Spring 2016

Earth Systems Science as Civic Participation: An approach to Youth Action Research for Social Change

Ciara Williams , '16

Earth Systems Science as Civic Participation: an approach to Youth Action Research for Social Change

by

Ciara Williams

Education and Environmental Studies special major

Advisors: Joseph Nelson, Professor of Educational Studies

Peter Collings, Professor of Physics and Astronomy

Abstract: Just as environmental justice challenges dominant notions of "environment" that cannot account for connections between social and natural processes, earth systems science pursues connections between science and society, challenging a dominant discourse which asserts that both can be fully understood without the other. Grounding "environment" and "science" as socially situated concepts helps to foreground, in turn, the ways that race structures exposure to risk and the exercise of citizenship both nationally and globally. My thesis draws on these discourses while focusing on youth as citizens and civic participation through the creation of an elementary school science curriculum.

Introduction

In the late 1980s and early 90s, the environmental justice movement was established to make the connections between processes affecting the natural environment and those which structure lived experience--including threats to life itself, as well as access to economic, civic and other forms of opportunity--more explicit. Environmentalism has traditionally excluded the issues faced by those in urbanized low-income communities and communities of color. Traditional environmentalism constructs nature as wilderness; accordingly, approaches to organizing favored conservation efforts that furthered the divide between people and the environment. However, urban and rural communities of color began organizing against the citing of landfills and incinerators in close proximity to their communities; these organizing efforts became known as the Anti-Toxics movement. These forms of organizing later grew into movements for sustainable development without displacement, living wages and access to the green economy (Anguelovski, 2014; Pellow, 2007). Initially, the large environmental organizations these communities sought out as allies did not see the issues faced by these communities as environmental. In response, the environmental justice movement began as a way to make connections between the environment, public health and access to opportunity and self-determination more visible.

Early environmental justice activism found that toxic facilities and other environmental bads are more likely to be in close proximity to African-American and other communities of color. In 1987, a report titled *Toxic Wastes and Race in the United States* was published. The report was commissioned by the United Church of Christ through their Commission for Racial Justice; it sought to uncover patterns between race and exposure to environmental risk in the United States. The report argued that efforts to address the "adverse environmental and health effects of toxic chemicals and other hazardous substances emanating from operating hazardous waste treatment, storage, disposal facilities, and thousands of abandoned waste sites" have failed to be inclusive to the "specific concerns" of minority communities (Toxic Wastes and Race xii). The report goes on to argue that minority communities are far more likely to be unknowing victims of exposure to environmental toxics (TWR xi). Because minority communities continue to face barriers relating to poverty, unemployment, underfunded public schooling, poor housing, and health, they are particularly vulnerable to the framing of hazardous waste facilities as avenues for employment and economic development (TWR xii). The exclusion of African-Americans from early environmental organizing does not mean people of color are less interested in the environment. Rather, approaches to addressing environmental injustices must encompass its impacts beyond environmental destruction while also improving access to and creating new means for civic participation to address these concerns: environmental justice was established to meet this need.

The major findings of the Toxic Wastes and Race report proved a connection between race and proximity to both commercial hazardous waste facilities and uncontrolled toxic waste sites. The two cross-sectional studies encompassed by the report found the following: (1), Race is the most significant variables in association with the location of commercial hazardous waste facilities across the United States. (2), Communities with the greatest numbers of commercial hazardous waste facilities had the highest composition of minority residents. (3), Race was a more significant variable than socio-economic status although both play a role. (And 4), Three of five of the largest commercial hazardous waste landfills in the US were situated in predominantly Black or Latino communities: at the time, the three landfills accounted for 40% of the total estimated landfill capacity for the entire country (TWR xiii). The data for uncontrolled toxic waste sites reveals a disproportionate burden placed on minority communities as well.

When the report was published, 3:5 Black and Latino Americans lived in communities with uncontrolled toxic waste sites. And 15 million Black Americans and 8 million Latinos live with more than one uncontrolled toxic waste site (TWR xiv).

Where traditional environmentalism constructs the "environment" as pristine pockets of wilderness in the absence of humans, the environmental justice movement asserts that the environment also encompasses the places people work, live, play and go to school ("Principles of Environmental Justice" 1991). The expansion of the term helps reframe and redirect the movement so that it can address the needs of working class communities of color, which are subject to greater risks because of processes of racialization that structure the devaluation of and disinvestment from their communities. Additionally, thinking about the environment in relation to the people who reside in and adjacent to it ties personal and community well-being to the health of the natural environment. Through this connection, the health of the environment is intimately dependent on the well-being of the people and vice versa. Thinking of the environment in relation to people has empowered communities and nonprofits to organize around environmental, civil rights, and social justice issues under the same banner. Through its focus on justice, self-determination and grassroots activism, environmental justice provides an intersectional approach to looking at race, class, physical space (and its uses), and community.

Organizing for environmental justice began as a movement sustained by grassroots activism. Seeing that their environment was not conducive to their health and the physical, emotional, social, and economic well-being of the community as a whole, environmental justice activists often take action because it is a necessity. Stakeholders experience a problem first hand, outreach to their community, identify additional stakeholders, then proceed to take action from the bottom up. This form of social change does not solely rely on the decision making structures and processes that are already in place. In fact, this approach is largely due to various forms of exclusion from these processes. Consequently, environmental justice activists have redefined what it means to be an active citizen in their communities. The scope of citizenship goes beyond voting and participation in other civic processes in which individual choice is deferred to a representative. Rather, this form of civic participation empowers communities to "set the agenda" so that political action and representation better reflects the needs and interests of those who are often marginal to local and national decision-making processes.

One specific way in which Environmental Justice activists have transformed citizenship is through the creation of the role of "citizen scientist." This method of organizing seeks to construct citizenship as more active than passive. Through community organizing, many residents of frontline communities may become increasingly involved in the decision-making processes already in place. Additionally, some residents assume a civic identity that goes beyond increased access to the means available to them. Rather, environmental justice activists began to frame the problem themselves by highlighting and addressing critical issues. More recently, citizen scientist programs have been created to empower participants to "gather information for a particular science research study [or] to lobby for environmental protection for their communities" (Jones, Childers, Stevens, and Whitley 36). However, in the context of environmental justice organizing, the term has a much older history.

Citizen science refers to the "citizen-initiated collection and communication of health information by concerned residents of a community," and this approach is critical to the environmental justice movement because it "foregrounds the knowledge and experiences of community residents and their allies" (Allen 89). As a practice, citizen science simultaneously borrows from the modes of data collection and argumentation prioritized in the field while also challenging the exclusion of ways of meaning making and communication embedded in the context of a community. Citizen science works to insure that "what counts as science begins to reflect broader community concerns rather than the professional biases of rarefied institutional or laboratory contexts" (Allen 90). Residents in one of the most concentrated sites of pollution in the U.S., also known as "Cancer Alley" or the "chemical corridor," have used citizen science to legitimize their claims against toxic industrial facilities in close proximity to their communities.

The chemical corridor is a 80-mile swath of land that includes 159 industrial facilities which emit 129 million pounds of toxins a year--this accounts for 1/16 of the total volume released in the United States (Lerner 43). In the late 1980s, the group Concerned Citizens of Norco (New Orleans Refining Company also the name of the town) was established to address issues they faced as a result of the dense concentration of environmental toxins in their community. Many members were from Diamond, the predominantly Black section of Norco in Louisiana. Diamond is situated between a Shell Chemical plant on one end and a Shell/Motiva oil refinery on the other. Their first demand was for relocation; but also included were concerns about health and longevity due to pollution, which included demands for "access to health care, more community involvement in the decision-making process, and access to more jobs at the industrial facilities" (Lerner 68). Air pollution and the resulting implications of prolonged exposure to toxic chemicals drove many residents to become involved in local organizing efforts.

Diamond residents often experienced headaches, sinus problems, and stinging eyes due to odors produced by Shell facilities--some days residents would report a chemical fog outside and seeping from cracks in their homes (Lerner 10). Additionally, there were large numbers of children with asthma; young adults with severe respiratory, allergic, and unusual skin problems; and older people whose breathing had to be aided with oxygen tanks (Lerner 10). However, resident testimonies were not enough to prove causal links between toxic chemical releases and public health. The Louisiana Bucket Brigade, an environmental health and justice organization with chapters nationwide, worked with Diamond residents to back their first hand experiences with data. Their mission is to use grassroots action to "create an informed, healthy society with a culture that holds petrochemical industry and government accountable for the true costs of pollution" (labucketbrigade.org). Citizen science aims to bolster the legitimacy of qualitative and experiential data with numerical data collected in the field.

