“Our Water, Our Community, Our Voice”: Environmental Civic Science Praxis as Education for Environmental Action, Agency and Justice

by

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A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
(Environment and Sustainability)
in the University of Michigan
2026

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Dedication

I dedicate this dissertation to my Mom, Connie Flanagan, for creating a roadmap for my journey as a scholar and researcher in support of youth civic action. I would not have done this without you. To my Dad, Les Gallay, for your support and unwavering belief in me. You have both taught me to fight for what I believe in, including a more just and sustainable world. To my kids, Elmore and Erzsi, for your understanding and for putting up with so many compromises over the last five years. You two are the heart of the reasons for this work. And to my husband, Jove Cantelon, for everything, including seeing the value in my work, reminding me of the things that truly matter and that deadlines are subjective. Thank you for building a life with me and working to make this world a better place. I am endlessly grateful to all of you.

Acknowledgements

This dissertation would not have been possible without the support and guidance of my dissertation committee. To Dr. Michaela Zint, thank you for believing in me and my work from the beginning, guiding me in navigating this journey and for the opportunities you provided me in this program. You challenged me by offering guidance and comments that stretched my thinking and pushed me to make this work the best it can be through your clear, constructive feedback on this dissertation. To Dr. Ethan Lowenstein, thank you for showing me what a scholar-activist can be and for your kindness and encouragement. I strive to emulate the compassion and care you showed me and with which you navigate your own scholarship. To Dr. Angela Calabrese-Barton, thank you for helping me see where my work fits into the bigger picture, for your leadership in justice-oriented education and feedback on my work, which strengthened my writing and approach to research. To Dr. Kyle Whyte, thank you for welcoming me into the environmental justice community, for reminding me what this scholarship is founded on and why it matters. I have learned from each of you and appreciate your guidance throughout my learning and this dissertation process.

To my partners in research and practice, Lisa, Alisa, Connie, Jessica, Paula, Matt, Audra, Jason, Anna and Dillon. I am so thankful to have worked on this project with all of you. Your scholarship, thoughtfulness, expertise and creativity shaped the praxis of environmental civic science. Your dedication, integrity, purpose and deep commitment to youth, justice, sustainability and community has been both an inspiration and roadmap for my own personal and professional life. I am proud to have worked beside you.

Finally, thank you to all the teachers and students who made this work possible by welcoming me into your classrooms, and sharing your time and experiences. Your generosity and trust truly made this work possible.

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Abstract

Environmental challenges are also civic and justice challenges. Addressing them requires young people to develop environmental knowledge along with the capacity, motivation, and sense of efficacy to work with others, understand decision-making systems, and participate in community change. This dissertation examines Environmental Civic Science (ECS) as a pedagogical framework to support this learning in formal school settings. Grounded in civic science, environmental commons theory, justice-oriented education, and theories of science agency, ECS integrates environmental science inquiry with civic engagement through four core elements: local environmental issue inquiry, collaboration with community partners, engagement with local decision-makers, and collective public action with peers.

Across three interrelated studies, I examine how ECS was implemented in science and social studies classrooms in four Michigan high schools and how participation related to four student outcomes: environmental civic learning, critical environmental science agency (CESA), environmental justice (EJ) understanding, and critical consciousness (CC). I draw on mixed-methods data from students and teachers, including teacher logs and planning documents, classroom observations, pre/post student surveys, student written reflections, and focus groups.

The first study documents ECS implementation across classroom contexts and examines what students experienced and learned through ECS's core elements. Across disciplines ECS operated as a flexible inquiry-to-action framework centered on community environmental decision-making. Findings suggest that ECS appeared to support environmental civic learning when students applied disciplinary knowledge in and with community, learned through partner relationships, collaborated with peers, and advocated to decision-makers with authority to respond to students' advocacy.

The second study builds on theories of science agency to develop CESA as an outcome specific to socio-environmental decision-making, and examines ECS's potential for developing students' CESA. I define CESA as students' capacity and drive to work with others in applying

environmental science and civic knowledge and skills to socio-environmental and EJ issues in their communities. Quantitative findings show significant student gains across CESA-aligned dimensions, including environmental actions, competence to address community water issues, sociopolitical control, and capacity to act for environmental change. Qualitative findings explain these gains by showing how students expressed and enacted CESA through local issue investigation, data gathering, decision-maker and community engagement, evidence-based action campaigns, and collective public advocacy.

The third study explores ECS as a context for EJ learning and CC development. Findings suggest that ECS can create entry points into EJ learning and CC by helping students interpret environmental problems as matters of rights, access, participation, accountability, and collective action. Findings also suggest that participatory inquiry alone is not sufficient for robust EJ understanding or CC; ECS's justice-oriented potential depends on teacher praxis that explicitly connects local inquiry to power, racism, classism, governance, institutional responsibility and rights to participation.

Together, these studies argue that ECS offers a theoretically grounded and practically useful framework for organizing environmental learning around community decision-making. Findings suggest that ECS can support students' environmental civic learning, CESA, EJ understanding, and emerging CC when students investigate local environmental conditions, interpret those conditions through civic and justice lenses, learn how decisions are made, and advocate for change with evidence-backed claims to authentic decision-making audiences. By offering empirical evidence of student outcomes associated with ECS participation, this dissertation contributes to environmental, civic, science, and EJ education and offers insights into how to prepare students to participate in environmental decision-making for more just and sustainable communities.

Chapter 1 Introduction

As humanity faces environmental crises on an unprecedented scale, the need for collective action to address these issues is increasingly urgent (Ardoin, Bowers, & Wheaton, 2023; Levy & Zint, 2013). These socio-environmental challenges are never only scientific or technical. They are also civic and justice challenges because they raise questions about governance, responsibility, power, and participation: whose knowledge is recognized, who makes decisions about these issues, who is affected, and who has the ability to shape responses. These questions also raise issues of justice within and across generations, especially as young people inherit environmental conditions shaped by past and present decisions.

Formal education has a vital role to play in equipping today's youth to confront these pressing socio-environmental challenges and their root causes in ways that support a sustainable and just future. To meet this responsibility, education must provide young people with the knowledge, skills, dispositions, and opportunities necessary to navigate and address these destructive environmental legacies. This requires integrating environmental and civic literacy across subject areas, cultivating students' scientific and civic competencies, emphasizing collective action, connecting classroom learning to community engagement, and incorporating the justice dimensions inherent in socio-environmental challenges (Lee et al., 2021; Tannock, 2021). It also requires educational approaches that connect knowledge to action, helping young people recognize the links between their learning and the contributions they can make to their communities.

In this dissertation, I argue that education is critical to preparing youth to face these socio-environmental challenges and to ensuring that sustainability and equity are intertwined in efforts to create sustainable, just, and hopeful futures. Specifically, I contend that education must foster agency in young people by building their capacity and drive to use both science and civic knowledge in collaboration with others to address socio-environmental and environmental justice (EJ) issues in their communities (Bandura, 2000; Zimmerman, 1995; Calabrese Barton & Tan, 2010).

Building from this argument, this dissertation examines Environmental Civic Science (ECS) as one pedagogical framework that has potential to meet these educational needs. To date, however, there is little empirical evidence to support this assertion. ECS integrates place-based environmental science inquiry with civic development and collective public action. It positions youth as community actors who investigate local environmental issues, collaborate with community partners, work collectively with peers, and engage with local decision-makers, to advocate for change (Gallay et al., 2025). ECS is grounded in the idea that students should not only learn about socio-environmental issues; they should practice the scientific, civic, and collective forms of participation through which communities understand problems, deliberate, and act (Gallay et. al., 2025; Gallay & Flanagan, 2026).

Across three interrelated studies, I examine teachers' praxis of the ECS framework and four related student outcomes: environmental civic learning, critical environmental science agency (CESA), EJ understanding, and critical consciousness (CC). In doing so, this dissertation advances both theory and practice. Theoretically, it develops and examines CESA as a construct for understanding students' capacity to use environmental science and civic knowledge collectively in relation to community environmental decision-making. It also contributes to theory on environmental civic science, environmental justice education (EJE), and CC by examining how participatory inquiry-to-action pedagogy can support agency and justice-oriented learning. Practically, it offers evidence-based guidance for educators, curriculum designers, schools, and professional learning facilitators seeking to connect environmental science learning with civic participation, community partnership, and justice-oriented action.

I argue that ECS matters because it provides young people with opportunities to develop environmental knowledge as well as the ability, motivation, and sense of efficacy to work with others, use evidence, understand decision-making systems, and participate in community change.

1.1 Theoretical Foundations

This dissertation responds to a core issue: young people are increasingly asked to understand and adapt to socio-ecological crises, but they are rarely given opportunities to practice the civic and scientific participation needed to respond to them. To conceptualize and interpret ECS, I draw on six complementary bodies of scholarship: civic science, science agency, justice-oriented science education, environmental justice education, environmental commons theory, and critical consciousness.

A participatory, community-engaged stance connects these perspectives. Across these bodies of scholarship is the premise that knowledge is strengthened when it is produced in relation to community concerns and when it draws on multiple forms of expertise, including scientific, civic, and lived knowledge.

1.1.1 Civic Science

ECS is rooted in scholarship on civic science, which focuses on science for the public good, conducted with and by community members on issues affecting community well-being (Bäckstrand, 2003; Derrien et al., 2020; Dillon et al., 2016). Civic science seeks to connect the institution of science to the public it is supposed to serve by engaging communities in defining problems, producing knowledge, interpreting evidence, and using findings for democratic action and civic decision-making (Derrien et al., 2020; Garlick & Levine, 2017).

Civic science differs from many citizen science models. In many citizen science projects, formally trained scientists determine the research questions and crowdsource data collection to members of the public. Civic science shifts this relationship. Community members, including youth, help identify issues, collect and interpret data, propose action steps, and use findings in relation to local policy and practice (Derrien et al., 2020; Dillon et al., 2016; English et al., 2018; Levy et al., 2021). This approach can increase the relevance of scientific questions, improve transparency and credibility in the knowledge-production process, and strengthen the likelihood that findings inform practice or policy (English et al., 2018).

Civic science also responds to a democratic challenge: scientific knowledge often shapes public life, yet many people are excluded from the institutions that produce and use that knowledge. For young people in particular, barriers include limited access to decision-making spaces and questions of legitimacy, including whether their ideas and evidence will be taken seriously. If young people do not feel qualified or are not recognized as credible participants, they are less likely to take part and speak up in civic processes (Kenis & Mathijs, 2012; Thew, 2018). ECS is designed to address these barriers by providing students with structured opportunities for intergenerational partnership, collective learning-action, engagement with local decision-makers, and participation as scientific investigators and advocates. In this way, civic science informs ECS's emphasis on community-defined inquiry, use of science for public purposes, and students' participation in environmental decision-making. ECS takes up civic

science pedagogically by positioning students not only as learners of scientific content, but also as contributors to public knowledge and community environmental action.

1.1.2 Science Agency and Critical Environmental Science Agency

Agency is central to this dissertation because it influences whether students view themselves as capable of addressing community issues and contributing to decisions that affect their lives. Science education scholarship has developed important constructs for understanding agency, including environmental science agency and critical science agency (Ballard et al., 2017; Basu et al., 2008; Schenkel & Calabrese Barton, 2020).

Environmental science agency refers to students' understanding of and identification with the natural environment, as well as their belief in their ability to address sustainability issues through inquiry, data gathering, and action (Ballard et al., 2017). Critical science agency extends this focus by emphasizing how youth use science learning to analyze and act on injustice. It foregrounds students' entitlement to voice, their use of science to challenge inequity, and their participation in individual and collective action for social change (Basu et al., 2008; Schenkel & Calabrese Barton, 2020).

Building on these constructs, I conceptualize critical environmental science agency (CESA) as young people's capacity and motivation to work collectively, use environmental science and civic knowledge, and participate in decision-making about socio-environmental and EJ issues in their communities. CESA is centered on decision-making, focused on collective action, and is justice-oriented. It is not only about whether students learn environmental science or take individual environmental action. It is about whether students develop the capacity to use evidence with others, understand power and responsibility, and participate in decisions that shape environmental conditions.

In this dissertation, I introduce CESA as a new theoretical construct and agency related student outcome. CESA builds on environmental science agency, civic efficacy, and sociopolitical control to name a form of agency needed for socio-environmental problem-solving in which scientific inquiry, civic/political participation, collective action, and justice are intertwined (Ballard et al., 2017; Basu et al., 2009; Schenkel & Calabrese Barton, 2020; Zimmerman, 1995). CESA has practical implications as an outcome of student learning because it helps to identify what educators should design for: students' competence, confidence, motivation, and perceived power to participate in community environmental decision-making.

CESA is conceptualized to develop through participation in relationships and practices with others. To develop CESA, young people need spaces and practices that enable them to work collectively on environmental challenges, experience their ideas and contributions as supported, and receive public recognition for contributions their group makes to the community. In this dissertation, CESA figures prominently as a student outcome of ECS because ECS explicitly seeks to create these conditions through local environmental investigation, peer collective action, intergenerational partnerships, and advocacy to decision-makers.

ECS and CESA serve different conceptual roles in this dissertation. ECS is the pedagogical framework, which includes the instructional process, practices, and relationships through which students investigate local environmental issues and participate in public action. CESA, by contrast, is a student learning outcome and analytic construct: it names the form of agency students may develop through participation in ECS.

1.1.3 Justice-Oriented Science Education and EJE

Justice-oriented science education critiques approaches that treat science learning as neutral, apolitical, or primarily aimed at assimilation into science as currently practiced (Bang et al., 2012; Vakil et al., 2022). It calls for pedagogies that center students' lived experiences and community knowledge, interrogate the purpose of science, question whose knowledge is recognized, and connect inquiry to collective action for social and environmental well-being (Calabrese Barton & Tan, 2018; Ladson-Billings, 2014; Schenkel et al., 2019). ECS shares these commitments, which shape its justice orientation.

Justice-oriented perspectives are essential to environmental education because environmental issues are embedded in histories of colonization, racism, disinvestment, and unequal distribution of risks and resources. Traditional discourses about individual responsibility and behavior change in environmental education can position young people's learning in ways that reinforce inequality rather than disrupt it (Dimick, 2015). EJE, by contrast, focuses on how environmental harms and benefits are distributed, how decision-making processes include or exclude communities, and what rights people have to participate in shaping environmental futures (Schlosberg, 2007; Walker, 2012; Mohai et al., 2009).

