans should be* → Why do you think needs to happen to help shift more people to that end of the spectrum? What do you think you could do about it?

2. How does this course compare to other AP courses you've taken? Or to other science or social studies courses?
   a. Compared to other AP course you've taken, did you feel prepared for the AP test?
3. What are you taking away from this course experience that's of value to you personally—that's helped you or served your needs in some way?
4. What advice would have for future teachers of this course? Future students? For yourself if you were to take it over again?
5. How could we make this course more successful for students like you?

Appendix B

Codes and code categories
Citizenship Codes:

Agency [expresses a sense of agency]
Awareness of environmental problems in world [Awareness of environmental problems but without agency/solutions]
Awareness of environment as a system/ecology
Awareness of human impact on environment
Citizenship Outlook: Activism
Citizenship Outlook: Caring/optimism [If we act, things will get better]
Citizenship Outlook: Depressing/lack of agency
Citizenship Outlook: Deprioritizing responsibility to Earth
Citizenship Outlook: Little things can make a difference
Citizenship Outlook: Passivity
Citizenship Outlook: Responsibility to Earth
Citizenship Outlook: Societal obstacles
Citizenship Outlook: Societal resources
Curriculum not solution focused

Identity Codes (based on Nasir & Hand, 2008):

Access to the domain—Citizen
Access to the domain—Scientist
Opportunities for self-expression in the discipline
Opportunities to take on integral roles

Personal connection to environment
Transfer Codes (Based on Engle & Conant, 2002; Engle et al., 2012):

Expected future use/connecting settings
No expected future use

Recognition of relevant prior knowledge
States lack of prior knowledge
Prior knowledge is transferred in and built upon
Prior knowledge is useful/valued socially
Prior knowledge not useful/valued socially
Recognition as author of transferable content
Practice of authoring knowledge
Future use—Disconnect (NOT applicable to my future)
Authenticity of APES activity

Authenticity: Activity not authentic

Reported Transfer

Talk of Transfer: AP Test
Talk of Transfer: Application to daily life
Talk of Transfer: Careers
Talk of Transfer: Economy
Talk of Transfer: Family
Talk of Transfer: Near transfer (APES class)
Talk of Transfer: Other science classes
Talk of Transfer: Personal health
Talk of Transfer: Recognition of opportunity but not transfer

Description of Environmental Problem/Solution

Problem: Environmental problems are huge
Problem: Proposing solution
Problem: Proposing solution—vague
Problem: Vague/incorrect statement of environmental problem

Appendix C

Affective and Classroom Climate Scales (APES).
Initial Environmental Interest measured on the beginning-of-year survey; all others measured on the end-of-year survey. Internal consistency (*alpha*) given for implementation Years 2 and 3.

Initial Environmental Interest *alpha* = .70, .73
I will use the things I learn in this class in the real world.
(Stem) Why are you taking this class?

Because I am interested in this subject
Because it is important for adults to know this information

Agentic Involvement *alpha* = .73, .80
(Stem) In this class…

I usually felt like I contributed to our learning.
I usually felt like my ideas were important to our learning.
I actively participated.

Flow *alpha* = .70, .73
(Stem) In this class…

I often wished class would end. (reversed)
My mind often drifted away from what we were doing. (reversed)
Time passed really quickly.

Learning Focus (Climate) *alpha* = .69, .69
(Stem) In this class…

Some big ideas came up over and over again.
Things I learned early in the year helped me understand later material.
Mistakes were OK, as long as we learned from them.
The teacher encouraged us to think for ourselves.
We usually got to apply what we learned right after we learned it.
We learned how to solve problems on our own.

Environmental Citizen Identity *alpha* = .70, .72
I am interested in environmental issues.
I believe people like me can make a difference.
I think I know enough to make informed decisions about environmental issues.
(Stem) In this class…

I was usually interested in what we were doing.
I usually really got into the activities.
The reading we did was interesting.