The Louisiana Bucket Brigade promotes citizen-initiated collection of air samples to challenge the faulty reporting done by polluting facilities. In a survey of 17 refineries, the EPA found a leak rate of 5.0 percent, which is 4 times higher than the 1.3 percent leak rate reported by refineries (Lerner 43). Given these discrepancies, and many more that go unquestioned, citizen science is all the more crucial to the organizing efforts of communities facing environmental injustices. Bucket Brigades use $75 air sampling equipment built from more readily accessible parts than its $2,000 counterpart, the summa canister (labucketbrigade.org). Air samples are then sent to independent labs for testing. Although originating in California in 1995, this form of air sampling has been used in grassroots organizing throughout Louisiana by communities of color living in the chemical corridor. Mossville, Louisiana for example, is surrounded by over 53 industrial facilities--40 of which are situated within 10 miles of the community (labucketbridage.org). Like Diamond, testimonials and concerns raised by residents of Mossville frequently go ignored by local representatives and environmental groups and organizations. In 1998, residents began taking samples using homemade air sampling buckets. Samples collected confirmed concerns already raised by residents--they proved ongoing violations of Louisiana standards for vinyl chloride, EDC and benzene, a carcinogen (labucketbrigade.org) Additional samples found benzene in quantities over 220 times the state standard (labucketbrigade.org).

Environmental Justice advocates for freedom from pollution but it also encompasses self-determination through the civic participation of those most directly impacted by resource extraction, incineration and other environmental bads. Environmental Justice calls for the right of all people to be free of environmental poisons but "at its core is the inclusion of all in the decisions that affect their health and the wellbeing of their communities" (Cox and Pezzullo 241). One's relationship to the decision making processes in and outside of their communities as well as the extent to which they face exclusion from those processes helps to shape one's civic identity.

Civic identity is constrained within participatory structures inside and outside of the community. Civic identity is defined as one's "sense of connection to and participation in a civic community" (Rubin 450). However, individuals have agency to act outside of those traditionally recognized platforms in favor of critical discourses: new ways to make meaning and to take action. The relationship between the structures of participation one is afforded and one's response to those structures constitutes one's civic identity. As citizen scientists, activists acknowledge the reality that science and the scientific process devalues first hand experiences and testimonials due to its focus on objectivity and distance. Citizen scientists also recognize the extent to which the valuation of science is often exclusionary to those without a background in science, due to lack of interest and or lack of opportunity and other barriers. However, in Louisiana and elsewhere inside and outside the US, scientific discourse and research remains a tool, among many leveraged by frontline communities.

Within the framework of Environmental Justice, self-determination of individuals and communities is intimately tied to civic participation and procedural justice. The definition of justice furthered by the environmental justice movement seeks to address distributive inequality, lack of recognition, disenfranchisement, exclusion, and more broadly, an undermining of the basic needs, capabilities, and functioning of individuals and communities (Scholsberg and Collins 3). In light of raising sea levels and increased exploitation of natural resources and other industrial activities that drive global climate change, the climate justice movement has extended the project of environmental justice to advocate for the right of people to be free from toxins and other environmental risks.

Addressing global climate change through working towards social justice has become a recent focus for environmental justice activists. In thinking about how communities can become more resilient to the changes already occurring as well as change that will occur in the future, activists are demanding jobs and educational opportunities that will equip and empower residents to do this work themselves. A science education rooted in civic participation has the potential to further the project of the environmental justice movement by working towards representational justice and self-determination for communities who are on the frontlines of environmental injustices. An education of this sorts can support communities to effectively advocate for themselves in situations where their voices and concerns are often ignored.

To develop a science curriculum with civic participation at its core, earth systems science can act as a lens to better understand global climate change as an interconnected web of feedback loops with natural and anthropocentric forcings. Global climate change as a phenomena and the global and local processes that drive it have impacted communities' access to potable water, air quality, grazing lands for cattle, soil health, and access to safe working environments and livable wages. Low-income and communities of color bear the disproportionate burden of climate change. Global climate change is more complex than increases in global climate, however; its effects can only be assessed through an analysis rooted in earth systems science. Unlike traditional science education, earth systems science positions science and society as intimately connected.

Earth systems science has risen in popularity as a tool to address global climate change. Earth systems science can inform large scale actions regionally and globally that mitigate or limit the effects of climate change. However, it is important to consider who must be involved and how. “Negotiations of the values society holds or will hold is legitimately within the purview of every stakeholder or citizen” (Schellnhuber, Crutzen, Clark, and Hunt 18). Just as environmental justice challenges dominant notions of “environment” that cannot account for connections between social and natural processes, earth systems science pursues connections between science and society, challenging a dominant discourse which asserts that both can be fully understood without the other. Grounding “environment” and “science” as socially situated concepts helps to foreground, in turn, the ways that race structures exposure to risk and the exercise of citizenship both nationally and globally. My thesis draws on these discourses while focusing on youth as citizens and civic participation through science education.

In this thesis, I will frame and present a unit rooted in the practice of earth systems science as anti-racist pedagogy. The unit acts as an introduction to a curriculum that would foreground youth civic participation and participatory action research. First, I will introduce the theoretical underpinnings for my approach to curriculum development, civic identity, and earth systems science. My literature review indexes a body of knowledge relevant to the unit; its focus is on youth civic participation and the development of earth systems science as a tool for understanding and communicating about global climate change, specifically the interconnections between environmental and society. To conclude, I argue for civic education across the discipline. But, more specifically, for a rethinking of science education as well as a shift in the role of communities and especially youth in public discourse and policy decisions at local and national levels.

Theoretical Framing

Curriculum Development: Backwards Design

My approach to curriculum development draws heavily from the theory of backwards design as exemplified in *Understanding by Design* by Wiggins and McTighe. Wiggins and McTighe argue that a curriculum must be intentionally designed if students are to gain an understanding of key concepts and processes. The design philosophy of "uncoverage" acts as a guiding principal for their theory of curriculum design. Uncoverage is defined as the "guided inquiry into abstract ideas to make those ideas more accessible, connected, meaningful, and useful" (Wiggins and McTighe 21). Through a process of uncoverage, students can gain an in-depth understanding which would include the 6 facets of understanding as described by Wiggins and McTighe: explanation, interpretation, application, perspective, empathy and self-knowledge. Wiggins and McTighe position teachers as designers. Through a process of backwards design, teachers can plan a curriculum that guides students to an in-depth understanding by first (1) identifying the desired outcomes in student thinking and performance, (2) determining evidence that would adequately demonstrate specific learning goals and, finally, (3) planning for the learning experiences and instruction within a unit.

As opposed to starting with specific activities or projects, Wiggins and McTighe argue that the process of curriculum design must first begin with specific educational objectives which would then inform the materials, content, instructional procedures, and assessments to be used within a unit or course. Specific objectives are an important starting point because they reflect the intended changes in students which, as a result, enable the teacher to plan for instructional activities designed to move towards those objectives (Wiggins and McTighe 8). Once objectives are identified, backwards designs calls for teachers to develop curricular priorities based on the unit objectives. When focusing one's priorities, ask: "When is it worth the trouble to get students to understand? When is it sufficient for students to only have familiarity?" (Wiggins and McTighe 22). To address this issue, Wiggins and McTighe provide a diagram that supports teachers in establishing their curricular priorities. (Refer to appendix C).

Because any discipline encompasses vast amounts of knowledge that cannot be addressed within the scope of a single unit, the outermost circle of the diagram would include knowledge students should encounter throughout the course of a unit. This circle includes what students should hear, read, view and research considering the overall objectives and goals (Wiggins and McTighe 9). The information covered in this section is considered more general and can help to provide historical context or other framing for the discipline or theme to be addressed throughout the unit. As "broad-brush knowledge," this information can be assessed through traditional quizzes or tests (Wiggins and McTighe 9). The middle circle identifies important knowledge (facts, concepts, and principles) and skills (processes, strategies, and methods) that support students to accomplish key performances (Wiggins and McTighe 9). This circle is more focused than the previous because it includes what Wiggins and McTighe call "prerequisite knowledge." The smallest circle identifies the enduring understandings designed to anchor the unit or course.

The term "enduring" refers to the "big ideas and important understandings" students are to "get inside of and retain after they've forgotten many of the details" (Wiggins and McTighe 10). Practically speaking, the purpose of a unit would be to equip students with an orientation and a set of skills with transferability to other experiences and concepts in and outside of schooling: the term "enduring" speaks to those goals.

The process of backwards design challenges the common practice of conducting assessments as culminations of a lesson or unit. As designers, teachers are encouraged to "operationalize goals and standards in terms of assessment evidence" (Wiggins and McTighe 8). Therefore, teachers determine acceptable evidence in stage 2 of curriculum design. In stage 2, teachers determine acceptable evidence that demonstrates student attainment of the desired results and proficiencies. Through a process of backwards design, teachers are encouraged to think like assessors before planning for lessons and activities. Because "understanding is developed as a result of ongoing inquiry and rethinking," assessment of understanding is a process that takes place over a period of time (Wiggins and McTighe 13). Accordingly, teachers have a variety of assessment methods to be used throughout and at the end of a unit or course. To better understand when and how to use each method, Wiggins and McTighe developed a continuum of assessment methods that considers: scope (simple to complex), time frame (short-term to long-term), setting (decontextualized to authentic) and structure (highly to nonstructured). As methods of assessment, the continuum includes informal checks for understanding, observations and dialogue, quizzes and tests, academic prompts, and performance tasks and projects (Wiggins and McTighe 12). Because the purpose of backwards design is to most appropriately facilitate the development of student understanding, the unit or course must be anchored by performance tasks or projects. Performance tasks and projects "provide evidence that students are able to use their knowledge in context. Application [in authentic contexts] are a more appropriate means of evoking and assessing enduring understanding" if the goal is transferable use within and outside of the classroom (Wiggins and McTighe 13). Before moving to stage 3: planning and instruction, one must first grapple with what is meant by "understanding." In addition to providing key strategies that work towards understanding, Wiggins and McTighe introduce six facets of understanding to capture its meaning in all of its complexity.