EJE calls for pedagogies that mirror the practices and principles of EJ (Tannock, 2021; Miles et al., 2025).These pedagogies should support youth in analyzing the social, economic, and political systems that uphold inequality; developing more nuanced understandings of how

societal-level decisions shape environmental issues; recognizing that political entities at multiple levels must be held accountable for healthy and sustainable environments; and participating in decision-making about the environmental conditions that affect their communities.

EJE also connects to critical consciousness. CC involves critical reflection on social conditions, analysis of systemic power, motivation to address injustice, and participation in action for change (Watts et al., 2011). In environmental contexts, CC requires students to understand environmental problems as socially, politically, economically, and historically produced. It also requires opportunities to act with others to address these conditions.

Although ECS is not positioned as an EJE curriculum, its emphasis on local inquiry, community engagement, decision-making, youth participation, and collective public action aligns with key EJE recommendations, EJ practice and the components of CC. This dissertation draws on EJ frameworks, EJE scholarship, and CC theory to examine how ECS creates pedagogical opportunities for students to reason about the justice dimensions of local environmental issues, including rights, access, accountability, governance, and structural inequality. This dissertation therefore examines both the promise and limits of ECS for supporting EJ learning and CC development.

1.1.4 Environmental Commons Theory

ECS is also informed by environmental commons (EC) theory which builds from the broader idea that communities share responsibility for the resources and systems that sustain life (Flanagan et al., 2019). EC theory treats environmental systems not as commodities or individual responsibilities, but as shared public commons that require democratic care and governance (Ostrom, 1990, 2010; Gallay et al., 2021). It draws on Elinor Ostrom's challenge to the inevitability of the "tragedy of the commons" and the characteristics of groups that make them effective in sustaining "common pool resources" that provide benefits to everyone but can be depleted if overused. Characteristics of effective commons-governing groups include proximity to the resource, identification with the group and its shared goal, and group dynamics marked by mutual respect, responsibility, communication, and trust (Cardenas & Ostrom, 2006).

EC theory includes both physical and political/social dimensions. The physical commons includes the natural systems and resources required to sustain life, such as water, air, land, and biodiversity. The political and social commons includes the public spaces, relationships, and democratic processes through which communities negotiate how those resources should be

protected, repaired, and shared. This framing matters for education because young people develop ideas about "the commons" through participation. When students engage in public environmental work, they learn to navigate different perspectives, find common ground, and take responsibility for shared resources (Flanagan et al., 2019; Gallay et al., 2021). They also learn that degraded environmental conditions are not inevitable or natural. They are shaped by decisions and therefore can be questioned, challenged, and changed.

ECS serves as a practical pedagogy informed by EC theory because it gives students opportunities to investigate shared environmental conditions and participate in public conversations and actions about these conditions. ECS applies commons theory to classroom practice by asking students to study local environmental conditions, collaborate with others, and contribute to community decision-making about shared resources. It also reflects key features of effective commons governance (Cardenas & Ostrom, 2006) by drawing students' attention to nearby environmental conditions and how they are affected by humans; emphasizing identification with a group and shared goal via a collective structure for learning and action; and supporting communication, trust, mutual responsibility, and attention to diverse perspectives through community engagement.

1.1.5 Integrating the Guiding Scholarship: ECS Design

ECS brings the abovementioned strands together as a pedagogical framework. Civic science contributes the idea that science should serve public problems and be shaped with communities, not only delivered to them. Environmental commons theory contributes the understanding that environmental resources are shared public goods whose care depends on collective responsibility and democratic governance. Justice-oriented science education contributes attention to whose knowledge counts, how science can reproduce or disrupt inequity, and how students can use disciplinary learning to address community problems. Finally, while not central in the development of ECS theory, science agency, EJE and CC scholarship clarify the kinds of student learning ECS is designed to support: students' capacity to see themselves as capable actors, recognize their rights to participate in environmental decision-making, analyze the structural foundations of socio-environmental conditions critically, and participate with others in efforts to change them.

ECS's four core elements- local environmental inquiry, collaboration with community partners, engagement with decision-makers, and collective public action- are the classroom

translation of these theoretical commitments. Local environmental inquiry grounds science in students' lives and places and creates opportunities for students to generate evidence about shared environmental conditions. Collaboration with community partners expands what counts as expertise by bringing together scientific and lived knowledge. Engagement with decision-makers makes governance, accountability, and institutional responsibility visible. Collective public action gives students opportunities to deliberate, communicate, and practice environmental decision-making and action with others in relation to environmental problems that affect their communities.

This integration matters because ECS is designed to move students from environmental awareness toward community environmental decision-making. In ECS, students do not only learn about water quality, flooding or pollution. They investigate how these issues affect people and places, learn who has responsibility or authority over them, and gather evidence of community conditions to advocate with others for change. In this way, ECS connects environmental science learning to civic participation and justice-oriented inquiry. The next section describes how these theoretical commitments were developed through a long-term research-practice partnership and translated into the ECS framework examined in this dissertation.

1.2 Environmental Civic Science: History, Framework, and Prior Research

ECS is the central theoretical and pedagogical framework examined in this dissertation. It sits at the intersection of environmental education, civic education, place-based education, science education, and justice-oriented pedagogy. It emerged from more than a decade of my work leading a research-practice collaboration among university-based researchers, classroom teachers, community-based organizations, informal educators, student participants, and the Southeast Michigan Stewardship Coalition (SEMIS), a regional leader in place-based education.

My past work as an environmental education practitioner, teacher professional development facilitator, educational coach, and leader of regional initiatives in justice-oriented place-based education and environmental action civics provided the initial foundation for ECS. This work eventually evolved into a research-practice partnership with the Southeast Michigan Stewardship Coalition (SEMIS), through which I coordinated research projects in K–12 schools and worked with a team to support and document these projects. Across these research projects, our research-practice team used observations, focus groups, interviews, reflective essays, and

pre/post surveys to document what educators and students did and learned through these experiences.

The theory and practice of ECS developed through these iterative processes. Insights were based on observing students engaging in place-based and justice-centered stewardship and reflecting on student outcomes (Gallay et al., 2016; Gallay et al., 2020). Early research examined students' understandings of the environmental commons, their capacity and motivation to collaboratively steward community environmental resources, and their beliefs about science, community contribution, and "green" STEM pathways (Gallay et al., 2021; Gallay et al., 2022; Gallay et al., 2024; Gallay et al., 2025).

This research provided a range of insights into what students were gaining from these experiences, including agency, collaboration skills, environmental knowledge, and community connections. However, this research also revealed the need for a more precise account of how students' learning occurred and what educational practices mediated it. Teachers enacted place-based stewardship and environmental action projects in different ways, and the field lacked a clear articulation of what the most important pedagogical elements were and what those elements looked like in practice. These efforts ultimately led to the development of ECS and its core elements as a theoretical framework for understanding and designing environmental learning that links inquiry, community partnership, collective action, and civic decision-making.

ECS developed as the research-practice teams' work increasingly focused on working with students and teachers in urban communities and pushed back against the idea that "nature" is located somewhere else, away from cities, schools, and neighborhoods. The justice focus in ECS developed through both theory and practice. Students were investigating issues such as flooding, drinking water, heat, pollution and green space. These issues are shaped by policy, public investment, institutional neglect, racialized and classed geographies, and unequal access to decision-making. These are not only environmental problems; their causes are also rooted in issues of justice.

Early iterations of ECS focused predominantly on direct-action projects, such as water quality investigation, air quality pollution awareness and prevention, stormwater management and mitigation, and urban green space development. These projects supported student agency and organizing, but tended not to explicitly address policy, governance, and decision-making. Over time, ECS evolved to have a greater focus on civic/political engagement, institutional

authority, and public advocacy. One reason for this shift was that socio-environmental challenges demand that “regular people” participate in environmental decision-making and governance because these complex crises cannot be solved by governments alone. To effectively tackle complex socio-environmental challenges, governance structures must evolve beyond top-down mandates. Incorporating "regular people" bridges the gap between academic/scientific expertise and community-level realities, ensuring policies are equitable, legitimate, and tailored to local lived experiences. From an epistemic perspective, students and residents have local knowledge about environmental conditions that agencies, textbooks, or scientific instruments alone may not capture. From an EJ perspective, communities most affected by environmental harms should have a meaningful role in defining problems and shaping solutions. From a governance perspective, public participation can make environmental decision-making more transparent, accountable, and responsive. ECS therefore evolved to make civic and political engagement more central, not as a replacement for direct environmental action, but as an extension of it. Direct action remains important, but systemic socio-environmental problems also require students to understand and engage the institutions, policies, and decision-making processes that shape environmental conditions.

1.2.1 The Four Core Elements of ECS

ECS is organized around four core elements: local environmental inquiry, collaboration with community partners, engagement with local decision-makers and collective public action with peers. Local environmental inquiry anchors learning in students’ own schools, neighborhoods, watersheds, and communities. This element draws from justice-oriented science education and environmental commons theory. It positions the local environment as a living context for inquiry and helps students connect abstract environmental concepts to observable community conditions. Local investigation also challenges the idea that meaningful environmental science happens only in distant wilderness settings or formal laboratories. Students learn that environmental science can be practiced in schoolyards, neighborhoods, streams, storm drains, drinking fountains, and community spaces. In ECS, local investigation also becomes a way for students to document environmental conditions that matter to their communities and to generate evidence that can be used to inform public decisions.

Collaboration with community partners connects students with community-based organizations, local experts, watershed educators, environmental advocates, municipal staff, and

other adults working on environmental issues. This element reflects civic science's commitment to community participation, EJE's emphasis on recognition, and environmental commons theory's focus on shared responsibility. Community partners help students understand that environmental knowledge is distributed across scientific, professional, local, and lived expertise. These partnerships also help students see environmental work as carried out by real people in their communities, not only by distant experts. Through these relationships, students encounter environmental problem-solving as intergenerational, collaborative, and embedded in community networks.

Collective public action with peers reflects the understanding that socio-environmental challenges are collective action problems. ECS asks students to work in teams, deliberate, divide responsibilities, build arguments, communicate publicly, and act together. This element draws from civic science, environmental commons theory and critical science agency. It helps students practice the "we" of democratic environmental action: listening, negotiating, finding common ground, and contributing to a shared public goal. Collective action is central to ECS because environmental challenges cannot be solved through individual behavior alone. They require people to work together, mobilize evidence, build shared commitments, and act in response to public problems.

Engagement with local decision-makers makes environmental "governance" visible. Students identify who has authority or influence over environmental issues in their schools and communities, such as facilities directors, school boards, municipal staff, or city council members. Students communicate with these audiences through call to action advocacy campaigns aimed at changing a policy or practice. This element distinguishes ECS from many forms of environmental education because it explicitly connects environmental inquiry to decision-making structures, accountability, and institutional change. It also supports CESA by helping students understand that environmental conditions are shaped through policy, infrastructure, funding, regulation, and public engagement.

Together, these elements organize ECS as an inquiry-to-action process. Students investigate local environmental issues, gather and interpret evidence, learn from community partners, identify decision-making pathways, and advocate to audiences based on evidence. ECS therefore provides both a theory and a pedagogical architecture for understanding and helping students move from environmental observation to civic participation.

1.2.2 Prior Research on ECS

Prior research on ECS including related civic science projects suggests that students can develop environmental knowledge, civic skills, community connection, and agency when they use science to contribute to community environmental action (Derrien et al., 2020; Flanagan et al., 2025; Gallay et al., 2021; Gallay et al., 2022; Trott et al., 2023). Earlier ECS work in partnership with SEMIS documented how students applied STEM learning through place-based action projects (Flanagan et al., 2024; Gallay et al., 2021; 2022). This work showed that ECS can support students' beliefs about the value of science and their own ability to contribute through science. This same work also suggests that ECS increases collective "eco-resilience" by giving students concrete pathways for action in the face of environmental uncertainty and eco- or climate anxiety.

However, overall, ECS scholarship is relatively limited. Existing studies offer promising preliminary evidence in support of its elements leading to desirable outcomes, but more research is needed on how ECS can be implemented across formal school disciplines, how its core elements lead to student learning, and what critical outcomes are associated with ECS experiences.

1.2.3 How ECS Differs from Related Educational Approaches

ECS pedagogy is related to environmental education, civic education/action civics, and justice-oriented science education but it is distinct in how it integrates these traditions. Like place-based education, ECS centers students' local communities as sources of knowledge and sites for contribution. Like environmental education, it supports environmental literacy and action. Like action civics, it emphasizes public participation and civic voice. Like justice-oriented science education, it asks whose knowledge counts and how science can be used to address inequity.

What distinguishes ECS is the integration of these commitments into a scientific-civic process directed toward influencing community environmental decision-making. In this way, ECS is related to existing pedagogical approaches advocated for across multiple disciplines but not reducible to any single one of them. ECS's contribution lies in how it synthesizes local environmental inquiry, community partnership, collective action, and institutional engagement into a theoretical framework and pedagogical process. ECS emerged from research and practice, was refined through exploratory research, and warrants deeper empirical investigation into how

it is enacted, what and how students learn from it, and what its justice learning affordances and limits are.

1.3 Gaps in the Literature and the Need for This Research

Although ECS shows promise, significant gaps in research about it remain. First, more research is needed on how ECS is enacted across formal school settings. ECS has developed through practice and research-practice collaboration, but there is limited empirical documentation of how teachers enact its core elements in different disciplines, how implementation varies by school context, and what those variations mean for student outcomes. This dissertation begins to address this gap by examining ECS praxis in high school science and social studies classrooms across multiple contexts.

Second, more research is needed on agency outcomes associated with ECS. Environmental education and justice-oriented science education both emphasize student agency and action, but less is known about how students develop agency specific to environmental decision-making contexts, where science practices intersect with civic participation, accountability, and decisions about shared socio-ecological systems (Ardoin et al., 2023; Delia & Krasny, 2018; Miles et al., 2025). This dissertation addresses this gap by developing CESA as a construct and examining it as an outcome of ECS. CESA contributes to theory by naming a form of agency that is environmental, civic, collective, justice-oriented, and centered on participation in decision-making.

Third, more research is needed on how participatory environmental learning supports EJ understanding and CC. EJE scholarship calls for pedagogies that help students analyze power, racism, classism, disinvestment, governance, and accountability. However, few empirical studies examine how participatory approaches enable EJ learning or how students come to understand environmental problems as justice problems in non-EJE classes (Guevara-Herrero et al., 2024; Miles et al., 2025). ECS may create important entry points into such understandings because it engages students in local environmental inquiry, community knowledge-gathering, decision-maker analysis, and public environmental action.