Understanding is measured in degree. As a process, understanding is "furthered by questions and lines of inquiry that arise from reflection, discussion, and use of ideas" (Wiggins and McTighe 45). In addition to questioning strategies, Wiggins and McTighe provide a multifaceted view of understanding using six "facets." To uncover important ideas within a unit of study, Wiggins and McTighe introduce two types of curriculum-framing questions: essential questions and unit questions. While posing essential questions are considered effective ways to frame a unit, the questions are often too "global, abstract, or inaccessible for students" (Wiggins and McTighe 30). To address this issue, unit questions are needed to introduce and guide the work within a unit of study. Unit questions are "subject and topic-specific, and therefore better suited for framing particular content and inquiry, leading to the often more subtle essential questions" (Wiggins and McTighe 30.) Accordingly, unit questions "provide subject and topic-specific doorways to essential questions, have no one obvious right answer" and, finally, are "deliberately framed to provoke and sustain student interests" (Wiggins and McTighe 30). In the early stages of student engagement within a unit, entry-point questions, a type of unit question, leverages "concrete and meaningful experiences, problems, applications, and shifts in perspectives" so that students are supported to engage with the larger, more complex problems within a unit (Wiggins and McTighe 33). Despite the distinction between essential and unit questions, the two are placed on a continuum of specificity. The purpose of the questions are to “frame the learning, engage the learner, link to more specific or more general questions, and guide the exploration and uncovering of important ideas” (Wiggins and McTighe 31).

When teaching for understanding, a key design strategy is to make the student perspective of “knowledge and coming-to-know more sophisticated by revealing problems, controversies, and assumptions that lie behind much given and seemingly unproblematic knowledge” (Wiggins and McTighe 26). This process of rethinking is furthered by questioning: “Questions not only focus learning, they also make all subject knowledge possible” (Wiggins and McTighe 33). Given this, instruction is designed to problematize the production of knowledge so that students are actively engaged in questioning that fosters “active reflection, testing, and meaning making” with the information they encounter (Wiggins and McTighe 26). Another key design strategy regarding questioning is to develop a curriculum around the questions that organize the discipline or area of study. Organization in this manner provides “sharper focus and better direction for inquiry” (Wiggins and McTighe 26). Rather than engaging in a series of disconnected activities, the key questions taken up in any discipline can offer coherence and an authentic context for problem solving using domain specific strategies and skills. Uncoverage towards understanding is an active process: “Knowledge must be more than mentioned or referred to in indiscriminate ways. Important ideas must be questioned and verified” (Wiggins and McTighe 27).

Civic Identity

For students, civic identity is developed in the overlapping contexts of classroom, school, and society. More specifically, civic identity is shaped by what Beth C. Rubin refers to as civic experiences. Civic experiences include the "larger social forces and daily experiences in schools and communities." Experiences that impact a student's "sense of self as a civic being help us to understand civic identity in ways that large-scale, quantitative measures are unable to capture" (Rubin and Hayes 354). In assessing the extent to which one's civic education adequately engenders an active citizenship, the goal of civic education must go beyond mastery of facts and intent to vote, as these assume students experience civic institutions the same. Rubin argues that an active civic identity is central to civic education; accordingly, students' experiences inside and outside of schooling must inform curriculum because citizenship is defined within these two contexts. "Engaging students in discussion, investigation, and analysis of the civic problems they encounter in their daily lives holds potential for fostering more aware and empowered civic identities" (Rubin and Hayes 355).

Traditional forms of civic education fail to sustain student interest, especially for Black and Latino students who are more likely to experience disjuncture. Disjuncture is defined as "the sense that one's immediate civic institutions are not looking after one's best interests" (Rubin and Hayes 353). A civic education that is more responsive to youth's civic experiences inside and outside of school is especially important for low-income and students of color. Ginwright and James provides a framework to actively involve youth in their communities through civic participation around issues and projects that they deem most important. They argue for a civic education rooted in youth action research towards the goal of "[transforming] civic learning into a meaningful endeavor that leverages, rather than denies, students' daily experiences as citizens"

(Rubin and Hayes 355). A student directed approach is important for students who experience disjuncture because it facilitates an aware and empowered civic identity that addresses, rather than ignores, the challenges students from marginalized backgrounds face in their communities.

Instructional Incongruency

The connections to everyday experiences that a youth action research model facilitates can help to challenge the instructional incongruency experienced by many students throughout their schooling; additionally, these connections can reshape civic education as a more interdisciplinary endeavor. The civic experiences of students from marginalized backgrounds are most often experiences of disjuncture. In "From assets to agents of change: Social justice, organizing, and youth development," Ginwright and James argue that one's experience of inequality (or disjuncture) is often intimately linked to identity: "identities are complex ways that young people (and adults) identify themselves, as well as how they are seen by the larger society" (Ginwright and James 36.) Bringing notions of civic identity and civic participation into instruction across the curriculum can help to promote relevancy for students. This allows the practices and tools of a discipline to be leveraged as means of social change, locally and globally.

A reconsideration of the public value of science education is needed, especially in low income and communities of color because these schools are often poorly resourced with equipment and other resources to conduct hands on experimentation. However, a science education rooted in civic participation and youth action research uses the local community as context for instruction. An earth systems approach to this project would allow for connections to be made between experiences and processes locally and those operating between and across boundaries.

Science Education and Earth System Science

In "Earth Systems Science: An Analytic Framework," Finley, Nam, and Oughton present Earth Systems Science as a replacement for an earth science education that teaches geology, meteorology, astronomy, and oceanography as unrelated disciplines. Their two-part framework "specifies a set of metalevel essential ideas and analytic concepts that can be applied to understand the substantive structures of ESS--the general nature of earth systems and [...] discipline specific concepts such as the materials, processes, and variables of earth systems" (Finley, Name, and Oughton 1066). Here, earth systems science is defined as "the study of natural and social systems and the interactions among these systems" (Finley, Nam, and Oughton 1067). Finley, Nam, and Oughton argue that "ESS is essential as a school subject if the goal of science education is the development of a scientifically literate population" (1067). Considering the impact human activity has had on the environment, systems thinking is especially important in science education for the recognition and empowerment of students as citizens and agents of social change in their communities.

Part one presents Earth Systems Science as an established methodological and theoretical approach based on the following central concepts: systems, materials, structures, intrasystem processes, intersystem processes, energy, variables, and models. Systems are defined as "any persistent, describable, and predictable arrangement of matter, energy, or both (Laing 46). Systems can be isolated or closed and they have inputs and outputs (Laing 47). The biophysical components of the earth system are often represented as spheres; this includes the atmosphere, biosphere, hydrosphere and geosphere. Each sphere "provides environmental processes that regulate the functioning of the Earth like the production of food and natural resources" (GEO-5 195). Processes in and between the Earth systems move and transform materials. Materials are defined as the basic physical components of systems like rock, minerals, and water (Finley, Nam, and Oughton 1074). Boundaries describe the points where energy and materials move between and among a system and its structures (Finley, Nam, and Oughton 1074). Structures are defined as the "identifiable physical units into which the materials are arranged within systems" (Finley, Nam, and Oughton 1074). Structures include rock layers, atmospheric layers and waterways.

The processes operating within and between the earth systems can be described as either intrasystem or intersystem. Intrasystem processes move and transform materials within a system whereas intersystem processes work between systems (Finley, Nam, and Oughton 1075). Waterflow in streams, weathering and wind occur within a system; evaporation and volcanism occur between systems. Systems are comprised of both intra- and intersystem processes, each of which require and sometimes produce energy. Forms of energy include solar, internal heat, potential-kinetic, and chemical energy (Finley, Nam, and Oughton 1075). Variables are used to quantify the earth systems and the processes that move within and between them. Variables describe "materials, structures, processes, and energy transfers and transformation (Finley, Nam, and Oughton 1075). There are specific values associated with variables which can be quantitative or qualitative--describing anything from mineral hardness to rock types. Lastly, earth systems science relies heavily on models. Models, either computer generated, cartographic, digital, or hand drawn, depict "relationships among materials. Processes, structures, and variables" (Finley, Nam, and Oughton 1075). Models help to make the interconnectedness of the earth systems more clear. Additionally, they are used to make projections based on current or hypothetical conditions.

In 2012, the United Nations Environmental Programme published a report titled *Global Environmental Outlook-5: Environment for the Future We Want*. In its forward, Ban Ki-moon, the Secretary General of the United Nations, credits the report as providing a "comprehensive, impartial, and in-depth assessment [of the global environment that] reflects the collective body of recent scientific knowledge" (GEO-5 xvi) Here, the earth system is defined as a "single, self-regulating system comprised of physical, chemical, biological and human components [in which] the effects of human activities can be detected at a planetary scale (GEO-5 xviii). However, the earth systems do not function in isolation of each other. Rather, all of the natural systems co-evolved over a period of 4600 million years (Laing 46). Given this interdependence, the earth is described as "one great system in which every part is an interactive subsystem that must behave in an appropriately persistent, describable, and predictable" (Laing 47).