In sum, this dissertation addresses both theoretical and practical gaps. Theoretically, it advances understanding of ECS as a pedagogical framework and introduces CESA and explores whether and how EJ learning and CC can emerge through its participatory inquiry-to-action process. Practically, it examines student outcomes associated with ECS and offers guidance for

teachers, curriculum designers, and schools seeking to create learning experiences that prepare students for environmental decision-making and justice centered community environmental action.

1.4 Research Aims and Questions

Rather than asking whether ECS "works" in a general sense, the dissertation investigates how ECS is enacted, what opportunities it affords for learning, and what student learning outcomes are associated with participation. The purpose of this dissertation is to examine ECS as a pedagogical framework for supporting students' environmental civic learning, CESA, EJ understanding, and CC development in formal secondary schooling. Environmental civic learning refers to students' developing understanding of environmental issues as community and civic problems, including environmental knowledge, civic systems knowledge, collaboration, communication, and public problem-solving. CESA refers to students' capacity and drive to use environmental science and civic knowledge collectively to participate in community environmental decision-making. EJ understanding refers to students' reasoning about rights, access, distribution, recognition, participation, accountability, and ecological responsibility. CC refers to students' developing critical reflection, sociopolitical analysis, motivation, and action in relation to injustice. In this dissertation, ECS is the pedagogical framework studied; these outcomes are the forms of student learning and outcomes that ECS may support.

Accordingly, I answer the following research questions across three interrelated studies:
1. How are the core elements of ECS practiced in high school science and social studies classes, and how do variations in practice relate to student learning?
2. To what extent and in what ways do students develop and enact CESA through participation in ECS?
3. How do students express understandings of EJ and aspects of CC through participation in ECS and how does teachers practice afford these opportunities?

To answer these questions, I use a mixed-methods approach that combines quantitative measures of student outcomes before and after ECS participation with qualitative analyses of a range of data sources. These methods allowed for examination of ECS enactment, measurement and triangulation of ECS outcomes as well as of the ECS elements to which these can be attributed across select school settings.

1.5 Study Context and Methodological Approach

This dissertation is the culmination of a multi-phase project that developed and iterated the theoretical ECS framework and pedagogical process including through previously mentioned collaborations (Gallay et al., 2025; Gallay & Flanagan, 2026). In this collaboration, I acted as the coordinator of the research-practice team that has been studying what educators and students did and learned as part of ECS. In this role, I led theory and pedagogy development and iterative phases of implementation during the 2021–2022 and 2022–2023 academic years in an urban district serving primarily students of color from low-income families. Based on teacher and student insights, implementation planning meetings, ongoing reflections with teachers and community partners, and classroom observations, I worked with the research-practice team through ECS development, implementation, evaluation, reflection and refinement. This iterative work led to refinements to ECS inquiry-action theory, articulation of its core elements and development of curricular classroom materials aligned with secondary science and social studies standards, meant to guide ECS enactment.

This dissertation focuses on a later phase of implementation conducted during the 2023–2024 school. In this phase, ECS expanded to four high schools in Southeast Michigan, including one rural, one suburban, and two urban schools serving students in grades 9–12. This expansion allowed for examination of ECS across different contexts, subject areas, student populations, and teacher practices. To prepare teachers to enact ECS, I led teachers through professional development on ECS theory and practice. In this professional development, teachers experienced the ECS process as learners, participated in place-based inquiry, and worked with the project team to adapt ECS to their courses.

Across the four sites, and consistent with ECS, students investigated local water issues, collaborated with community partners, engaged decision-makers, and developed public-facing advocacy campaigns, referred to as “calls to action”, based on their analyses and evidence. Water served as the guiding entry point for student inquiry because it is scientifically, civically, and pedagogically useful. Water issues are locally observable in schools and neighborhoods through drinking fountains, stormwater systems, flooding, erosion, rivers, and infrastructure. They can be investigated with school-based tools such as mapping, observation, water testing, interviews, and document analysis. Water is also directly shaped by governance, infrastructure, funding,

regulation, and public accountability, making it a suitable environmental context for connecting science with civic decision-making.

The water focus also provided manageable boundaries for teacher learning and curriculum design. Because teachers came from different disciplines and had different levels of experience with place-based instruction, water created a shared starting point while still allowing for local adaptation. Importantly, while water was the entry point for inquiry, it was not a required endpoint for action. Students' calls to action could address broader environmental issues that emerged through their investigations, including infrastructure, flooding, heat, pollution, green space, and community environmental health. This flexibility reflects ECS's broader design: it can be organized around water, but it is intended to be transferable to other socio-environmental issues and community contexts.

1.6 Positionality

My positionality shaped this dissertation in important ways. I entered this work not as a detached evaluator, but as an environmental educator, professional development facilitator, curriculum designer, and regional partner who has spent years working with teachers, community organizations, and students on place-based environmental learning and action. I have personal, professional, and geographic ties to the region in which this study took place, including to communities shaped by deindustrialization, disinvestment, environmental contamination, flooding, and aging infrastructure. These experiences informed my commitments to environmental justice, youth participation, and community-centered education.

This positionality strengthened the research in several ways. It gave me access, trust, and contextual knowledge that strengthened the research. It helped me recognize the significance of local histories, community relationships, teacher decision-making, student comments and local environmental issues that might have seemed ordinary or incidental to an outside observer. It also shaped the development of ECS itself, because ECS emerged through long-term work with educators, community partners, and students rather than through a purely external design process.

At the same time, my closeness to the work created methodological responsibilities. Because I helped design, facilitate, support, and study ECS, I could not treat myself as a neutral observer of implementation. My presence may have shaped teacher enactment of ECS, student engagement, and my interpretation of the results. To address this, I used multiple forms of data,

including observations, teacher logs, planning artifacts, student reflections, surveys, focus groups, and student artifacts. I also engaged in ongoing analytic memoing, discussion with the research-practice team, and triangulation across data sources. Rather than attempting to erase my positionality, these practices helped me make it visible and accountable within the research process.

1.7 Dissertation Outline

This dissertation is written in a three-paper format. This chapter, Chapter 1, introduces the overall dissertation, including scholarship and practice that influenced the development of ECS along with research needs leading to my overarching research questions and methods. Chapters 2 through 4 are designed as stand-alone, publishable manuscripts and are written for the purpose of submission to The Journal of Environmental Education, Journal of Research on Science Teaching and Environmental Education Research respectively. To ensure that each manuscript is self-contained, some background and methodological information appears across chapters. In combination, however, the chapters build a cumulative argument: ECS offers a theoretical, yet flexible inquiry-to action framework that can support students' environmental civic learning, CESA, EJ understanding and CC development when implemented in formal school contexts.

Chapter 2 examines how ECS was implemented in high school science and social studies classrooms and how students experienced its core elements. Using a qualitative comparative case-study approach grounded in participant observation, the chapter analyzes how three Michigan high school teachers adapted ECS across biology, world history, and earth science. Qualitative data, including classroom observations, teacher logs, planning artifacts, student reflections, focus groups, and student work, are used to document implementation and to examine students' environmental civic learning. Findings suggest that ECS can be enacted flexibly across disciplines while maintaining a shared inquiry-to-action arc. Students experienced ECS as more immersive, relevant, and empowering than typical instruction because they engaged in firsthand local investigation, worked with peers and community partners, and advocated to authentic audiences. Accordingly, the chapter argues that ECS supports environmental civic learning most strongly when local inquiry, community partnership, decision-maker engagement, and public advocacy are connected.

Chapter 3 presents a mixed-methods comparative study examining CESA as an agency-related outcome associated with ECS participation. The chapter introduces CESA as a theoretical construct and investigates whether and how ECS participation was associated with students' development and enactment of CESA. Quantitative analyses examine four CESA-aligned dimensions: environmental action, competence to address community water issues, sociopolitical control, and capacity to take action for environmental change. Students who participated in ECS showed statistically significant gains in these dimensions while those n comparison classes did not. Qualitative data are used to triangulate and explain these outcomes by showing how students enacted and expressed CESA through local community monitoring and data gathering, identification of pathways for civic engagement, decision-maker engagement, and collective planning and public advocacy. The chapter argues that CESA should be a central outcome of science teaching and learning, particularly in relation to socio-environmental challenges.

Chapter 4 explores ECS as a participatory educational approach that can support EJ understanding and CC development, especially in classrooms not primarily designed as EJ courses. Drawing on EJ frameworks, EJE scholarship, and CC theory, the chapter examines how ECS created opportunities for students to reason about water as an EJ issue, critically reflect on water issues and take critical collective action. Qualitative analyses of student reflections and classroom observations show that ECS appeared to support multidimensional EJ understanding and emerging CC by positioning students as community observers, knowledge producers, and civic actors; making environmental governance visible; centering community expertise; and structuring opportunities for public action. Students named understanding water issues as issues of rights, access, governance, and accountability while reflecting on the sociopolitical causes of these issues. At the same time, students did not name environmental racism or their rights to participation, indicating that participatory inquiry alone may be insufficient for robust structural EJ analysis. The chapter argues that ECS's justice-oriented potential is likely to depend on teacher praxis that explicitly connects local inquiry to racism, classism, historical disinvestment, governance, and power.

Chapter 5 synthesizes findings across the three studies and articulates the dissertation's theoretical and practical contributions. It discusses how ECS advances scholarship on environmental civic science, CESA, and EJE. It also synthesizes empirical evidence into design

considerations for ECS practice, including structuring inquiry around local environmental conditions, building sustained community partnerships, making governance and decision-making visible, supporting collective learning-action, and designing public advocacy for authentic audiences. The chapter concludes by outlining implications for teacher preparation, curriculum design, professional learning, and future research on participatory, justice-oriented environmental education.

Table 1.1 Key Concepts and Outcomes, clarifies how key concepts are used across the dissertation and where environmental civic learning, CESA, EJ understanding, and emerging CC are the student outcomes examined across the three studies.

Concept	Role in dissertation	What it refers to	Where examined
ECS	Pedagogical framework/ process	The instructional design: local inquiry, community partnerships, decision-maker engagement, collective public action	Chapters 2–4
Environmental civic learning	Student learning outcome	Students' understanding of environmental issues as community and civic problems, includes: environmental knowledge, civic systems knowledge, collaboration, communication and public problem-solving	Chapter 2
CESA	Student outcome/analytic construct	Students' capacity and drive to use environmental science and civic knowledge collectively to address socio-environmental and EJ issues	Chapter 3
EJ understanding	Student learning outcome	Students' learning and reasoning about rights, access, distribution, recognition, participation, accountability, and ecological responsibility	Chapter 4
Critical consciousness	Student learning outcome/process	Students' critical reflection, sociopolitical analysis, motivation, and action in relation to injustice	Chapter 4

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Chapter 2 "I Learned That We Can Actually Make a Difference in Our Community": Environmental Civic Science Praxis

2.1 Abstract

This article examines Environmental Civic Science (ECS) as a pedagogical framework that integrates scientific inquiry with civic engagement by positioning students as community actors. Using a comparative case study design, the study investigates how three Michigan high school teachers implemented ECS across 11 classes (N = 253) in science and social studies and how students experienced and learned through four core ECS elements: (1) a local environmental/water issue focus, (2) collaboration with community partners, (3) engagement with local decision-makers, and (4) collective public action with peers. Data sources included ethnographic field notes, teacher logs and planning artifacts, student written reflections (n = 170), student focus groups, and student artifacts. Findings show that ECS was implemented flexibly across disciplines while maintaining a common inquiry-to-action arc anchored in place-based inquiry, intergenerational learning, collective learning-action, and public-facing advocacy. Across cases, students described ECS as more immersive, relevant, and consequential than typical instruction, citing firsthand local investigations, teamwork, community partnerships, and public communication and advocacy as reasons. Reported learning outcomes extended beyond environmental content to environmental civic learning. This included strengthened collaborative, scientific and civic skills, expanded civic systems knowledge, increased public voice, a sense of care and responsibility for their community and environment and heightened civic efficacy. Impacts were most salient when locally grounded inquiry culminated in advocacy to decision-makers with authority or responsibility related to the issue, making student efforts feel more consequential. This study provides evidence of ECS features that appeared to support these outcomes and discusses implications for environmental, civic, and science education and educators and researchers seeking to cultivate students' capacity for community environmental decision-making.

2.2 Introduction

Transformative change toward a just and sustainable future depends on an engaged populace that actively addresses socio-environmental challenges within their own communities. Although participatory approaches involving residents are frequently recommended for municipal decision-making around sustainability, they are rarely implemented in practice (Zint & Wolske, 2014). Developing a populace equipped to contribute meaningfully to their communities is a developmental process, nurtured through collective action and real-world participation. Education is central to this endeavor; it requires models that prioritize collaboration, foster scientific and civic dispositions, integrate environmental and civic literacy across disciplines, and connect learning with civic engagement that influences local policy and practice. Environmental Civic Science (ECS) offers such a framework, demystifying science and civics as fields reserved only for professionals or "experts" by directly engaging students in environmental inquiry and civic action.

In this paper, I present findings from a comparative case study (Amaral, 2022), investigating Environmental Civic Science (ECS) as a pedagogical approach that holds potential to cultivate students' capacity and motivation to contribute to community environmental wellbeing. I detail the core elements of ECS (local environmental/water issue focus; collaboration with community organizations; collective public action with peers; and local decision-maker engagement) examining how high school teachers adopted these elements across different subject areas, analyzing both the unique characteristics of each teacher's practice and the common trends across teachers and student outcomes that emerged. Specifically, I address the following research questions: (1) In what ways is ECS practiced in high school science and social studies classes? (2) How do students experience the core elements of ECS? and (3) How does the practice of ECS and its core elements relate to and impact student learning? Findings highlight essential ECS practices and associated student impacts, demonstrating how ECS can foster collaborative decision-making skills and environmental civic action while valuing students' local knowledge. I use environmental civic learning as an umbrella term for the student outcomes students described through ECS participation. This includes environmental understanding, civic systems knowledge, collaboration science and civic skills, community responsibility, public voice, and emerging civic efficacy. I conclude by discussing the

implications of ECS for students' participation in community environmental decision-making and consider ECS' broader significance within movements for participatory environmental science and civic education.

2.2.1 Background

Today's youth face environmental challenges at every scale, and experience firsthand the impacts these problems have in their communities. Supporting young people in developing the capacity to address environmental challenges and enabling their participation in local decision-making and action toward community goals should therefore be a critical educational and societal priority. To meet this need, pedagogies must support the development and practice of scientific and civic literacy (i.e. knowledge, skills, and competencies) for real-world problem-solving, emphasize collective action, and empower youth as change-makers.

Despite national standards in both social studies and science that highlight overlapping competencies (National Council for the Social Studies, 2013; National Research Council, 2013), there has been little integration of scientific and civic literacy in formal education. Yet, addressing socio-environmental challenges requires inter-disciplinary and collaborative approaches that link scientific inquiry with civic responsibility (Ardoin et al., 2023; Mueller & Tippins, 2012; Schusler & Krasny, 2015), making it essential for environmental education (EE) to move beyond isolated science classes, support teamwork, and engagement across disciplines. This shift is necessary not only for cultivating scientific understanding but also for developing civic competencies and strengthening community networks among youth.

While both science and environmental education can cultivate "environmental citizenship," actual practice often falls short in promoting collective decision-making and active participation (Hadjichambis & Reis, 2020; Parra et al., 2020). EE has always aimed to foster environmental literacy by incorporating knowledge, skills, attitudes, and participation for environmental change (UNESCO, 1978). However, the field has prioritized individual behavior change rather than collective action for systemic impact. Recent calls within the field highlight the need for research on action-oriented learning through community-based and participatory approaches (Sezen-Barrie et al., 2025), with a focus on strategies that empower learners as agents of transformative change who address environmental challenges through shared responsibility and collaboration. Scholars have pointed out a lack of understanding regarding

"how and under what conditions" school-based EE relates to student outcomes, signaling an urgent need for empirical research (Ardoin et al., 2023). Despite EE's potential, a critical gap remains in the literature: few empirical studies have examined how educational experiences foster youth's civic engagement in environmental contexts, how curricula can be intentionally designed to build both scientific knowledge and civic agency in youth, or how participatory and critical pedagogies influence their attitudes and behaviors (Caeser, 2013; Gyles, 2024; Levy & Zint, 2013).

Environmental Civic Science (ECS) offers a promising interdisciplinary approach, one in which students apply scientific methods and knowledge to real community issues, developing the shared skills and dispositions needed for both scientific practice and civic engagement. Although the theory and conceptualization of civic science (CS) has expanded in recent years (Bäckstrand, 2003; Flanagan et al., 2022; Garlick & Levine, 2017; Levy, Oliveira, & Harris, 2021), there is limited associated empirical research. More specifically, there is a critical lack of studies exploring how ECS impacts student learning or how its core practices (e.g., community engagement, participatory action, and advocacy), are experienced by students (exceptions include Derrien et al., 2020; Flanagan et al., 2025; Trott et al., 2024).

This study aims to help fill this critical gap and respond to calls for research in curriculum design that empowers students to engage in meaningful environmental and civic change (McNeill & Vaughn, 2014; Derrien et al., 2020; Trott et al., 2023) by providing empirical evidence of how ECS is enacted in high school science and social studies classrooms. It demonstrates how students can actively engage with local environmental issues, collaborate in participatory research, and develop both environmental literacy and civic competencies through the core elements of ECS. By doing so, this study contributes to both knowledge and practice by illuminating pathways for integrating environmental action and civic agency into high school curricula.

2.2.2 Environmental Civic Science

Environmental Civic Science (ECS) is an interdisciplinary pedagogical approach that integrates scientific and civic literacy and empowers learners to investigate, understand, and act on environmental challenges within their communities (Ballard et al., 2017). Unlike traditional

models where students are passive recipients of knowledge, ECS positions students as active "co-producers" of scientific and civic understanding. It emphasizes science as a tool for the public good, values students' unique community knowledge as an essential asset, and recognizes the iterative and inclusive nature of scientific inquiry, highlighting the importance of diverse perspectives and student motivation to serve their communities. By integrating environmental inquiry, civic agency, and community engagement, ECS fosters both scientific literacy and democratic participation, transforming the classroom into a space for real-world environmental problem-solving.

2.2.3 Foundational Underpinnings

In ECS, students take the lead in identifying environmental issues, collecting and interpreting data, and translating their findings into action, including advocacy to address socio-environmental challenges (Flanagan et al., 2021; Gallay et al., 2022; Trott et al., 2024). The theoretical foundations of ECS are grounded in civic science, which emphasizes science for the public good and local well-being through a community-based approach. This means that community members rather than external "experts", decide on issues of importance and methods to achieve results (Bäckstrand, 2003; Dillon et al., 2016). ECS also builds on key work in political science regarding the management of common pool resources, challenging the notion that citizens should be passive observers and instead highlighting their essential role in the design and implementation of public policy, particularly with respect to democratic participation in environmental decision-making (Ostrom, 2010; 2012; 2015).

ECS is related to and informed by several interconnected strands of educational theory and practice, including action competence and empowerment in environmental education (Hungerford, 2010; Jensen & Schnack, 2010), civic ecology (Tidball & Krasny, 2010), youth civic and political development (Flanagan, 2013), action-oriented education (Sass et al., 2025) education for environmental citizenship (Hadjichambis & Reis, 2020), place-based education (Lowenstein & Smith, 2017), and eco-justice education (Martusewicz et al., 2015). For example, Education for Environmental Citizenship encourages students to engage actively in community action as part of their roles as citizens (Parra et al., 2020), reflecting ECS's goal of cultivating the knowledge, skills, and mindsets needed for real-world problem-solving. Likewise, action-

oriented education for sustainability emphasizes inquiry-based engagement and partnerships with diverse stakeholders, which are hallmarks of ECS practice (Sass et al., 2025).

Community-driven and justice-oriented science education (Calabrese-Barton & Tan, 2020; Calabrese-Barton & Upadhyay, 2010; Schenkel et al., 2019) also inform ECS as they center students' voices, lived experiences, and local knowledge as essential resources for democratic engagement. Justice-oriented science scholarship, like ECS, questions the social purposes of science and advocates for educational approaches that reveal power imbalances, explicitly connects science learning to action, and empowers students to understand science concepts while also motivating them to address community issues they identify (Bang et al., 2012; McNeil & Vaughn, 2012; Schenkel et al., 2019).

2.2.4 ECS Praxis: Core Elements and Programmatic Theory of Change

Four central elements make up the ECS framework, intended to guide learning from investigation to advocacy and support transformative student outcomes (Gallay et al., 2025; see Table and Figure 1):

1. Local Environment Inquiry Focus: Students investigate human interdependence with their local ecology, contextualizing environmental issues within their immediate community.
2. Engagement with Local Decision-Makers: Students consider questions of power and influence, identifying who makes decisions in their schools and communities (e.g., facilities directors, superintendents, government officials), and learn how to engage these stakeholders to assert their right to effect change.
3. Collective Public Action with Peers: ECS models civic engagement as inherently collective, providing students with authentic opportunities to work together to address community challenges.
4. Collaboration with Community Partners: Students extend their civic work beyond their school, partnering with local organizations and community members who are actively involved in environmental issues.

These elements manifest through distinct ECS practices:

1. Place-Based Inquiry: Learning is anchored in students' everyday environments, highlighting human-nature interactions and the social landscape as living laboratories.

2. Intergenerational Learning: Collaboration with local experts, community organizations, and policymakers enriches research and fosters authentic civic action.
3. Collective Learning-Action: Students gather data to inform their positions, acting as stewards and advocates, developing competencies, including confidence to influence local policy and practice.
4. Public Advocacy: Culminating in advocacy campaigns and presentations, students communicate their positions and proposals for change to decision-makers and community members, contributing meaningfully to community dialogue and action.

Table 2.1 Core elements of ECS

	Core Elements			
	Local Environmental Issue (Water) Focus	**Engagement with Local Decision-Makers and Environmental Policy/Practice**	**Collective Public Action with Peers**	**Collaboration with Community Partners**
Overview	Learn about water systems & watersheds and connect them to human-environment interdependence	Learn about local decision-makers, connect with local officials and staff to demystify community policy and practice change	Work with peers on project teams, learn how to work in teams, deliberate and act together in the public sphere	Community stakeholders work with teachers and students in their investigations and support students in their action projects
Core Concepts	-Water issues include land, water, & ecosystems -Policies, and management impact community health and thus require public input -Water issues are a justice issues	-Focus on local decision-makers -Government's job is to work in communities' best interest -Students have the right to hold leaders accountable	-Civic work is done by people working together -Democracy is about people deciding together -Working in teams necessitates collaboration -We all have the right to voice community decisions	-Addressing issues requires engaging with community stakeholders -Young people need opportunities to connect with community -Community Based - Organizations are drivers of civic life
Core Skills	Knowledge about water issues; observing, monitoring, research, analyzing	Researching, analyzing; communicating,	Listening, perspective-taking, deliberative skills; Persuasive communication and advocacy	Perspective-taking, communication; listening and

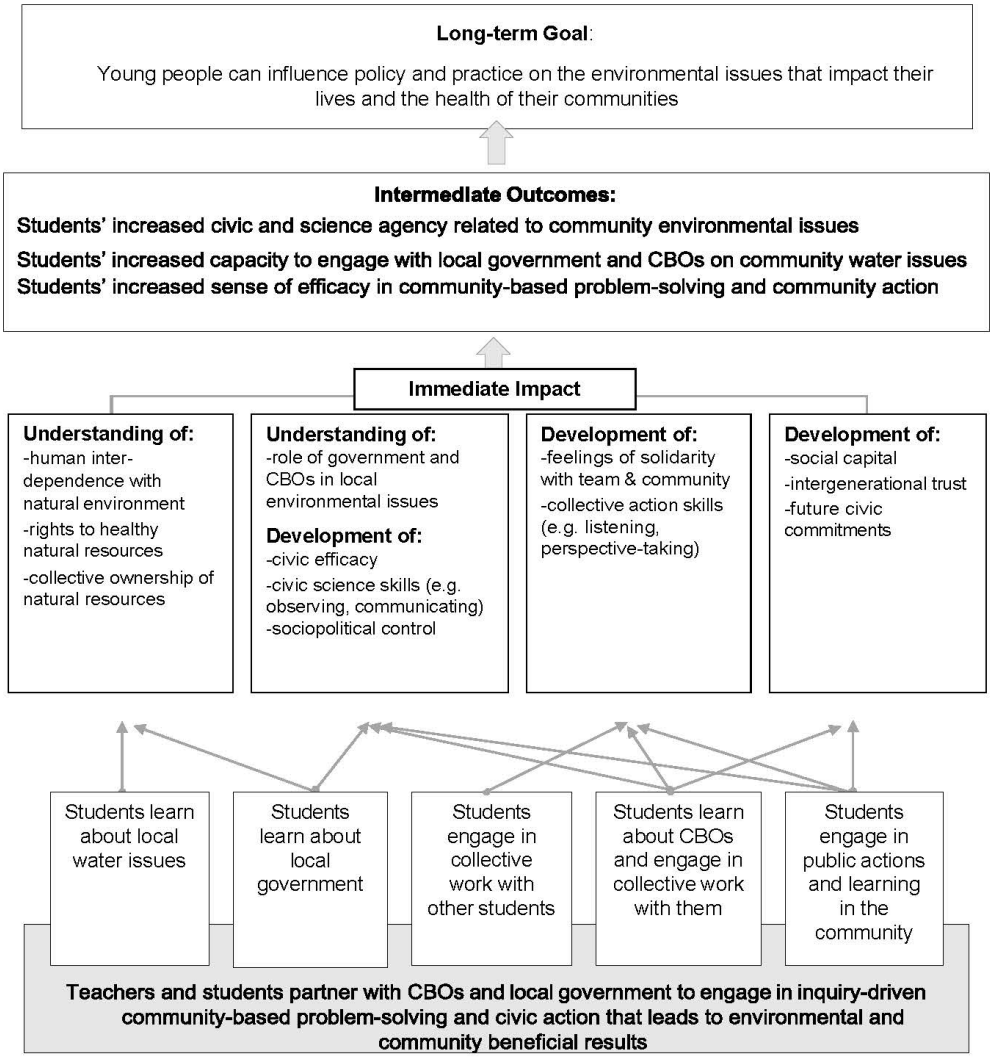
				community engagement
Student Outcomes	-Understand relationship between water and community well-being -Identify with and feel responsible for stewarding their community's natural systems	-Understand role of government/decision-makers in local environmental issues -Understand how to work with/persuade officials -Civic efficacy	-Feelings of solidarity with their team and larger community -Agency	-Understand community engagement, how to mobilize residents -Social capacity, sense of community, intergenerational trust, and civic intentions
Example Activities	MyMaps; community eco-strolls; online research activities	Mapping local officials; meeting with local officials	Working in teams; self-reflection on team participation; crafting and communicating calls to action	Community asset mapping; partner presentations (watershed overview, care webs)

In the ECS programming described here, students worked collectively in peer teams and collaborated with adults from community-based organizations (CBOs) to identify and investigate environmental issues (specifically water concerns) impacting their communities. They gathered and interpreted relevant scientific and civic information, learned about and interacted with local government and environmental policies, determined solutions, and engaged in advocacy through public forums and calls to action with decision-makers. In the case studies presented, I partnered with teachers and CBO partners, who received training in the ECS model, to guide high school classes through an iterative ECS process. While all classes incorporated each ECS framework element, teachers varied in their approach to ECS praxis. Lessons covered topics such as water quality and pollution, urban land use, human impact, and green infrastructure; collecting, analyzing, and mapping scientific and community data; interacting with local government agencies affecting water policies; mobilizing community action; and developing action campaigns for policy and practice change.

The long-term goal of ECS programming was to empower young people to influence policy and practice on environmental issues affecting their lives and community health. Grounded in the understanding that local government policies and the efforts of community

environmental organizations shape environmental conditions, and that scientific and civic literacy are complementary skills for civic participation, the intermediate goal of ECS was to provide experiences that enhance students' capacities, including efficacy to engage with local decision-makers and community organizations regarding environmental policy and practice (see Figure 1).

Figure 1 Environmental Civic Science Theory of Change



2.3 Methods

This research employs a community-based participatory action research (CBPAR) framework, aligning with the recommendations of equity and community engagement scholars

who advocate for research conducted in partnership with local stakeholders, grounded in the lived experiences of the community (Calabrese-Barton et al., 2020; Lau & Stille, 2014; Israel et al., 2012). By centering collaborative knowledge generation, this approach aligns with constructivist epistemology and situates researchers, teachers, students, and community members as co-investigators in the educational process (Ültanır, 2011).