The Earth System is inherently complex and has natural variability independent of people. Although within the last 250 years, the impact of human activity is so great that some experts suggest our current geological epoch, which began at the start of the industrial revolution, should be called the anthropocene (GEO-5 195). The industrial revolution marked a shift in human impact on the planet because of increased extraction and use of natural resources and a dependence on fossil fuels in modes of industrial and food production, transportation, etc.

Mapped onto current content standards for earth science education, the central concepts of earth systems science act as an organizing principle which connects seemingly discrete topics. Instead of teaching about Earth's landforms and changing landscapes, characteristics of neighboring planets, and ecosystems as separate thematic units, my unit leverages earth systems science to explore the connections among these topics. Systems thinking allows the characteristics of not only Earth, but any planet, to be understood as results of interactions between systems, society, and environment--both naturally occurring and anthropogenic. Science standards addressed in my unit include reasoning and analysis; process, procedures, and tools of scientific investigations; systems, models, and patterns; ecological behavior and systems; and finally, earth structure, processes, and cycles. However, earth systems thinking adds a complexity to these standards in which social systems, created and sustained by people, are understood as a shaping force in earth's systems.

Finley, Nam, and Oughton's framework carries a lens that reorients connections between environment and society. *Part two* presents overarching and underlying components for systems thinking. The overarching theme, or "enduring understanding," in Wiggins and McTighe's sense of the word, are (1) "the earth can be understood as a complex set of interacting natural and social systems" and (2) natural systems include the geosphere, atmosphere, hydrosphere, and biosphere while social systems may include agricultural, economic, legal, communications, transportations, moral, political, cultural and other systems" (Finley, Nam, and Oughton 1073). Underlying that enduring understanding is a set of 22 "essential earth systems ideas" that are support one's understanding of any aspect of the earth system. (See appendix D for the list in its entirety.) Of the 22, the following are most appropriate for an elementary science education and will be used in my unit:

(1) the earth has "evolved over a period of 4.6 billion years and will continue to do so

(2) changes in the natural systems can be described in terms of the transfers and transformations of matter and energy within and across systems
(3) some changes within and among systems are cyclic and thus have feedback loops
(4) the earth systems are dynamic--constantly changing
(5) humans are dependent on the earth's materials
(6) humans are a part of the earth system, in particular the biosphere, and have created the social systems

> (7) complex and interacting social systems express our relationships with the natural systems and provide our interactions with those systems
> (8) humans encounter hazards that are the result of interactions among natural systems, among social systems, and between various natural and social systems.
> (Finley, Nam, and Oughton 1074)

Literature Review

Youth Civic Participation

In his essay "Learning in Public Places: Civic Learning for the Twenty-First Century," which introduces the edited volume *Civic Learning, Democratic Citizenship, and the Public Sphere* (2013), Gert Biesta advocates for a particular understanding of citizenship and civic learning. Though the stated context for his argument is a very general sense of a crisis of the liberal democratic state in Western Europe, several of his theoretical points are useful for my purposes. For Biesta, democracy is an "ongoing and never-ending experiment . . . [and] a process of transformation" (7). Citizenship or civic identity, which underpins the idea of democracy as an experimental process in which transformations in the social order may occur, is used to understand a subject's orientation towards "collective interests and common good" (7). However, Biesta describes a tension between two competing notions of citizenship: citizenship as a "social" identity versus citizenship as a "political" identity (Biesta 1-2). The distinction is important because different visions of civic learning follow from each definition of citizenship. When citizenship is conceived as social, "plurality and difference" in the social body is regarded as a problem and a threat to be overcome. This curriculum moves towards sameness and social cohesion through a normative definition of the citizen. When citizenship is understood as political, however, this same plurality and difference can instead be seen as the grounds of the democratic process itself (2). This tension has implications for the role of education in democratic societies, in particular for models of civic learning and civic participation.

The "socialization conception" of civic learning, which follows from citizenship conceived as social, posits a stable body of "knowledge, skills, and dispositions" one must acquire to embody a properly civic identity (6). Conversely, a "subjectification conception" of civic learning, which follows from citizenship conceived as political, is "about the learning that is involved in engagement with what we might call the experiment of democracy" (Biesta 6). Only the latter conception supports the practice of democracy as "transformation." Here, Biesta builds on the work of Jacques Rancière, who argues every society "is all-inclusive in that in any given order everyone has a particular place, role and identity" (Biesta 4). Some positions are "included as excluded," however, in the sense that they have no place in "the ruling of that order" (4). For students experiencing disjuncture in the way they understand citizenship and the opportunities they face exclusion in, citizenship as political aims to leverage their experiences while also empowering these students to work for social change in their communities and beyond. In this sense, democracy and citizenship are not exercised (or at least not primarily) through voting or other acts of civic participation conceived traditionally. Rather, both are achieved when the logic of any particular order, with its hierarchies and exclusions, is called into question.

The socialization conception of citizenship desires social consensus and therefore legitimates the social order as such; the subjectification conception of of citizenship values dissensus understood as "the production, within a determined, sensible world, of a given that is heterogeneous to it" (Rancière, cited in Biesta 4). Democracy happens, according to Biesta via Rancière, when the social order is presented with an unassimilable difference that brings about—

perhaps forces—change and transformation. Democracy and civic learning are in this sense best understood as "practices" and "events" (Biesta 5). I am less interested in Biesta's meditation on liberal democracy than I am in the implications of his argument for education theory and practice. If civic learning does not happen as students progressively acquire the knowledge and skills of normative citizenship but rather in the moments where an already-embodied citizenship is performed as a practice of questioning any given social order, then education research and practice must focus on creating spaces and moments in which such practices and events can happen. Better and more just democracies are not waiting for better citizens: rather, citizens await better opportunities to practice justice as politics. Analogously, educators should not be waiting for citizens to emerge as students acquire knowledge and skills; they must instead create spaces and structures for students to exercise the modes of citizenship they already possess. Biesta writes: "instead of blaming individuals for an apparent lack of citizenship . . . we should start at the other end by asking about actual opportunities for the enactment of the experiment of democracy that are available" (8). This position differs in its emphasis against the socialization conception of citizenship.

More suited to the U.S. contexts I am focused on is Sven De Visscher's comparable argument in "Mapping Children's Presence in the Neighborhood" that social spaces—his example is the neighborhood—both "place children spatially and socially into society" but are also "made" by children as residents of the space. Any approach that "fails to reveal the meaning children themselves give to their neighborhood" leads to a "narrow view of children's fellow citizenship" (De Visscher 74). De Visscher borrows from Biesta by regarding children not as awaiting citizenship but as practicing it already, not as citizens in the future but as citizens and political agents in the present. As with Biesta, the value of De Visscher's insights for my work inheres in its understanding that youth citizenship cannot be seen as merely social, reflecting their ideas about their place in society, but also, and more importantly, as political: "children [are] fully competent social and cultural agents, by definition," thus "actual here and now citizens" (75, 87, italics in original).

De Visscher expands on Biesta's theoretical work by applying his notion of citizenship to education research involving children in the space of the neighborhood, whose meanings are made by children no less than adults. His methodological points are perhaps more important than his theoretical ones, though, insofar as they share a set of ideas and principles with youth action research, from which my own curriculum borrows. For De Visscher, "the child (and his or her behavior, dispositions, etc.) is not the object of research but becomes a research subject" (87). This shift of focus has another consequence: the focus of research moves from the child to the neighborhood as a space and, more importantly, "the opportunities and restrictions that it holds for children to realize their citizenship" (De Visscher 87).

We might think of the student in the space of classroom as similar: the research object is not the student but the classroom, or the spatial and social environment in which it is more broadly defined. This shift of focus parallels Biesta's emphasis on better democratic opportunities because the research imperative becomes "generat[ing] situations where democratic moments may occur that question the social order of that particular neighborhood" (88). Much here overlaps methodologically with action research, defined by Rudi Roose, Maria Bouverne-De Bie, and Greet Roets in their "Action Research and Democracy" as: "(1) a way of social interaction (2) in response to a problematic situation 3) in order to change the situation (4) in collaboration with the people involved, (5) while striving for the development of theory" (108). This approach is inspired by the work of Paulo Freire primarily and rests on several assumptions: that because social realities have been constructed by people they are changeable by people, that "the life experiences of actors involved in the research process are also symbolic references to how they view social realities as well as social relationships in these realities," and finally that "citizenship is not translated as an individual status, but rather as a practice to be realized through various activities and social relations; a citizenship as practice" (106). Action research theory and methodology defines change—and, relatedly, civic learning—in a manner that overlaps with Biesta and Rancière because they both involve not a "solution" per se but the questioning or "problematizing" of a given situation and its "underlying assumptions" (113, 119).

The theoretical currents examined in this section, while rooted largely in the discursive and social conditions of Western European nation-states, trace a set of ideas about citizenship and its practice that have relevance for my project's focus on youth civic participation. They speak collectively to the theoretical and political imperative to regard young people—especially those most often positioned in dominant discourses as lagging "behind," on the wrong end of a "gap," and needing to "catch up"—not as failed or unrealized citizens but as agents responding actively to failed and unrealized democracy. Or, more specifically for my project, to failed and unrealized opportunities for civic participation in the context of a state and its institutions that mark only some forms of civic practice as legible and valuable. These underlying assumptions—ultimately about what matters and who—must be transformed.

~

In 'We Speak for Ourselves, Cole and Foster trace the early history of the environmental justice movement, first in telling the story of how residents of a small farming town discovered the largest toxic waste dump west of Alabama situated only 3.2 miles away from their community. The discovery would increase civic participation in pre-existing structures while also promoting the creation of new forms of advocacy and activism. The 1,600 acre toxic waste dump, owned and operated by Chemical Waste Management, Inc was built in Kettleman City in the late 1970s "without the community's consent or knowledge" (Cole and Foster 2). Kettleman City is a predominantly Latino community of 1,100 residents in Kings County, in the San Joaquin Valley. In the 1980s, 95% of its residents were Latino--70% spoke Spanish at home and 40% were monolingual Spanish speakers (Cole and Foster 1). Residents learned about the dump after reading in a local paper about multimillion-dollar fines levied by the Environmental Protection agency against Chem Waste in 1985. The EPA fined the company 2.1 million for violations including "operating additional landfills and waste ponds without authorization" (Sahagun 2).

Despite environmental regulations in place that are designed to inform stakeholders about the citing of toxic facilities, residents of Kettleman City were excluded from the entire process. Environmental laws in California outline three ways in which government agencies are required to provide public notification about the citing of facilities such as toxic waste dumps: (1) newspaper notices for "general circulation," (2) sign posts on and off site, and (3) sending notices to adjacent landowners (who at the time were large agribusinesses and oil companies) (Cole and Foster 2). Although these environmental regulations were in place and presumably followed by Waste Management, Inc, residents of Kettleman City still had no representation in the decision making process that allowed a toxic facility to be situated so close to their community. Upon discovery of the toxic waste dump hidden behind the hills outside of their town, residents "saw few ways in which they could challenge the dump" because outside of the fines levied against the company, they had been following other regulations and therefore deemed harmless to the surrounding community (Cole and Foster 2).

The threat to the health of Kettleman City residents posed by the toxic waste dump became even more apparent in 1988 when Chem Waste proposed to build a toxic waste incinerator at the site. Similar to their first discovery of the dump, residents were not notified about this plan until they received information from an outside source. A Greenpeace organizer in San Francisco received a call from the Kings County sheriff in January 1988, asking if Greenpeace had planned a demonstration at the hearing in Kettleman City that same night (Cole and Foster 2). The organizer then alerted a resident of Kettleman City; she and other community members did not know about the hearing. To challenge this proposed expansion of the Chem Waste facility, residents attended the hearing. There, they learned that the proposed incinerator would burn 216,000,000 pounds (108,000 tons) of toxic waste every year, which equates to about 5,000 truckloads of waste moving through Kettleman City--not including those already present due to the dump and other nearby facilities (Cole and Foster 3). Again, residents of Kettleman City found themselves in a situation where they were forced to act in order to insure that their needs and best interests are reflected in the development and implementation of public policy surrounding them. What originated as an experience of disjuncture, grew into a movement in which political power was created and leveraged by community members.

Facing exclusion from formal processes of civic participation and decision making in their community, residents of Kettleman City formed El Pueblo para el Aire y Aqua Limpio or People for Clean Air and Water. Through their research about the dump, the proposed incinerator, and the company more generally, the group found that the air in San Joaquin Valley was severely contaminated: it was considered the second-worst polluted air basin in the United

States (Cole and Foster 3). Residents began to understand the risks they were exposed to as part of a larger system of inequality and marginalization of communities of color in decision making processes critical to their health and overall wellbeing. The group, El Pueblo, also found a 1984 report funded by the California Waste Management Board known as the Cerrell Report (Cole and Foster 3). The Cerrell Report suggests companies and corporations wishing to site garbage incinerators chose communities that would offer the least resistance. According to the report, these communities are rural, poor, have low educational attainment levels, are highly Catholic, have less than 25,000 people, and have many residents employed by resource-extractive jobs like mining, timber, and agriculture (Cole and Foster 3).

The Cerrell Report suggests a pattern in which low income, working class communities, who are more likely to rely on resource-extractive (and therefore hazardous and environmentally destructive) jobs are more likely to respond passively to the citing of toxic facilities. The passivity mapped onto communities like Kettleman City appear to result mostly out of exclusion from decision making processes and failure to provided timely and accessible information to this predominately Spanish speaking community. Accordingly, El Pueblo focused their attention on other similarly positioned communities. They found that California has three Class I toxic waste dumps--sites that can process almost every known toxic substance (Cole and Foster 3). Chem Waste in Kettleman City is the only one in California licensed to accept carcinogenic polychlorinated biphenyls (or PCBs) which are responsible for “serious illnesses, birth defects and deaths among children” (Suhagun 2). The other two dumps were in communities in which greater than 60% of the population were Latino (Cole and Foster 3). It became obvious that the siting of toxic facilities in California was discriminatory and largely targeted communities in which residents were mostly people of color. The Cerrell report confirmed the results of the 1987 study Toxic Wastes and Race in the United States.

On September 7th, 1993, the Chem Waste plant withdrew its application for the toxic waste incinerator in Kettleman City. Despite this victory, more recently, Chemical Waste Management, INC remains a large capacity toxic dump site in close proximity to Kettleman City. Its close proximity to the community and its history of unreported spills continues to create problems for residents. In 2003, Chem Waste (and 21 other facilities) were determined to be emitting unusually high levels of radiations. In 2005, Chem Waste was fined $10,000 for violation of federal PCB monitoring requirements. In 2007, the company received another citation for "failing to properly analyze incoming wastes, storm water runoff and leachate for PCBs, and for failing to properly calibrate analytical equipments". In 2010, the EPA fined Chem Waste $302,100 for failing to properly manage PCBS. A year later, the company paid $400,000 in fines and $600,000 on upgrades to properly manage hazardous materials (Sahagun 3).

Earth Systems Science

Writing in the 1980s and 90s, James Hutton, an early earth scientist, argued that natural changes occurring over very long periods of time shaped the history of the earth; he continues, "these processes continued to operate in the present and they would into the distant future [and] could only be fully understood using methods of science" (Boardman 61). In the 1960s, consensus was reached on plate tectonics, or the "existence and likely movements of the earth's continent-and ocean-bearing plates," which was preceded by an understanding of seafloor spread (Boardman 66). Plate tectonics shapes the earth's surface; movements associated with this phenomenon cause events like earthquakes and magma flows that can form mountains. In his observations of rock and the natural world, Hutton contributed to the development of earth-systems thinking and frameworks through his arguments about geological timescales and other slow processes which contributed to future assertions about the earth (Boardman 66). Hutton's contributions also support the connection between geological and biological processes that is now understood in terms of "systems" (Oldroyd, 1995: 285; Watson, 1999: 77 cited in Boardman 67). Risks due to environmental injustices and global climate change can be understood using analysis rooted in Earth Systems science.

In *Governance of Earth Systems: Science and Its Uses*, Boardman describes environmental issues as being both local and global--as involving not only naturally occurring systems but also social systems like politics and culture. He argues that environmental issues

> go through complex processes at all levels of governance. They engage the concerns of residents of small coastal communities, activists in environmental organizations, and government delegates […]. They have an unruly habit of spreading across national and other jurisdictional boundaries, display multiple forms of connectedness with each other, and have different economies and cultures that give them many different forms. (Boardman viii)

Environmental issues such as natural disasters, exposure to toxics, and global climate change cross boundaries of jurisdictional responsibility and impact. As an organizational tool and a set of underlying principles, Environmental Justice began as a vision of "democratic inclusion of people and communities in the decisions that affect their health and well-being" (Cox and Pezzullo 42). Because environmental issues cross national and political boundaries, the representation of those most impacted by global and local decisions and transactions is central to efforts towards social justice. However, climate change is not only an issue of representational democracy; it is a conflict between dominant and critical discourses in which environmental issues are framed without inclusion of the voices and experiences of those most impacted. Within these boundaries are norms translated through economic and cultural processes and practices. These norms help to frame not only what constitutes the environment, but also what (and who) must fall under the onus of environmental protection.

Sociologist Erving Goffman popularized the term "frame" in his 1974 book, *Frame Analysis*. In this book, frames were defined as "cognitive maps or patterns of interpretation that people use to organize their understanding of reality." (cited in Cox and Pezzullo 62). Frames carry explicit or implicit assumptions about the environment. For example, the media often uses language that communicates that the science around global climate change is questionable. The Cato Institute, a libertarian think-tank based in D.C, published an article titled "Do Scientists Suppress Uncertainty in the Climate Debate?" The article questions the willingness of climate scientists to "support the alarmist narrative of CO2-induced global warming" (Idso). Framing climate change as a "debate" ignores ongoing experiences of climate change in the global south and in the north. Additionally, this communicative frame also ignores consensus in the scientific community about the role human activity continues to have in fueling global climate change.