Prior to the study presented here, the ECS curriculum and its theoretical foundations were developed and iterated by a project team composed of classroom teachers, community-based informal educators, university researchers, student participants and leaders of a regional place-based education coalition. This collaborative partnership extended across curriculum design, professional development, implementation planning, with engagement including co-curricular development meetings, bi-weekly reflective team sessions, co-teaching, and joint observation and interpretation of classroom activities and student artifacts.

This foundation enabled my ethnographic approach and participant-observer role (Atkinson & Hammersley, 1998).as I participated in ECS implementation while documenting classroom interactions, conversations, and learners' experience as well as associated social and political contexts (Gay et. al., 2011). I was present in classrooms, co-planning ECS implementation with teachers and community educators, supporting and occasionally leading ECS activities as needed. By spending significant time participating in the program developing relationships with students and cementing trusting relationships with educators, this role allowed me to closely observe and document ECS practice in action, providing rich insight into how teachers facilitate its implementation and how students experience its elements. I had close access to the everyday enactment of ECS, but I also recognize that due to my participant-observer role, my presence and facilitation may have shaped what occurred. I therefore treat the findings as interpretive and contextually grounded rather than as detached or fully generalizable accounts of ECS implementation.

This study focuses on how three high school teachers implemented the core elements of ECS across different subjects, analyzing both the unique characteristics of implementation of the core elements across cases and examining multiple instances of environmental civic science in real-life contexts (Gall et al., 2010). I use a collective case study approach (Amaral, 2022; Gall et al., 2010) to address three research questions: (1) In what ways is ECS praxis applied in high school science and social studies classes? (2) How do students experience the core elements of

ECS? and (3) How does the practice of ECS and its core elements relate to and impact student learning?

2.3.1 Research Context and Sample

For this case study analysis, I focus on three teachers from three schools, who taught 11 classes and a total of 253 students in grades 9–12 (Benson HS: n=128; Community Area HS: n=25; South Central HS: n=100). The cases were intentionally selected for their contrasting contexts: the schools represent suburban and urban districts in Southeast and South-Central Michigan; student populations are demographically diverse; and teachers reflect a range of experience levels and disciplinary backgrounds. The participating teachers taught earth science, biology, and world history, with courses spanning basic to AP/honors levels. I worked with district partners to recruit teachers, whose baseline familiarity with water and environmental issues ranged from novice to moderate. One teacher, Mr. Z, was part of the iterative development team, and thus had prior experience with ECS, while the other two were new to both ECS as well as place-based instruction. ECS was either woven into their regular curriculum or implemented as a supplemental project.

Prior to implementation, all teachers participated in a five-day ECS summer institute, which I co-planned and co-facilitated with project partners. The institute covered place-based pedagogical practice and ECS theory through fieldwork, stakeholder interviews, data mapping, and community engagement strategies. I supported each teacher in adapting ECS to their unique context, subject area, and comfort level while following the core elements and objectives of ECS praxis. All project activities occurred during regular school hours, meaning students did not self-select into the program and participation was not based on prior interest in ECS content.

Student demographic data indicate a diverse sample across the three cases, though diversity varied within each school. South Central HS had the most homogenous student group, with most participants in 9th grade (63%) and the remainder in 10th grade (37%). Among these students, 57% identified as female, 42% as male, and 1% reported a different gender identification. The majority self-identified as white only (76%), while 17% selected multiple race/ethnicities, and 1% each identified solely as Black, Latine, or American Indian/Native Alaskan. South Central also had the highest proportion of “economically disadvantaged” students, as 45% were eligible for free or reduced lunch.

Benson HS students represented a more diverse group. Most were 10th graders (82%), with 11th graders (12%), 12th graders (4%), and a small percentage of 9th graders (2%). Female students comprised 53%, male students 44%, and 3% selected another gender identification. Forty-four percent self-identified as white only, 26% as Black, 18% selected multiple race/ethnicities, 5% as Latine, and 4% as Asian American. Benson HS served a majority (>60%) of "economically disadvantaged" students.

Community Area HS represented students in the highest grade levels: 12th graders (53%) and 11th graders (47%). Female and male students each made up 47% of the population, with 6% selecting another gender identification (although there was only one student in this category). Most students (47%) self-identified as Black only, 18% as Latine only, 12% as White only, and 24% identified with multiple race/ethnicities. Like Benson HS, Community Area HS served a majority (>60%) of "economically disadvantaged" students.

2.3.2 Data Sources and Collection

Data for this study were gathered from multiple qualitative sources to triangulate perspectives and strengthen validity. I used ethnographic field notes to capture observed moments of learning and teachers enactment of ECS core elements. Two additional members of the research practice team observed and took field notes of ECS classroom sessions/activities led by teachers and community partners and presentations of students' advocacy campaigns to stakeholder audiences, with the combined three-person observation team documenting roughly 70 sessions. Consistent with ethnographic participant-observation and case study classroom research, which emphasizes rich description to capture contextual uniqueness and to avoid prematurely deciding "what matters," we utilized unstructured, open field notes focusing on descriptive observations (Frankham & MacRae, 2011; Atkinson & Hammersley, 1998). Spradeley, 1980: Stake, 1995) and met regularly as a team to discuss observations. Teacher activity logs and planning documents/notes recorded instructional decisions, adaptations, and reflections. They also served as an implementation validity checklist to measure fidelity of implementation of the ECS elements based on common criteria including: dosage, adherence to delivering components as intended, and differentiation (Buckley et al., 2017). Students' post-project open-ended survey reflection questions provided insight into perceived changes and learning outcomes, with 170 students (Benson HS: n=53; Community Area HS: n=21; South

Central HS: n=96) submitting written reflections on how ECS differed from their usual science or social studies classes and what they considered the most important learning outcomes. (Question prompts: What are some ways this way of learning was different from other science or social studies classes you have taken; In your opinion, what are the most important things you've learned and why do you think they're important). Additionally, I conducted focus groups (n=39), with a subset of students discussing their experiences and perceptions of the pedagogical practices and documented student responses via audio recordings and photographs of class generated discussion notes.

Because this study asks how students experienced ECS and their perceptions of what they learned through its core elements, student reflections and focus groups were central data sources. These data sources provided direct access to students' interpretations of their experience: what they noticed, valued, found meaningful, and believed they learned. This was important because some forms of learning central to outcomes of ECS, such as feeling heard by adults, seeing local issues as relevant, or understanding one's work as consequential, are not always visible through observation alone. For example, an observer can document that students interviewed peers or presented to decision-makers, but students' reflections help explain whether those experiences felt empowering, confusing, relevant, or consequential.

At the same time, reliance on student perceptions has limitations. Reflections and focus group responses may be shaped by recall, the wording of question prompts, or students' desire to describe the project positively. For this reason, I used classroom observations, teacher logs, and planning documents to contextualize and triangulate students' accounts. Observation notes and teacher logs were used in two main ways. First, they documented implementation of the ECS core elements in each classroom, including the activities and practices teachers used to enact each element, forms of teacher facilitation, community partner involvement, decision-maker engagement, and public advocacy. Second, they helped contextualize student reflections by linking students' statements to specific classroom experiences and illuminating how students interpreted those experiences. For example, when students referenced advocating to "people in charge," teacher logs and field notes helped clarify whether those audiences included school administrators, board members, city staff, facilities personnel, or community partners. In this way, observations and logs connected students' perceptions to documented implementation.

2.3.3 Analysis

Analysis followed an iterative coding process, moving between field notes of observations, teacher logs/planning documents, student reflections and focus group transcripts/notes to generate and refine themes (Kushnir, 2025). Across data sources, I used indictive and deductive approaches and multiple rounds of reading, memoing, team discussion, theme generation and code refinement.

First, I created chronological descriptive summaries of ECS implementation in each teacher's classes. These summaries drew from field notes, teacher logs, and planning documents and described the implementation of ECS activities, including local inquiry, community partner involvement, decision-maker engagement, collective work, and public advocacy. Second, I applied a deductive framework based on the four ECS core elements to examine how each teacher enacted ECS. Open coding was used to interpret ECS praxis across classrooms and surface emergent themes. This stage helped establish that all three cases included the core elements while also showing variation in how those elements were emphasized and connected.

Coding of student reflections and focus group data then began with open coding to identify how students described their experiences and learning. Initial codes included firsthand/local experience, hands-on learning, relevance, teamwork, public speaking, being heard, community connection, community partners, human impact/interdependence, using/applying science, science understanding, confidence, collective efficacy, action, and real-world impact. I compared these codes across cases and organized them into broader environmental civic learning themes: environmental understanding, civic systems knowledge, collaborative civic skills, public voice and efficacy, and community connection. I then returned to field notes, teacher logs, and artifacts to examine which implementation features appeared to support these themes. Multiple cycles of coding and theme development allowed for further refinement of themes, helping to clarify categories and explain patterns in the data, and ultimately to identify practices and program characteristics most influential on student outcomes,

Finally, I interpreted my findings through cross-source triangulation and cross-case comparison. For example, the claim that authentic audiences mattered was supported by student reflections about presenting to "people in charge," field notes documenting who attended public presentations, and teacher logs describing follow-up responses from school or municipal officials.

2.4 Results

I present results following the three teachers' implementation of ECS chronologically. Within each case study, I categorize implementation under each of the four core elements of ECS and highlight how each teacher took a different approach in their praxis. Data sources are noted in the case studies by the abbreviations FN (field notes of observations), SR (student reflection), SFG (student focus group) and TL (teacher log/planning notes). Quotes are presented verbatim from the source, unless doing so obscured the meaning.

2.4.1 Case Study 1: Environmental Civic Science in Freshman Biology Classes- A Focus on Student Driven Inquiry and Investigation, Collective Learning Action with Peers and Call to Action Demands

At South-Central High School, a suburban campus in South-Central Michigan, Mr. G reimagined his required freshman (ages 14-15) biology course as the site for Environmental Civic Science (ECS), centering student inquiry, collaboration, and public-facing advocacy.

2.4.1.1 ECS Element: Local Environment Focus; ECS Practices: Place-based Inquiry.

ECS in Mr. G's classes began with students making personal observations about water in their neighborhoods and sharing their existing knowledge of these issues. To broaden the context, Mr. G and I presented local water-related challenges such as flooding, contamination, and concerns raised in Benson's city Environmental Action Plan (FN).

A particularly formative practice, noted by all four of Mr. G's classes (SFG), was the "ecostroll." During these campus explorations, students observed water issues first-hand, guided by targeted questions about topics like impermeable surfaces, evidence of erosion, low areas prone to flooding, and stormwater infrastructure. They discovered a pond that "looked dirty," blocked drains, litter, and flood-prone fields. Students catalogued these observations and the places of personal significance using Google My Maps, grounding their learning in the geography of their own lives (FN). The impact of these field investigations was evident in student feedback and reflections. Themes such as "being outside," "touring campus," "seeing for ourselves," and "first-hand experience" consistently emerged as making the experience especially meaningful (SR; SFG). One student remarked that it "made us be more observant," (SR) suggesting a shift in how they viewed their surroundings, even beyond the coursework. Other students emphasized the value of applying scientific and civic practices in their

community (SR): “We would actually go out and look at the examples of what we were studying, rather than just sitting around listening about it.” Another noted (SR), “It … allowed me to apply the things I learned first-hand.” The importance of local relevance was also clear to students in comparison to their standard coursework as captured by the student who stated (SR): “We never research stuff around Benson. It's always the bigger picture.”

2.4.1.2 ECS Elements: Collaboration with Community Partners; Engagement with Local Decision-Makers and Environmental Policy.

Student-driven inquiry extended to investigating the systems and people behind school water decisions. My role as a participant observer, being at the school, present and aware, allowed me to discover federally mandated drinking water quality reports and stormwater management plans posted at school’s entrance (FN). To the students (FN), I took on the role of community partner in the project, introducing them to federal policy in the form of the Clean Water Act and the local role the school district plays in potable and stormwater management (FN).

Students learned that the school district is responsible for complying with federal regulations, and the Director of Maintenance, who they see in the halls every day, is the person who conducts tests and oversees compliance (FN). These encounters with regulatory documents and the people responsible for implementing policy introduced students to the role of governance in maintaining the health and safety of water in their district. This was evident in one student’s reflection: “We actually got to do tests and had access to actual testing results done by officials” (SR). Mr. G engaged students with the question, “How does the school board work? What is their role?” This led to modified power-mapping exercises that demystified local authority and helped students learn for the first time about previously hidden roles, such as the Director of Maintenance, giving a face to local decision-makers (TL).

2.4.1.3 ECS Element: Collective Action with Peers; ECS Practices: Place-Based Inquiry and Collective Learning-Action.

As students considered which issue to address in their ECS projects, they became most passionate about the poor taste of their school drinking water, which impacted them daily, including academically and athletically. Students explained that “everyone knew” the only fountain that had “good-tasting water”, and the lines were so long that they often were late to class or avoided drinking water altogether (FN). These real concerns shaped the group’s

advocacy efforts; ultimately, all four classes decided to focus on improving the taste of drinking water at their school.

The drinking water issue combined everyday relevance, student expertise, and a plausible pathway to decision-making. Students were not learning about an environmental problem at a distance; they were naming a condition they navigated daily. Their comments showed detailed local knowledge which helped shift the project from a general water unit to a student-defined public problem. As Mr. G observed (TL), "It seemed like they were all the most passionate about… making the drinking water better... they had a lot of buy-in because if you ask most students here, they would probably say that they don't really like the water." One student echoed this sentiment, saying, "We actually learned about something affecting us… We got to physically do something that we all felt strongly about." This highlights both the personal investment and agency students experienced, as they were able to take meaningful action on an issue relevant to their daily lives.

A recent voter-approved district bond for a millage increase to improve school property and buildings was particularly relevant in this case. Students formed research teams across the four classes to build an evidence-based "call to action" to advocate to their principals, superintendent, and school board to use funding from the recent millage to add water softeners and chillers to the school drinking fountains. Each team focused on different aspects of the issue, such as bond research, water testing, education, maintenance, community opinions, cost, benefits, and health and safety. The influence of this practice on students' development of science and civic skills, including scientific processes, communication, and teamwork, was evident. One student noted (SR), "It made us research more, and work with other groups in order to make a final presentation." Another student described how this collaborative process fostered a sense of solidarity, (SR): "We were more hands-on and we became closer as classmates working together." Students emphasized both the civic impact and the collaborative nature of the project, showing how powerful these experiences became when pursued collectively.