The Intergovernmental Panel on Climate Change (IPCC), which was created in 1988 by the World Meteorological Organization and the United Nations Environmental Programme, has conducted assessments on Global Climate Change. More broadly, the purpose of the IPCC is to "evaluate the state of climate science as a basis for informed policy action, primarily on the basis of peer-reviewed and published scientific literature" (Oreskes 1). The most recent report produced by the IPCC states that without a doubt, there is consensus of scientific opinion that "human activities... are modifying the concentration of atmospheric constituents...that absorb or scatter radiant energy. Most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations" (Oreskes 1) Such an argument demands specific actions, namely the reduction of greenhouse gas emissions due to human activity.

The act of framing can "shape or construct how [people] perceive both problems and solutions and attempt to persuade others of a particular perspective" (Coz and Pezzullo 63). News media, cultural practices, economies and education employ specific frames that communicate a specific understanding of the environment: what constitutes the environment, what are its uses, who must be involved in its protection, and who (or what processes) is at fault for environmental issues. Communicative frames are "constitutive," they "help to construct a particular view or orientation to some aspect of reality" (Coz and Pezzullo 63). Whereas the Cato Institute frames policy and science as separate, the IPCC argues that Scientists play an important role in policy and decision-making in regards to global climate. This frame positions scientists as civic actors and science as a form of civic participation. Frames can also be persuasive, in that they may support or confirm one worldview over another (Coz and Pezzullo 63). Earth Systems Science, leveraged in traditional science education, communicates a frame that helps to structure our understanding of the environment. Increasingly, Earth Systems Science has come to include people as being one of the Earth's "interacting spheres." Earth Systems Science communicates a frame that positions people as a shaping force on the planet, especially within the last 50 years.

The Keeling Curve, produced by The National Historic Chemical Landmarks program of the American Chemical Society, describes the first data collected that explored natural and manmade carbon trends. In 1958, at the Mauna Lua Observatory in Hawaii, Keeling of the Scripps Institution of Oceanography became the leading authority in the creation of a global atmospheric carbon dioxide (CO2) record. The record, which continues today, is important because it provides scientific linkages to "fossil fuel combustion and global climate change due to the greenhouse effect" (American Chemical Society National Historic Landmarks). Although the Earth has a history of warming and cooling, the carbon dioxide record proves that present warming is occurring at a rate that can only be credited to anthropogenic forces. In a 1965 study, President Lyndon B. Johnson's Science Advisory Committee sought to address issues of air, water, and land pollution.

The report, titled "Restoring the Quality of Our Environment," was led by a panelist of 14 "outstanding physicians, scientists, and engineers" over the course of 15 months (Johnson 1102). The report argued that pollution is an inevitable consequence of an "advanced society" although efforts should be made to reduce its impacts:

> If we are to manage our pollution as we should, we must give more or nearly the same attention to how we dispose of our waste materials as to how we gather and transform our raw materials. Society must take the position that no citizen, no industry, no municipality has the right to pollute. (Johnson 1102).

The report continues by drawing a connection between increased carbon dioxide and human activity. It argued that carbon dioxide is added to the Earth's atmosphere by the burning of coal, oil and natural gas at the rate of 6 billion tons a year (Johnson 1102).

In 1973, a report compiled by Keeling and his colleagues at the Scripps Institution found that carbon moves between the Earth systems: oceans, atmosphere, biosphere and the geosphere. Using the carbon record, they compared CO2 presently accumulating in the atmosphere against future estimates of CO2 due to the burning of fossil fuels--that figure became known as the airborne fraction. It was concluded that 55% of CO2 released by coal, oil and natural gas remained in the atmosphere for an extended period which caused the Keeling Curve's annual rise--the remainder of CO2 is dissolved into the oceans, processed by plants, or accumulated in the soil (American Chemical Society 2015). In 1978, Keeling continued studies on the isotopic ratios of carbon found in air samples from as early as 1955--a subsequent paper published in 1979 drew connections between atmospheric accumulation of CO2 to the "liberation of long-sequestered banks of carbon [through] the burning of fossil fuels by mankind" (American

Chemical Society 2015). The report framed human activity as a disruption to the standard carbon cycle.

In the 1980s, research of air samples found in polar ice deposits extended the carbon record. CO2 levels from these samples dated back thousands of years and were used to situate recent carbon levels within climate patterns established before the industrial revolution which marked increases in man-made emissions. The research identified a trend in which the present CO2 concentrations had not been seen on Earth in more than 800,000 years. This emerging pattern was said to exceed natural trends; according to the report, possible effects this would have on climate included "increases in average global temperatures, melting arctic ice sheets resulting in rises in sea levels, [and] increased acidity of water bodies" (American Chemical Society). However, at the time, many impacts resulting from increases in atmospheric CO2 were largely unknown. The report concluded, "Through his worldwide industrial civilization, Man is unwittingly conducting a vast geophysical experiment" (American Chemical Society 2015).

Emerging in part as a response to the science of climate change, the study of the earth as a complex set of systems began to take shape during the 1980s when the earth's components were first described as "interacting spheres" (Boardman 69). In the 1980s, scientists and engineers from the National Aeronautics and Space Administration (NASA) were advocates of an area of thought that uncovers linkages between the environment and its systems and human activity. They argued, an understanding of the earth requires "knowledge of the cycles of the atmosphere and oceans, terrestrial biosphere, and other earth domains; external factors, particularly forcing from the sun; and the transformative effects of human activities" (NASA, 1988 cited in Boardman 71). Although it drew from Hutton's associations between biological and geological forces as well as his assertion about processes taking place across time, Earth

Systems science has been described as a revolution in scientific thinking because it involves an interdisciplinary approach. Some Earth Systems science work deals with values of autonomy and diversity while other efforts deal with quantification and modelling (Boardman 70). At best, Earth Systems Science is described as “an emerging holistic super-discipline that tried to embrace all processes in nature and society as one interlinked systems” (Lovbrand et al., 2009 cited in Boardman 70). Its applications include resource use, sustainable development, response capabilities in natural disasters, the alleviation of poverty and other issues (Boardman 71).

The development of Earth Systems Science became especially important in relation to the mounting environmental issues of the late 90s and 2000s. Global Climate Change as well as interests in the global climate cycle, consequences of perturbations produced by fossil-fuel dependent economies and the prospects of low-carbon transitions helped the field of Earth Systems Science maintain its momentum from the previous decades. Boardman argues, “a defining characteristic of the study of Earth systems [is the] acknowledgement of the need for robust cooperation among scientists, whether in looser and more decentralized (multidisciplinary) formats or in more integrated (inter- or transdisciplinary) ways” (Boardman 76). Instruction in earth systems science through a youth participatory action approach promotes increased collaboration between scientists, communities and policy. Due to the complicated nature of the earth system and the unpredictability of the current epoch, science as civic participation becomes even more critical to mitigating and adapting to climate change while simultaneously working toward social justice for communities so often at the periphery.

Conclusion

Imagining and constructing nature as wilderness, traditional environmentalism excluded issues faced by those in urbanized low-income communities, particularly communities of color. Relatedly, traditional forms of civic education have tended to be confined to their own discipline or area of study and have been focused on, and rooted in, forms of civic participation that often further the disjuncture experienced by Black and Latino students. These discursive and institutional exclusions parallel and inform a broader racism that structures U.S. and global governance and society, a racism perhaps best understood as environmental in the sense furthered by the environmental justice movement. In *Golden Gulag: Prisons, Surplus, Crisis, and Opposition in Globalizing California* (2007), geologist Ruth Wilson Gilmore defines racism as involving "the state-sanctioned and/or extralegal production and exploitation of group-differentiated vulnerability to premature death," a definition that can incorporate factors such as exposure to toxics, climate change, poverty, underfunded public schooling, the policing apparatus, and more—all under the rubric of "environment" (Gilmore 28). This vulnerability is produced on both local and global scales, which are always interwoven, and speaks to the various accounts of environmental racism described here, as well as the approaches that particular communities (for instance in Diamond, LA and Kettleman City, CA) have developed to address, reframe, and confront it.

Drawing on the activist and scholarly traditions of environmental justice, my thesis develops an approach to science education that is grounded in the effort to create new means for youth civic participation. Central to this approach are the theoretical and methodological principles of earth systems science. I have therefore attempted to imagine how earth systems science, and science education more broadly, can be marshalled for an antiracist project.

Although earth systems science emerged largely as a response in the scientific community to the challenge of climate change, it has not often included an antiracist theoretical component. My curriculum explicitly and implicitly develops that component. Because the problem of climate change is in part a problem of racism, an earth systems science approach informed by environmental justice expands its scope in accordance with the expanded conception of the environment and its multiple structuring systems, both natural and social.

Several additional insights have followed from this project's focus on environmental justice, earth systems science, and youth civic participation. A science education rooted in earth systems science and youth participatory action research can promote inclusivity in the science community and in the public discourse surrounding the unpredictable impacts of global climate change (among other environmental challenges). This inclusivity could transform the scientific community itself, transforming its approaches to questions and problems, as well as public discourse around various issues related to science, society, and the environment. It is also necessary with respect to the challenge of climate change specifically; the inclusion of marginalized voices and those that bear the burden of climate change more fully is critical to any efforts to mitigate and adapt to global climate change. Long term, this approach to science education can likewise support growth in science fields in which students from minoritized communities face continued exclusion. Science and science education can be seen not only as a public good but also as an organizing tool, and science education as civic participation.

Earth systems science, moreover, can empower students to participate more fully in their communities by adopting roles as citizen scientists. The reconceptualization of science education as civic education finds its agent in the figure of the citizen scientist, which itself represents a reconceptualization of the figure of the citizen. Earth systems science positions citizenship as local and global; through the application of systems thinking students are encouraged to see the local in the global and vice versa. Two concrete examples of the implications of systems thinking include cradle to grave assessment (in which any product or commodity is understood and traced in terms of its material production, consumption, and disposal) and a focus on dissociation (in which the use of a particular produce or commodity is seen in relation to what happens before and after it is used.

Earth systems science challenges dissociation by helping to perceive how goods and waste, which are materials and energies, move between and among systems; it encourages us to look at where they originate, who was involved with production, what are the economic and political structures in which production takes place, who consumes, and who has to deal with waste: all these factors and more are best analyzed under an earth systems rubric, and all can be approached through the role of the citizen scientist. In this role, students perform an empowered civic participation that involves questioning, analysis and action, each of which are forms of science education as civic practice.

The five week unit developed here is conceived as part of an expanded earth sciences curriculum in which it functions as an introduction to one that more directly borrows from youth participatory action research. It incorporates the theoretical currents described above and aims to create opportunities for their practice as both science education and civic participation. Beginning with an overarching emphasis on the changing earth and the changing impact of humans on the planet—natural versus anthropogenic changes—the first week builds toward an understanding of the connections between weather, earth systems, and human activity. The second week pursues these connections further and in more detail by focusing on the transfers and transformations of matter and energy that characterize changes in the earth's natural systems; it explicitly introduces the foundational concepts of earth systems science and asks students to consider the differences between isolated, closed, and open systems.

Weeks three and four delve yet deeper into the concepts introduced at the beginning, asking questions of the earth and other planets that students engage through activities involving concepts such as cybernetic systems, cyclical changes, and feedback loops. The fourth week in particular links the theory and methodology of systems thinking to questions involving humans' impact on the earth's systems and climate. The fifth and final week of the unit brings issues of justice to the forefront and asks students to engage the unit's enduring understandings—both scientific and social, and thus environmental in the broadest sense—through a variety of practices including discussion and debate, questions and answers, and designing and presenting a poster.

Finally, a youth action approach, which links earth systems science and environmental justice theory to youth directed action, promotes and demands the inclusion of communities made marginal to local and global decision making processes. This inclusion refers not only to people and communities but to discourses and practices. Often, the role of science in policy decisions (locally or nationally and so on) is limited to very specific and narrow conceptions of science and the effects it has, and can have, on social life. These conceptions are not only narrow but actively exclusionary. The model of the citizen scientist, which adopts scientific languages and methodologies, addresses these exclusions while also transforming the relationship between school and society. Youth, as an extended subcategory of identity or difference, often face exclusion from participating in public discourse especially in more specialized fields like science. However, my focus on youth aims to leverage their insights and experiences as shaping forces in their communities while situating them in a broader emphasis on intergenerational collaboration as citizen scientists and community activists.

An earth systems science curriculum informed by environmental justice theory and practice also bridges traditional divides between civic education, science education, and environmental activism. It ultimately reconceptualizes science education *as* civic education. And it contributes to a reconceptualization of democracy as an event, an interruption of the social order and its underlying assumptions—specifically, in the moments when disjuncture is challenged via practice. Throughout my thesis, then, the emphasis on connected systems from earth systems science informs the emphasis on interlocking structures from environmental justice, and together they point to the ways that civic education must not be confined to its own area of study. By developing a theory and practice of science education as civic participation, and science education as part of a broader anti-racism, my thesis has aimed to promote congruence and relevance—as opposed to exclusion and disjuncture—for young people of color in educational contexts and beyond.

~

Topic: Intro to Earth Systems Science

Week 1	Day 1	Day 2	Day 3	Day 4
Learning Objective: the earth has "evolved over a period of 4.6 billion years and will continue to do so	Natural vs Anthropogenic changes: Key Qs: Has the Earth always been like it is today? What are some ways the Earth has changed (or remained the same)?	(see day 1)	Key Qs: What was the earth like when there were dinosaurs? Have human always had an impact on our planet?	Introduce Global Climate Change and the connection between weather and earth's systems
Standards	S4.A.1.3		S4.B.3.1	3.3.4.A5, S4.B.3.1
Description	Students debate the key question. One side believes that the Earth has remained the same and the other side does not Teacher records main points from both sides on the board. And introduces the term: evidence. Students then independently read texts to support a claim of their choosing from the debate	Students continue reading but reconvene in groups by topic or interest Teacher introduces the terms natural v. anthropogenic	Students discuss the key questions then watch a short video on the evolution of planet Earth Class returns to the key questions considering new evidence	Students will conduct a debate about whether or not climate change is true As a class, we'll then talk about whether or not variations in the planet (specifically weather) are naturally occurring or caused by people
Strategies Used	Debate, independent	Thematic reading in	Think, pair, share	Debate

	reading, mini lecture	groups, mini lecture		
Week 2	**Day 1**	**Day 2**	**Day 3**	**Day 4**
Learning Objective: changes in the natural systems can be described in terms of the transfers and transformations of matter and energy within and across systems	Bathtub experiment	Define Isolated, Closed, and Open systems Introduce Earth Systems Science	The Earth's Spheres	The Earth System Key Qs: What would happen if Earth were an isolated or open system?
Standards	S4.A.2.1	3.3.4.A2	3.3.4.A2, S4.A.3.1	S4.A.1.1
Description	In groups, students will perform various tasks using a bucket of water, a tap, a large bowl, and a plastic tube Students will configure the materials (which represent a system) differently to represent isolated, closed, and open systems As a group, students will record the different materials used for each system as well as observations	Review classwork from the previous day Groups share their responses As a class: Where does the water go in each configuration? Students match each configuration with a more conceptual depiction of the various systems. Introduce "models" as a	Teacher introduces geosphere, hydrosphere, and biosphere as open systems. As a practice, ESS aims to describe the interactions between and among these spheres. Students play on interactive games that simulate earth systems modeling	Students debate key questions in small groups After answering a set of questions for each scenario, students create visual representations of their earth systems Teacher introduces cybernetic systems. These are often a sign of life and in these, "energy potentials are maintained within predetermined,

		tool used by Earth Systems Scientist		optimum ranges, instead of being allowed the fluctuate freely" (Laing 50) Review compilation of satellite images that show the earth "breathing" through its seasonal changes
Strategies Used	Teacher modeling, experimentation	Small group work	Mini-lecture, experimentation	Group discussion, independent work
Week 3	**Day 1**	**Day 2**	**Day 3**	**Day 4**
Learning Objective: some changes within and among systems are cyclic and thus have feedback loops	Key Qs: Imagine if Earth were not a cybernetic system. Would our temperature remain average or would it get really hot or cold?	Key Qs: Venus is hotter than Mercury but is further from the sun (which is a heat source). Why?	Key Qs: Why doesn't Mercury have a thin atmosphere?	The Earth's atmosphere
Standards	S4.A.1.1, S4.A.2.1, S4.A.3.2	S4.A.3.2	S4.A.3.2	3.3.4.A2, S4.A.1.1
Description	As a class, we create a visual model that represents simple cybernetic systems like flood pumps Experiment: Heat an object with the same light source and distance from the sun but with	Teacher shows model of the arrangement of our solar system. Asks, what is the heat source? Which planets are hottest? Individually, students	Mercury has a thin atmosphere because of interactions between and within its systems Review evidence collected from prior classwork about the two planets and create	Continue working on models. Watch video about the uniqueness of planet Earth and the question for a planet similar to it for possible human habitation

	different barriers between the light and the object to observe how heating is different	complete short reading and worksheet about venus, earth and mercury's atmospheric contents, temperature, and distance from the sun	a model about the interactions between the sun, the planet (venus and mercury), atmosphere, and solar winds	Closing assessment: What planet (earth, venus, mercury) would you like to live on? Why?
Strategies Used	Experimentation, visual modeling	Mini-lesson, call and response, portfolio	Visual modeling, manipulatives	Exit ticket, visual modeling
Week 4	**Day 1**	**Day 2**	**Day 3**	**Day 4**
Learning Objective: the earth systems are dynamic and constantly changing	Key Qs: Is Carbon in the atmosphere always a bad thing?	Key Qs: Due to global climate change, what are some ways the Earth system has changed?	Key Q: What are some natural changes and processes in the Earth System?	Custom Systems
Standards	S4.A.1.3, S4.B.3.1	S4.B.3.1	S4.A.1.3	
Description	The presence of carbon is a huge factor in the variations between venus and mercury Students will read about the carbon cycle, the greenhouse effect, and its impacts on climate As a class, students will debate the key	Class discusses seasonal changes in temperature Review CO2 record as it relates to global climate present day and in the preindustrial periods	Review natural changes and forcings: heating and cooling and weathering Watch climate change debate between believer and skeptic	Create your own system; either closed, open, or isolated

	question			
Strategies Used	Independent reading, debate	Class discussion	Call and response	Project
Week 5	**Day 1**	**Day 2**	**Day 3**	**Day 4**
Learning Objective: humans are dependent on the earth's materials	The Climate "debate" Key Qs: In the scientific community, there is consensus about the human impacts on GCC but the topic is still framed as a debate. Why?	(see day 1)	Key Qs: What is the largest contributor to the greenhouse effect on Earth? How is CO2 released on earth? Who benefits from the burning of fossil fuels?	Social Systems: Framing GCC as an environmental injustice
Standards	S4.A.1.1	S4.B.3.1	S4.A.3.3, S4.A.1.3	S4.A.1.1
Description	Students take a vote: do you believe in global warming? Students answer the key question Students explore evidence on both sides with online research	Students repeat the debate from week one, this time with evidence from the previous class	Students watch videos by climate justice activists and organizations then answer the key questions in small groups	Individually, students design a poster that communicates how their one of the communities in the videos from yesterday is impacted by global climate change
Strategies Used	modeling	Debate	Small group discussion	Project