While crafting their argument for policy change, students gathered information about the bond issue, costs of water softeners and chillers, access to potable water, the benefits of hydration for academic achievement, and results from water quality testing, both their own and official results. They conducted surveys and interviewed students, faculty, and staff about their opinions and experiences (FN). These activities were impactful, as reflected by one student:

"This was a more hands-on experience where the students got to be directly involved in taking and surveying the data" (SR).

In Mr. G's classes, this centering of students' leadership, community knowledge and expertise were evident in students' reflections, which emphasized problem-solving and taking charge of their own learning. One student noted, "Instead of people just telling us what to do, we had to put the pieces together and figure out things about the water" (SR). The way ECS was implemented also contributed to this sense of autonomy and empowerment through self-direction; as another student explained, "It was hands on and we were trusted out of class," and "We were given a lot more freedom when doing the project" (SR). These responses suggest that students were building agency around their own learning which contributed to the relevance of that learning.

Gathering community opinions emerged as a particularly meaningful experience, as noted during focus group discussions with three out of four classes (SFG). Students appreciated obtaining other people's input, explaining that interviewing others "helped to get more points of view" and gave them new perspectives, such as "being considerate of what others have to deal with" (SR). Listening to others, especially regarding issues students cared about, was cited as different and important: "Our group interviewed people to get their opinions on what we were working on" and "I got to interview students and hear their opinions on things we were doing in class" (SR). Through this process, students developed feelings of solidarity not just within their class, but with the broader community, recognizing that others cared about the issue. One student shared that interviewing others made her more confident in her ability to talk to people and strengthened her advocacy campaign by including information from outside the project (SFG), underscoring how collective decision-making is enriched by a multitude of voices. Community outreach thus integrated civic engagement with science, instilling civic confidence as students reported greater comfort engaging with diverse community members and valued input beyond their immediate circle.

2.4.1.4 ECS Element: Collective Public Action with Peers; ECS Practice: Public Advocacy.

The project culminated in presentations to the superintendent, school board members, principals, facilities manager, and project partners, where students advocated for installing coolers, water bottle fillers, and softener systems to improve drinking water taste throughout the school. Each class presented their portion in a gallery-walk format, engaging directly with those

in positions of authority (FN). All four classes identified these public advocacy efforts as a defining experience. Although students described feeling "scared" or "nervous," they consistently added qualifiers like "but fun" and "but we had a voice" (SFG). This sense of being heard was also a major theme in focus groups, with students noting that presenting "to people in charge" made them feel their voices mattered (SFG/SR).

Students observed that their perspectives, efforts, and demands were taken seriously by those in power. One student commented, "we talked to higher up people for more information/to give them information about what we learned," (SR) while another remarked, "There were lots of adults in charge looking at our work and commenting on it, thinking about how to do it" (SR), showing their growing sense of political efficacy and an appreciation of the reach of their influence. This impact was heightened by direct feedback from decision-makers. The superintendent affirmed the students' efforts, noting that their advocacy mirrored real policy processes and subsequently requested a summary of their proposals to present to the board (FN).

2.4.1.5 ECS Element: Local Decision-Makers.

Student responses reflected a growing understanding of the role of government officials and other decision-makers. For example, one student shared, "We talked in front of our superintendent and a board member, instead of just a class or a teacher" (SR). This recognition of the difference between an audience that included district-level leaders rather than just peers, demonstrates an awareness of the civic and political landscape and decision-making authority within it. Another student noted, "We actually talked to board members and they listened," (SR) highlighting the political capital and influence the students felt they had and illustrating the belief that young people can impact policy and practice on environmental issues in their communities. Mr. G shared this sense of agency the classes felt, saying, "We could definitely tell that when our superintendent left, he was really thinking about it and wanted to look into it more, and our board members are really excited about it too" (TL).

2.4.1.6 Outcomes: Agency and Real-World Impact Through ECS.

Students witnessed tangible improvements as a direct result of their advocacy: the head of maintenance installed a cooler at the drinking fountain identified by students as most in need. Mr. G described this ripple effect, explaining, "I actually just talked with our head of maintenance and he said we have a cooler to install on one of your drinking fountains. Not all of them have it, which was one of the issues we found, not all of them cooled. They got one and

wanted to know which drinking fountain to put it on. I told them which one the students didn't like and they put it on that one" (TL).

As one student described, the ECS experience transformed them from passive learners to active participants: "Usually, while I am learning within a classroom setting I am being informed with cold-hard facts to store within my brain. With this project, I was able to actually have a part in what I was learning and how I collected the information" (SR). Although this outcome might be expected in student-directed inquiry, the genuine ownership students took of their learning reflects their enhanced problem-solving abilities and agency, critical elements for community decision-making on environmental issues. In these biology classes, ECS provided a blueprint for centering student voices, building civic science skills, and inspiring youth-led environmental change.

2.4.2 Case Study 2- Benson High School World History Classes- Understanding the Historical, Social, Political and Environmental Landscape Through Community Partnerships and Municipal Literacy

In Ms. T's world history classes at Benson High School, ECS interwove historical, environmental, and civic engagement, challenging students to interrogate the enduring influence of past governmental decisions on contemporary community landscapes, including water systems. As Ms. T described, "Part of my goal is to ask what role government plays in our lives, how do we hold government accountable, [and] what do we want government to be doing?" (TL)

2.4.2.1 Elements: Local Environmental Focus and Collaboration with Community Partners; ECS Practice: Place-Based Inquiry.

Central to Ms. T's approach was partnership with local community experts. The unit began with an "ecostroll" around the school and neighborhood, led by Ms. W, an expert in place-based education and environmental history. During this activity, Ms. W explained to students how to "read the landscape", examining urban infrastructure, community engagement with the area, watershed topography, and historical influences to understand how past decisions have shaped current social and environmental conditions. Students grappled with questions such as: Who controls water? Who is responsible for environmental decision-making? (FN)

A second walkabout, facilitated by a representative from the local watershed council ("the water guy"), introduced students to ecological perspectives and highlighted broader

concerns linked to industrialization and urbanization. Students compared their observations of neighborhood flooding and pollution with historical examples of river degradation, synthesizing these insights into lists of community issues and project ideas (FN).

The inquiry-based "ecostrolls" also utilized photography to document community assets and evidence of water issues, allowing students to see firsthand the connections between water systems and urban development. Student engagement noticeably increased during these activities (FN). As one student observed (SR), "I enjoyed going outside and observing rather than someone just telling us." Reflections highlighted the impact of these participatory practices; one student shared that the experience "helps students understand their environment and builds knowledge" (SR). Another remarked that this real-world investigation, beyond simply building understanding, offered insights into possible solutions: "We did a more hands-on approach to it which helped understand the problems and how to fix them after seeing them first hand" (SR).

2.4.2.2 ECS Element: Collaboration with Community Partners.

Student reflections highlight the impact of community partnerships within ECS praxis (SR). Several students noted the significance of these interactions (SR): "We had speakers come in and do activities with us. Which, by itself isn't what usually occurs. We would probably have gone through an article or something. Not only did we have them come in not one, not two, but four days." Others shared a newfound appreciation for the breadth of community expertise and involvement (SR): "I learned more about groups in my area that work on this type of stuff and how they help." Through ECS, students recognized collective responsibility and community resources, gaining a sense that their work connected them to something larger: "There are a lot more people who care about the Benson community than I thought there was." Another student explained, "We actually had people come in who actually focus and fight for things like this. it gives you a way different perspective," illustrating the transformative power of witnessing environmental activism firsthand. This same student continued "I learned more about people in my community who can help," showing their recognition of these community partnerships as sources of social capital (SR).

2.4.2.3 ECS Element: Engagement with Local Decision-Makers; ECS Practice: Intergenerational Learning.

Class discussions extended students' community observations into analyses of power. Students were prompted to identify visible and invisible structures of authority in their

community, naming entities such as the mayor, Department of Environmental Quality, city council, and ward representatives as decision-makers (FN).

A field trip to city hall further enhanced students' civic engagement and strengthened the connections between governmental actions and community consequences, or as Ms. T emphasized to students "the decisions people we talked to today make are the things that make a difference to the places you care about" (FN). Classes were hosted by a city sustainability commissioner, toured operational departments and discussed real-world environmental policies, including replacing old lead service lines and strategies for runoff management, and learned about roles of municipal governance, such as water system infrastructure. These interactions demystified governmental authority and reinforced that civic institutions can be accountable and open to youth participation; as one staff member expressed, "You have to remember…We answer to you" (FN). Students learned about governmental decision-making, and how the public can participate in environmental management and decisions at the municipal level (FN/TL).

This was a meaningful experience for students, as indicated by numerous reflections referencing the field trip. One student commented (SR), "We actually went to city hall… instead of just someone explaining." Another addressed how the trip clarified the often murky structure of environmental policies and authorities, noting one of the most important things they learned was, "Who makes decisions on our water and why" (SR). Student reflections also highlighted what they saw as the accessibility and responsiveness of local government. One student remarked, "City hall is very helpful and takes input from younger people" (SR). These responses suggest that students were not only learning content about government; they were reinterpreting government as something potentially accessible and responsive. Echoing these student statements, Ms. T reflected on the trip, noting, "students got to meet a variety of people and learn from different perspectives what governing actually does" (TL). A few students became a direct and longer-term part of city sustainability decision-making as a result of this experience (SR), with one reflecting on the impact of the trip: "I learned about the youth council so I joined." The City Hall visit appeared to support a form of municipal literacy that went beyond knowing that local government exists. Instead, students began to understand specific roles, departments, and decision-making processes related to water and infrastructure.

Ms. T and her students subsequently examined changes over time in water systems, political decision-making, and community activism, such as the decades old municipal practice

of concrete “capping” of and later campaign to “daylight” (i.e. uncap) the local river. One student’s inquiry (FN), “What will happen when we run out of well water?” led to the teacher’s discussion of the historical event of the Aral Sea’s ecocide, illustrating the interplay of human decisions and environmental consequences.

2.4.2.4 ECS Element: Collective Action with Peers; ECS practice: Public Advocacy.

The ECS experience culminated in student-led calls to action, grounded in both data and personal insight. Students had autonomy to choose environmental issues and solutions via a policy or practice change (e.g. stormwater management, urban heat islands and aging infrastructure), conduct research, develop goals and strategies, and identify allies and target audiences. They presented their advocacy campaigns to administrators, local officials, and community partners, fostering dialogue, feedback, and consideration for policy change. One student pointed out how unique this was compared to other classes, saying that this experience was different because of “adults from the community coming to hear students’ voices” (SR), reflecting the sense of efficacy ECS promoted. Another remarked, “I learned that we can actually make a difference in our community with the right resources. That's important because as a teenager it’s easy to forget the power you hold” (SR), highlighting a sense of agency and belief in their ability to effect change.

2.4.2.5 Outcomes: Agency and Real-World Impact through ECS.

Whether or not their advocacy positions were ultimately adopted, the experience of being heard was impactful for students. One student explained, “It felt to me like our opinions actually could make a difference to the community.” Another described how unique the experience was: “we were asked how WE feel and how WE could make a difference. i liked that, wasn't used to it.” (SR). Several students summed up the long-term impact of the ECS experience, with one commenting) “I learned to pay more attention to the world around me and the things that negatively affect the neighborhoods I live in” drawing attention to the civic science skills they built that will serve them long-term (SR). Addressing the broad applications of their learning in ECS, one student explained, “We [learned] about how to be [persuasive] and talk to [officials]. This is [important] because we might need to use these skills in the long run.” Finally, one student expressed the impact of ECS on future civic engagement: “This is a very good way to increase the likelihood of actually taking action in the future for some and I really liked it” (SR).

Ms. T's framing mattered. Her repeated questions like "What role does government play in our lives?" and "How do we hold government accountable?", helped students analyze public responsibility. In this case, ECS appeared to support environmental civic learning by making governance visible and by helping students see local environmental conditions as shaped by human decisions rather than as inevitable features of the landscape. ECS, as experienced in Ms. T's classes, serves as a design for bridging the gap between historical learning and present-day advocacy, effectively engaging community partners, and directly engaging with policy to help students develop new literacies- scientific and civic- that extend far beyond the classroom.

2.4.3 Case Study 3- High School Earth Science Investigations to Build Science Agency, Student Voice and Civic Engagement

From the outset, ECS in Mr. Z's Earth Science classes (grades 10–12) was designed with an advocacy orientation. Students were informed that their work would culminate in a presentation to officials and community members, giving their project a purposeful public audience and emphasizing its civic dimensions (TL).

2.4.3.1 ECS Element: Local Environment Focus; ECS Practice: Place-Based Inquiry.

The implementation of ECS in Mr. Z's classes followed a scaffolded approach, beginning with introductions to local water challenges. Mr. Z and I prompted students' inquiry with open-ended questions about water systems, usage, and availability to draw out students' existing knowledge and personal connections to water (FN). In a "first words water issues" activity, students reflected on images depicting various community water concerns, encouraging them to connect both emotionally and intellectually with the topic. The subsequent "water questioning gallery walk" allowed students to pose and answer questions such as, "How often do you get water quality reports?" and "Is access to water a right?" (TL).

Continuing in this vein, through "ecostrolls" around the school and nearby neighborhoods, students observed and documented environmental features like land, water, and infrastructure. As Mr. Z noted, they "started to really make it about our community, transitioning into making this about our project, things about us" (SFG). Assignments extended beyond school, encouraging students to make observations during commutes or walks home and to collect images and data using Google MyMaps (TL). One student commented on her personal connection to the project, saying, "I went to walk around the River because I live there. The odor

of the river, my mom can smell it on me. I chose a place next to my home from my own experience… It was an amazing experience" (SFG).

This geographic contextualization culminated in mapping community spaces associated with water and green infrastructure, particularly those connected to the River (TL). The class selected shared spaces as focal points for water testing, using environmental sensors and collaborating with River watershed council staff to test surface water quality and compare local data to EPA standards. For one student, "Water testing was the first step. It was fun and educational." (SR). Other students echoed the impact of water testing and the knowledge they gained: "Being able to know more about our water. It could look clean and not be healthy. We found some surprising things" (SR). Students displayed a developed understanding of how the water cycle, and natural and man-made features connect to water pollution and understandings of differing standards for drinking versus surface water and why we have them (FN).

2.4.3.2 ECS Elements: Collaboration with Community Partners and Engagement with Local Decision-Makers.

Students extended their learning and investigation further into the community with a visit to the municipal water treatment plant, which proved to be a significant experience. Several students referenced the profound impact, noting, "the water plant was an impactful experience, we learned a lot of stuff…" and "when you go to the place where it's happening … [from] seeing it really happening is a big impact, in class you're trying to imagine. In the place, the smell, the life experience is totally different" (SFG). Another student reflected on the growth in their knowledge and understanding after the visit, stating, "before, I didn't know where it came from and how it was cleaned."

One student further explained how this experience changed her entire outlook on water, describing how it became part of her everyday thinking (SFG):

> "I learned a lot from the treatment plant… I get shower thoughts out of it… I care and think about water more, makes me act differently… how water is filtered and stuff, how it comes back and it's reused and just a lot of information I didn't know about basic water that we drink and use every day from showering and stuff. It definitely made me care about it more… definitely thinking about it more. Whenever I do use water it reminds me of this project in this class… If I see trash in the water I'll just kind of pick it up because

they have that water filtration system that can't pick up large amounts of trash, because we saw like, where things were flushed down, it would get clumped up… Gives me a different mindset for water and stuff."

After these activities, students synthesized their findings into data-driven narratives and developed a call to action focused on promoting stewardship of the River and broader community water resources. The advocacy component of the project was enhanced by the involvement of a STEM professional and a community engagement expert, who led exercises to strengthen storytelling, public outreach skills, and student leadership (FN). One student explained the impact of working with community members dedicated to these issues, stating, "I'm not worrying about it too much, but like since it was so important to many people… I opened my eyes more and like went to like actually make effort to go see what was in the community and like what's needed. Just by doing this and knowing that there was other people out there that cared about it" (SFG).

2.4.3.3 ECS Element: Collective Public Action with Peers; ECS Practices: Intergenerational Learning and Public Advocacy.

The unit culminated with students presenting their project findings at both a school-based and region-wide community forum, where they raised awareness and advocated for local community action (FN). For many, this was the most meaningful part of the project. One student reflected that the most important thing she learned was "how we can share our voice about the matter in our community as students" (SR). Another shared, "My favorite thing was the community forum because we got to hear other peoples take on different communities… we're all talking about things that was important to us in the community" (SFG). Listening to and learning from others made a strong impression; several students echoed the sentiment that engaging with peers working on similar issues heightened their own engagement: "For me the most impactful was going around the community forum. Since it was important to so many other people that cared about it" (SFG).

The response from the audience at the community forum was also significant, reinforcing that students' ideas and opinions mattered: "I noticed that people were interested and wanted to hear what we had to say" (SFG). One student was surprised by the level of engagement from community members: "I noticed that people were like, actually interested. Just being able to

know more about our water in the community" (SFG). Ultimately, this experience helped solidify for students that people in their community cared not just about the environment, but also about the students and their opinions.

2.4.3.4 Outcomes: Agency and Real-World Impact through ECS.

Overall, students in Mr. Z's classes reported greater awareness of water quality issues and expressed a willingness to apply project insights in their daily lives, such as picking up litter and being mindful about water use (SR). For many, the connection between water quality and human health and safety was particularly important, and they valued the autonomy gained in monitoring these issues. One student shared, "The most important thing I learned was figuring out different ways to understand how water works around us and if it's safe enough for us to use and drink" (SR). Another noted, "the most important things we learned about was what was in our water, how to protect/clean it and WHO protects/cleans it. This is important because it helps us improve the quality of our water for us and future generations" (SR). This sense of agency was reflected in students' willingness to implement their learning in everyday life, and for some, even beyond their immediate context. One student highlighted the project's global relevance, saying, "I want to travel to my [home] country and do water tests… The presentations to the community I want my country to do it and I know my friends want to too." ECS in Mr. Z's earth science classes clearly demonstrated the value of hands-on experience and the real-world application of science and civic skills.

In Mr. Z's case, students' reflections emphasized awareness, stewardship, and public communication more than direct institutional influence. Students described learning where water comes from, how it is cleaned, what makes it safe or unsafe, and why local water systems matter. Student responses suggest that ECS helped students connect environmental science knowledge to public responsibility and community care. However, because the final advocacy audience was less directly tied to a specific decisions students wanted changed, students' reflections emphasized voice, awareness, and motivation more than concrete institutional impact. This contrast with Mr. G's and Ms. T's cases helps clarify how the authority and responsiveness of the public audience may shape students' sense of consequentiality.

Table 2.2 Cross-Case Comparison of Variation in ECS Implementation

ECS element	Biology / Mr. G	World History / Ms. T	Earth Science / Mr. Z	What this suggests
Local inquiry	School drinking water fountains, campus observations	Neighborhood ecostrolls, historical landscape reading	River/water testing, water treatment plant	Local inquiry worked differently by discipline and shaped what students noticed
Community partners	Researcher/facilities staff as local experts	Place-based educator, watershed council, sustainability commissioner	Watershed staff, STEM/community engagement experts	Partners shaped how students interpreted environmental issues
Decision-makers	Superintendent, school board, facilities director	City hall, ward reps, municipal staff	Water utility staff, community forum audience	Direct connection to authority appeared important for perceived influence
Collective action	Class-wide drinking water campaign	Student-selected small group policy/practice campaigns	Public awareness and stewardship campaigns	Advocacy varied in target, leverage, and perceived impact
Student outcomes	Concrete institutional response, efficacy, school infrastructure knowledge	Municipal literacy, civic voice, policy thinking	Water awareness, stewardship, public communication	Student outcomes reflected implementation emphasis

2.5 Discussion

2.5.1 Overview and Contribution

Across cases, ECS emerged as a flexible and practical framework that extends central aims of EE and broadens established models of action-oriented environmental learning (Ballard et al., 2016; Monroe et al., 2017; Schusler & Krasny, 2015). Like EE, ECS emphasizes place, environmental literacy, and meaningful engagement with local socio-ecological systems. Like approaches in EE that address empowerment and action competence, ECS emphasizes students' capacity to analyze issues and act. What ECS adds is a more explicit civic- and science-based process for action: students are not only encouraged to "take action," but are supported to identify who holds decision-making power, develop evidence intended for use in civic arenas, and engage in collective, public action with peers, community partners, and authentic audiences. In doing so, ECS shifts the focus from individual behavior change or classroom-contained

projects toward collective, public-facing participation in community environmental decision-making.

This study makes three primary contributions. First, it provides comparative empirical evidence of how ECS can be implemented across high school science and social studies classrooms under everyday school constraints. Second, it provides empirical evidence for how the core elements of ECS appeared to act as key mechanisms to support student learning. Third, it advances EE and civic learning frameworks by positioning ECS as a pedagogical approach that aligns scientific inquiry with collective civic action around community environmental decision-making.

The discussion below is organized in relation to the three research questions. I first discuss how ECS was practiced across biology, world history, and earth science classrooms. I then examine how students experienced the core elements of ECS, followed by a discussion of how ECS practices related to student learning. I conclude by clarifying what ECS adds to environmental and civic education, discussing limitations, and outlining implications for research and practice.

2.5.2 ECS as an Adaptable Cross-Disciplinary Framework

In relation to my first research question, "In what ways is ECS practiced in high school science and social studies classes?", teachers implemented ECS through the four core elements: local environmental inquiry, engagement with local decision-makers, collective public action with peers, and collaboration with community partners. However, teachers practiced these elements differently depending on subject area, goals and objectives, classroom realities, and available community relationships.

In biology, students used place-based inquiry, including mapping and local data gathering, and coordinated group investigation to build an evidence base for advocacy that contributed to infrastructure changes. Their work centered on a school-based drinking water issue that students experienced directly. Students gathered observations, researched possible solutions, analyzed testing results, interviewed members of their school community, and presented their call to action to school and district leaders. This case shows how ECS can be

embedded in science instruction as a process of local investigation, evidence-building, and advocacy for school environmental change.

In world history, ECS was practiced through policy-oriented and historically grounded inquiry. Students analyzed water governance historically and contemporarily while partnering with local government and community experts. This case illustrates that ECS can be embedded in social studies as the study of power, institutions, public problems, and accountability, not only as "science content." Through ecostrolls, community partner engagement, city hall visits, and advocacy campaigns, students connected historical learning to contemporary environmental decision-making.

In earth science, students took on the role of community monitors. They investigated local water systems, conducted water quality testing, visited a municipal water treatment plant, worked with watershed and STEM professionals, and culminated in public calls to action at school-based and regional community forums. In this case, ECS emphasized collective learning-action through environmental monitoring, public communication, and community awareness, showing how ECS can position students as environmental observers and community monitors while also supporting public communication about local water issues.

Across these enactments, ECS functioned less like a fixed curriculum and more like an adaptable set of practices linking investigation to advocacy. The variation across cases matters because it shows that ECS can be implemented through different disciplinary entry points, e.g., ecological systems, policy histories, and hydrology, while maintaining the same underlying approach: students generate locally grounded evidence and mobilize it through collective, public action in relation to real stakeholders and possible community change. At the same time, the findings suggest that ECS is not a checklist of activities and how the core elements are implemented matters to student learning.

2.5.3 Student Experiences of ECS

In relation to my second research question, "How do students experience the core elements of ECS?", students across cases experienced ECS as legitimizing and motivating because it positioned their observations, questions, and claims as relevant to real community issues. Student reflections repeatedly emphasized "seeing for ourselves," being outside,

conducting hands-on investigations, interviewing others, learning from community members, and presenting to people beyond the classroom. These experiences appeared to matter because they changed both the content and purpose of schoolwork. ECS positioned students not only as learners of environmental content, but also as credible knowledge contributors and stakeholders in local environmental issues.

In terms of specific elements, first, the local environmental focus made learning consequential. Students' data and observations were about places they inhabited, which increased relevance and urgency. For example, in Mr. G's biology classes, students were motivated by the drinking water issue because it affected their everyday school experience. They knew which fountains had better-tasting water, described long lines at those fountains, and connected drinking water access to athletics, academics, and daily comfort. This helped explain why students described the work as meaningful: the issue was not distant or hypothetical, but something they felt positioned to investigate and address.

Second, collaboration with community partners expanded what counted as knowledge and who counted as an expert. Students learned from watershed educators, community-based organizations, municipal staff, STEM professionals, school facilities personnel, and local advocates. These interactions helped students see that environmental work is carried out by real people in their communities, not only by distant experts or formal scientists. For example, students in Ms. T's classes described learning about "people in my community who can help," while students in Mr. Z's classes described becoming more attentive to local water issues after seeing that other community members cared about them. This finding aligns with environmental and civic education scholarship emphasizing social interaction and community engagement, as important conditions for agency and civic development (Ardoin et al., 2023; Schusler & Krasny, 2015).

Third, engagement with local decision-makers shaped how students understood power and authority. Students learned not only scientific or environmental explanations, but also who has authority, how decisions are made, and how community members can use evidence and testimony to participate in, and potentially influence, decision-making processes. In Mr. G's biology classes, students worked with school- and district-level leaders, including the superintendent, school board members, principals, and facilities staff. This helped students

understand where decision-making power and responsibility lie within school systems. In Ms. T's world history classes, the city hall visit demystified municipal governance by making "decision-makers" visible and approachable. These experiences mattered because they transformed civic literacy from abstract knowledge into navigable relationships and procedures, a key condition for students to experience themselves as capable of participating in civic life (Anderson, 2018; Ardoin et al., 2022).

Finally, collective public action with peers supported agency as a shared practice rather than only an individual trait. Students worked in teams to gather data, divide research tasks, conduct interviews, develop claims, and prepare presentations. In Mr. G's classes, students described becoming closer as classmates through collaborative work. In Mr. Z's classes, students presented at community forums and listened to peers from other communities. These experiences suggest that ECS supported agency not by telling students they could make a difference, but by giving them structured opportunities to deliberate, collaborate, and act with others.

Together, these experiences suggest that students' learning was shaped not by any single activity, but by how local inquiry, community partnership, decision-maker engagement, and public advocacy were connected across the ECS process. Its educational value appeared strongest when the core elements were connected to one another. Ecostrolls, water testing, community speakers, city hall visits, stakeholder interviews, and public presentations each mattered, but their significance came from how they were organized into a broader inquiry-to-action process. Local inquiry gave students something substantive to investigate; community partners helped students interpret the issue; decision-maker engagement helped students understand authority and accountability; and public advocacy gave students a reason to synthesize and communicate their findings. ECS helped students move from observing environmental conditions, to interpreting those conditions through scientific and civic lenses, to communicating claims in relation to community concerns and decision-making systems. In this sense, ECS's contribution lies not only in its individual elements, but in the way those elements organize learning as a sequence from inquiry to civic action.

2.5.4 ECS and Student Environmental Civic Learning

In relation to my third research question, "How does the practice of ECS and its core elements relate to and impact student learning?", ECS was associated with environmental civic learning that extended beyond environmental content knowledge. Across cases, students described learning in five related areas: environmental understanding, civic systems knowledge, collaborative civic skills, public voice and efficacy, and community connection.

First, students developed environmental understanding by investigating water systems, pollution, stormwater, infrastructure, and human-nature interdependence in familiar places. Second, students developed civic systems knowledge by learning who makes decisions, how school or city systems work, and what institutions are responsible for water-related issues. Third, students developed collaborative civic skills through teamwork, interviewing, deliberation, communication, and public presentation. Fourth, students expressed public voice and civic efficacy when they described feeling heard by adults, speaking to people beyond the classroom, and believing their work could matter. Finally, students expressed community connection and responsibility when they described local environmental issues as shared concerns that affected people and places they cared about.

The relationship between ECS practice and student learning was not uniform. Student learning varied depending on how the ECS core elements were enacted and connected. A key mechanism for student learning overall appears to be coupling place-based inquiry with public advocacy. When students collected and analyzed local data and then advocated for change to authentic audiences, their work became "real" in ways that classroom-only projects often cannot. In Mr. G's classes, for example, students' investigation of school drinking water led to presentations to district leaders and a concrete response when a cooler was installed at one fountain. This does not mean ECS programming reliably produces institutional change, but it illustrates how authentic audiences can make evidence-based advocacy feel consequential to students.

In settings where advocacy audiences were less central to decision-making, students still reported meaningful growth in process outcomes, including confidence, teamwork, persistence, and motivation, but referenced fewer examples of institutional impact. For example, students in Mr. G's and Ms. T's classes had more direct interaction with decision-makers who had authority related to the issues being studied. Their reflections more frequently emphasized

civic voice, influence over policy, and understanding "who" makes decisions. In Mr. Z's classes, where the advocacy audiences were less directly tied to policy or practice decisions, students more often emphasized process outcomes such as water awareness, stewardship, community connection, and motivation. This pattern suggests that decision-maker engagement may be especially important for whether students interpret their work as influencing institutional outcomes, while community forums and public presentations may be especially important for building voice, confidence and belief in their ability to influence others.