Standards

Assessment Anchor: Reasoning and Analysis

S4.A.1.1 Identify and explain the application of scientific, environmental, or technological knowledge to possible solutions to problems

S4.A.1.3 Recognize and describe change in natural or human-made systems and the possible effects of those changes

Anchor: Processes, Procedures, and Tools of Scientific Investigations

S4.A.2.1 Apply skills necessary to conduct an experiment or design a solution to solve a problem

Anchor: Systems, Models, and Patterns

S4.A.3.1 Identify systems and describe relationships among parts of a familiar system (e.g., digestive system, simple machines, water cycle)

S4.A.3.2 Use models to illustrate simple concepts and compare the models to what they represent

S4.A.3.3 Identify and make observations about patterns that regularly occur and reoccur in nature

Anchor: Ecological Behavior and Systems

S4.B.3.1 Identify and describe living and nonliving things in the environment and their interaction

Anchor: Earth Structure, Processes and Cycles

3.3.4.A2 Identify basic properties and uses of Earth's materials including rocks, soils, water, and gases of the atmosphere

3.3.4.A5 Describe basic weather elements. Identify weather patterns over time

Additional Connections and Add-ons

Standard - **3.1.4.A3**

Identify differences in the life cycles of plants and animals.

Earth, as a cybernetic system, has natural fluctuations and rhythms that maintain energy potentials within predetermined ranges. The earth's climate is regulated by this system. Differences in climate can be understood as having seasonal variations: Summer, Fall, Spring, Winter. Seasons fluctuate according to this natural rhythm; therefore, seasons can be understood as one of earth's cycles. The lifecycles of plants and animals as well as how people interact with the environment can also be understood as earth's cycles. Each are influenced by seasonal cycles but to different extents. The unit can be expanded to guide students in learning more about the life cycles of plants and animals, specifically how they respond to natural variations in the earth's systems.

Video resource: https://www.youtube.com/watch?v=r2yLSLmnsY4

Works Cited

Allen, Barbara. “Women Scientists and Feminist Methodologies in Louisiana’s Chemical Corridor.” *Michigan Feminist Studies* 13 (1998-1999). n. pag. Web. 1 May, 2016.

American Chemical Society National Historic Chemical Landmarks. “The Keeling Curve: Carbon Dioxide Measurements at Mauna Loa.” 30 April, 2015. Web. 1 May, 2016.

Anguelovski, Isabelle. *Neighborhood as Refuge: Community Reconstruction, Place Remaking, and Environmental Justice in the City.* Cambridge, MA: MIT Press, 2014. Print.

Biermann, Frank, Michele M. Betsill, Joyeeta Gupta, Norichika Kanie, Louis Lebel, Diana Liverman, Heike Schroeder, Bernd Siebenhüner, and Ruben Zondervan. “Earth system governance: a research framework.” *International Environmental Agreements: Politics, Law, Economics* 10 (2010): 277-298. Web. 1 May, 2016.

Biesta, Gert. “Learning in Public Places: Civic Learning for the Twenty-First Century.” *Civic Learning, Democratic Citizenship, and the Public Sphere*. Eds. Gert Biesta, Maria De Bie, Danny Wildemeersch. New York: Springer, 2014. 1-14. Print.

Boardman, Robert. *Governance of Earth Systems: Science and Its Uses*. New York: Palgrave Macmillan, 2007. Print.

Carter, Lyn and Ranjith Dediwalage. “Globalisation and science education: the case of Sustainability by the Bay.” *Cultural Studies of Science Education* 5 (2010): 275-291.

Cole, Luke W. and Sheila R. Foster. *From the Ground Up: Environmental Racism and the Rise of the Environmental Justice Movement.* New York: NYU Press. 2000. Print.

Cox, Robert. *Environmental Communication and the Public Sphere.* 3rd Ed. Thousand Oaks, CA: SAGE Publications, 2013. Print.

De Visscher, Sven. “Mapping Children’s Presence in the Neighborhood.” *Civic Learning, Democratic Citizenship, and the Public Sphere*. Eds. Gert Biesta, Maria De Bie, Danny Wildemeersch. New York: Springer, 2014. 73-90. Print.

De Winter, Micha. “Subjectificating Socialisation for the Common Good: The Case for a Democratic Offensive in Upbringing and Education.” *Civic Learning, Democratic Citizenship, and the Public Sphere*. Eds. Gert Biesta, Maria De Bie, Danny Wildemeersch. New York: Springer, 2014. 55-72. Print.

Environmental Justice Atlas. “Shell petrochemical plant and Pollution in Norco, US.” n.d. Web. 1 May, 2016.

Finley, Fred N., Younkeyong Nam, and John Oughton. "Earth Systems Analysis: An Analytic Framework." *Science Education* 95: 1066-1085, 2011.

Ginwright, Shawn and Taj James. "From assets to agents of change: social justice, organizing, and youth development." *New Directions for Youth Development* 96 (2002): 27-46. Web. 1 May, 2016.

Goyette, Jared. "How one woman fought one of the world's biggest oil companies—and won." *Public Radio International.* 27 March, 2015. Web. 1 May, 2016.

Idso, Craig D. "Do Scientists Suppress Uncertainty in the Climate Change Debate?" *Cato Institute.* 4 February 2016. Web. 1 May, 2016.

Johnson, Lyndon. *Public Papers of the Presidents of the United States: Lyndon B. Johnson,* 1966. Web. 1 May, 2016.

Jones, Gail, Gina Childers, Vanessa Stevens, and Blake Whiteley. "Investigating Science in the Community: Providing Meaningful Contexts for Students to Engage in the Processes of Science." *The Science Teacher 79.9* (2012). Web. 1 May, 2016.

Laing, David. *The Earth System: An Introduction to Earth Science.* Dubuque, IA: Wm. C. Brown Publishers, 1991. Print.

Lerner, Steve. *Diamond: A Struggle for Environmental Justice in Louisiana's Chemical Corridor.* Cambridge, MA: MIT Press, 2005. Print.

Louisiana Bucket Brigade. www.labucketbrigade.org. n.d. Web. April 1, 2016.

Oreskes, Naomi. "Beyond the Ivory Tower: The Scientific Consensus on Global Warming." *Science* Vol. 306 no. 5702 (2004): 1686. Web. 1 May, 2016.

Pellow, David Naguib. *Resisting Global Toxics: Transnational Movements for Environmental Justice.* Cambridge, MA: MIT Press, 2007.

Roholt, Ross Velure, R. W. Hildreth, and Michael Baizerman. *Becoming Citizens: Deepening the Craft of Youth Civic Engagement. Child and Youth Services* 29.3 (2007): 1-182.

Roose, Rudi, Maria Bouverne-De Bie, and Griet Roots. *Civic Learning, Democratic Citizenship, and the Public Sphere.* Eds. Gert Biesta, Maria De Bie, Danny Wildemeersch. New York: Springer, 2014. 107-122.

Rubin, Beth C. "'There's Still Not Justice': Youth Civic Identity Development Amid Distinct School and Community Contexts." *Teachers College Record* 109.2 (2007): 449-481.

Rubin, Beth C. and Brian F. Hayes. "'No backpacks' versus 'Drugs and Murder': The Promise and Complexity of Youth Civic Action." *Harvard Educational Review* 80.3 (2010). Web. 10 May, 2016.

Schellnhuber, Hans Joachim, Paul J. Crutzen, William C. Clark, and Julian Hunt. "Earth Systems Analysis and Sustainability." *Environment* 47.8 (2005): 11-25. Web. 10 May, 2010.

Schlosberg, David and Lisette B. Collins. "From environmental to climate justice: climate change and the discourse of environmental justice." *Climate Change* 5.3 (2014): 359-374. Web. 10 May, 2016.

United Church of Christ Commission for Racial Justice. *Toxic Wastes and Race in the United States: A National Report on the Socioeconomic Characteristics of Communities with Hazardous Waste Sites*. Benjamin F. Chavis Junior, Executive Director. New York: United Church of Christ, 1987. Print.

United Church of Christ Commission for Racial Justice. "Principles of Environmental Justice." 27 October, 1991. Web. 1 May, 2016.

United Nations Environment Programme. *The fifth Global Environment Outlook, GEO-5: Environment for the Future We Want*. United Nations Environment Programme. Valetta, Malta: Progress Press, 2012. Web. 1 May, 2016.

United States. Citizens' Advisory Committee on Environmental Quality. *Report to the President and to the Council on Environmental Quality*. Washington: GPO, 1971. Web. 1 May, 2016.