These patterns also suggest that authentic contact with authority structures was especially important for students' civic learning. Direct encounters with city officials, district leaders, and facilities staff helped students connect environmental issues to institutional responsibility, constraints, and possible leverage points. Where students worked with school- or district-level leaders, they gained insight into where decision-making power and responsibility lie, as well as into institutional constraints inside education systems. Where students engaged municipal actors, they began to see how local government, infrastructure, and public accountability shape environmental conditions.

The findings do not show that all students developed lasting civic identities or that all advocacy efforts produced policy or infrastructure change. Rather, students' reflections suggest that ECS created conditions in which many students could begin to see themselves as legitimate participants in environmental and civic life. In some cases, students' efforts were connected to tangible outcomes, such as students learning about and joining a youth council. More broadly, however, the significance of ECS was that students practiced forms of participation that are often absent from classroom learning: gathering evidence about and to address local issues, communicating with stakeholders, and advocating for change to audiences outside of their classroom context.

Taken together, ECS appeared to support multiple layers of environmental civic learning: disciplinary understanding, civic literacy, collaborative problem-solving, communication, and emerging science and civic agency. These findings align with research emphasizing that action-oriented environmental learning can support competence, engagement, and civic development when students participate in meaningful inquiry and social interaction (Derrien et al., 2020; Flanagan et al., 2025; Jensen & Schnack, 2010; Trott et al., 2023). ECS

contributes to this literature by showing how these outcomes may be supported through a structured sequence of local inquiry, community partnership, decision-maker engagement, and public advocacy.

2.5.5 Contributions to Environmental and Civic Education

The study's findings support environmental education scholarship which advocates for local context, participatory engagement, action-taking, skill development, and meaningful social interaction (Jensen & Schnack, 1997; Schusler & Krasny, 2010). They also align with scholarship on action competence, environmental citizenship, and youth civic development, which emphasizes that students need opportunities to participate in meaningful environmental and civic action rather than only learn about environmental problems (Hadjichambis & Reis, 2020; Hungerford, 2010; Jensen & Schnack, 2010).

At the same time, ECS adds specificity about the civic conditions under which agency becomes actionable in schools. Rather than treating "action" as a generic outcome, ECS foregrounds how action is organized, where it is directed, and what it is built from. In ECS, action is organized collectively, directed toward local institutions and decision-making processes, and built from evidence that integrates scientific knowledge, local knowledge, and community concerns.

This differentiates ECS from educational approaches that emphasize individual behavior change, general environmental awareness, or classroom-contained projects. ECS does not reject stewardship or individual responsibility, but it extends them and foregrounds systemic change by asking students to consider questions such as: Who is responsible for this issue? What evidence matters? Who needs to hear from us? What institutional, infrastructural, policy, or community changes might address the problem? By making these civic questions explicit, ECS helps bridge environmental literacy and civic engagement.

ECS also offers a practical model for integrating science and social studies. The cases show that scientific inquiry and civic analysis can be mutually reinforcing. Students can learn about water quality, pollution, infrastructure, ecosystems, and environmental monitoring while also learning about government, accountability, community organizations, public communication, and advocacy. This integrated approach responds to calls for educational models

that connect environmental and civic literacy across disciplines and support youth participation in community problem-solving (Ardoin et al., 2023; McNeill & Vaughn, 2014).

By documenting ECS across subjects and settings, this study helps fill a gap in empirical studies on student outcomes and curricular design supporting scientific knowledge and critical science agency (McNeill & Vaughn, 2014; Ardoin et al., 2023). The evidence suggests that agency and engagement may be best supported when students navigate real authority structures, engage in genuine advocacy, and connect their learning to community-level action.

2.5.6 Limitations

This study has several limitations. First, as a comparative case study, findings are context-specific and should not be interpreted as evidence that ECS will produce the same outcomes across all schools, communities, or civic opportunity structures. Second, student learning is primarily evidenced through student reflections and classroom observations. These data provide rich insight into how ECS was enacted and experienced, but they do not allow for strong causal claims about ECS effects. Finally, teacher experience and access to community networks differed across cases, affecting enactment and making it difficult to separate ECS-related learning opportunities from the enabling conditions that shaped implementation quality.

2.5.7 Implications for Research and Practice

For educators, the cases suggest that effective curricular design requires more than selecting a local issue. It requires structuring place-based inquiry so students apply disciplinary knowledge in and with community; building intergenerational learning through sustained partner relationships; supporting collective learning-action through routines that make collaboration productive; and planning public advocacy with authentic audiences so that students' advocacy claims have a meaningful chance to be heard, considered, and potentially acted upon. This study also has implications for teachers across disciplines. It shows that environmental inquiry and action can be integrated beyond science classes, opening possibilities for broader environmental learning-action integrating environmental inquiry and civic analysis.

For schools and districts, enabling ECS may require flexible scheduling, support for community partnerships, approval for civic engagement activities, transportation or field trip support, and time for students to prepare public products such as testimony, presentations,

reports, and data visualizations. Teacher preparation and professional learning should emphasize partnership-building, facilitation of student-led inquiry, and scaffolding civic communication. Teachers may also need support helping students identify decision-makers, understand local governance systems, and translate evidence into public-facing arguments.

For researchers, future studies should examine which combinations of ECS core elements are necessary for particular outcomes. For example, comparative work could test whether decision-maker engagement predicts stronger gains in civic efficacy and civic literacy than public outreach or presentation alone. Future research should also examine the long-term impacts of ECS on students' civic participation and environmental action beyond the classroom, using mixed-method and longitudinal designs to assess durability of agency, civic efficacy, and participation trajectories. Finally, studies across disciplines can clarify how ECS is translated into broader contexts and what forms of evidence, argumentation, and civic participation are emphasized in different settings.

2.6 Conclusion

This comparative case study extends environmental, civic, and science education by documenting how ECS was practiced in high school science and social studies classrooms, how students experienced its core elements, and how those elements related to students' environmental civic learning. The study provides empirical evidence that ECS can be implemented flexibly across disciplines under everyday school constraints while maintaining a coherent inquiry-to-action arc. It also identifies implementation features of ECS core elements that appeared to support student learning: locally meaningful inquiry, community and institutional expertise, structured peer collaboration, explicit attention to decision-making, and public advocacy to authentic audiences.

Overall, ECS advances existing EE and civic learning frameworks through its interdisciplinary approach for connecting environmental learning with civic participation. The findings do not show that ECS alone produces transformative environmental or civic change. They do suggest, however, that when students investigate their own environments, collaborate with peers and community partners, identify decision-makers, and bring evidence into public arenas, classrooms can become important sites for practicing the scientific, civic, and collective

capacities needed for more participatory environmental decision-making and more just, sustainable futures.

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Chapter 3 **"It Shows How Much Power We Hold": Critical Environmental Science Agency Development in Environmental Civic Science**

3.1 Abstract

Given the socio-ecological challenges of our time, education must rise to the challenge and reimagine practice to equip young people with civic and scientific capacities to address community environmental challenges and participate in local decision making. Environmental Civic Science (ECS) is one educational framework uniquely situated to meet this challenge. In this article, I advance a new conceptualization of agency, critical environmental science agency (CESA), specific to the context of socio-environmental issue decision-making. I present results from a mixed methods study of high school science and social studies students' participation in ECS on their enactment and development of CESA, i.e. students' capacity to collectively use science and civic learning to address community environmental and environmental justice issues. Combining pre-post surveys, students' open-ended reflections and classroom observations, I measured change in CESA outcome dimensions (frequency of environmental actions, sense of sociopolitical control/political efficacy, competence to address community water issues and capacity to take action for environmental change) comparing students in ECS (n=310) with students in standard science and social studies classes (n=241) using used repeated-measures general linear modeling. Analysis revealed statistically significant gains on all measured outcomes for the ECS group and none for their peers in the comparison classes. Qualitative data were analyzed for evidence of and references to these core dimensions of CESA, to support and add depth to quantitative findings. Findings point to students' in-depth development and enactment of CESA including a growing sense of sociopolitical control, civic skill ability, sense of efficacy and power, capacity and drive to address community environmental issues. Results reinforce the need for participatory processes like ECS, that connect environmental science with civic action and center students as active change agents, to prepare students for environmental action and build their CESA.

3.2 **Introduction**

3.2.1 Background

Younger generations are inheriting a world in which the consequences of climate change (CC) and other socio-environmental challenges are expected to increase risk and uncertainty in daily life. Compared to their grandparents' generation, today's children are projected to encounter two to seven times more "natural disasters" across their lifetimes (Thiery et al., 2021). Formal education must therefore be reimagined to equip youth with the tools, dispositions, and opportunities necessary to navigate and address these destructive legacies within their communities. This reimagining requires integrating environmental and civic literacy across subject areas, cultivating students' scientific and civic dispositions, emphasizing collective action, connecting classroom learning to civic engagement that influences policy and practice, and incorporating the justice dimensions inherent in socio-environmental issues (Lee et al., 2021; Tannock, 2021).

Socio-environmental issues also represent collective action challenges, inviting the critical question: "What should we do?" (Levine, 2022). To prepare youth for such problem-solving, schools must provide opportunities for students to develop a sense of collective identity ("We, the people"), have their voices heard, practice civic reasoning, and pursue shared goals in the public sphere (Lee et al., 2021). Although young people may be motivated to address environmental challenges, without such experiences they may not recognize pathways to participate in democratic decision-making. They may not view themselves as able to drive change unless they experience themselves as change makers (Kenis & Mathijs, 2012; Pykett et al., 2024).

In this context, I argue that youth agency (i.e. skills/competence, dispositions/motivations, efficacy/belief in ability and power/capacity to act) should be a central outcome for science teaching and learning. Specifically, in the context of socio-environmental challenges, I conceptualize this outcome as critical environmental science agency (CESA). I define CESA as young people's capacity and drive to work collectively to apply environmental science and civic knowledge to act on socio-environmental and environmental justice (EJ) issues in their communities. CESA foregrounds agency as decision-making-centered, collective, and justice-oriented. It is not only about students learning environmental science or taking individual environmental action; it is about students developing the capacity to use evidence, understand

power and responsibility, and participate with others in decisions that shape environmental conditions in their communities.

To foster students' CESA I advance and examine Environmental Civic Science (ECS), a pedagogical framework that integrates environmental science inquiry with civic participation through collaborative action on local environmental issues. In this paper, ECS and CESA serve different conceptual roles. ECS is the pedagogical framework: it describes the educational process through which students investigate local environmental issues, work with community partners, identify decision-makers, and engage in collective public action. CESA is an analytic construct and potential student outcome: it names the form of agency specific to participating in decision-making about socio-environmental challenges that students may develop through participation in ECS. Put simply, ECS is the praxis educators enact; CESA is one form of student learning and development that ECS is intended to support.

In this mixed-methods study, I investigate whether participation in ECS is associated with students' development of CESA in high school (grades 9-12) science and social studies classes. The design integrates quantitative (pre/post surveys) and qualitative (classroom observation, open-ended survey questions) data sources to assess: (a) changes in CESA-related outcomes associated with ECS participation, and (b) the practices, behaviors, and processes through which students enact and express CESA.

The research addresses the following questions:

1. To what extent is participation in ECS associated with growth in students' CESA-related outcomes?
2. How do students enact CESA during ECS participation?
3. How do students express CESA as an outcome associated with ECS participation?

These questions have direct implications for science teaching and learning. Although socio-environmental issues are taught primarily in science classes (Henderson et al., 2017), the knowledge, skills, and dispositions required to address them extend well beyond scientific knowledge and technical solutions. Addressing such problems involves interpreting scientific evidence and uncertainty, but also navigating institutions, engaging stakeholders, communicating to a range of audiences, and participating in decision-making at multiple levels (Tannock, 2021). For these reasons, science teaching about socio-environmental issues should intentionally cultivate civic competencies alongside science practices (Ardoin et al., 2023; Levy & Zint,

2013). Moreover, socio-environmental issues should not be siloed within science classrooms; other subject areas, including social studies, should incorporate socio-environmental issues into students' learning (Tannock, 2021).

Agency is integral to critical scientific, environmental, and civic literacy, enabling students to participate politically in environmental decision-making (Ardoin et al., 2023). Science education scholarship has developed influential constructs for understanding students' agency in relation to sustainability and justice, including environmental science agency (ESA) and critical science agency (CSA) (Ballard et al., 2017; Basu et al., 2008; Schenkel et al., 2019). Yet little is known about the processes whereby youth develop agency specific to environmental decision-making contexts (i.e. wherein science practices intersect with civic participation, accountability, and decision-making about the socio-ecological systems that members of a community share). Significant gaps also remain in understanding how education can nurture collective environmental action competencies (Clark, 2016), stimulate environmental political engagement (Levy & Zint, 2013), and leverage critical pedagogy to support meaningful changes in attitudes and behaviors (Caeser, 2013). These gaps motivate this study's focus on ECS as a pedagogical framework that may support students' development of CESA.

3.2.2 Connecting CESA to ECS

3.2.2.1 Developing and Defining CESA.

In previous iterations of ECS programming, student action projects focused predominantly on direct actions intended to provide immediate, tangible impact through mitigation or prevention of community environmental challenges. Research of student learning associated with this programming identified agency as a predominant student outcome (Gallay et al., 2022; Gallay et al., 2024). Because addressing socio-environmental problems requires students to understand and engage with the institutions, policies, and decision-making processes that shape environmental conditions, ECS programming in this study shifted to focus on students' civic/political engagement and public advocacy. Therefore, the intention was to have students take indirect actions to influence community policy, practice and decision-making. In this context, student agency as an outcome was conceptualized to include developing the capacity to use science and civic skills, understanding power and responsibility, and participating collectively in making decisions about and taking action to influence the environmental conditions of their communities. I defined this outcome as CESA.

My conceptualization of CESA builds on and extends theories of agency in science education, specifically, ESA and CSA (presented as a comparison in Table 1). ESA refers to students' understanding of and identification with the natural environment and their belief in their ability to address sustainability issues through inquiry, data gathering, and action. It involves understanding inquiry practices in conservation and ecosystem health, developing expertise and "roles" in environmental science, and using environmental science expertise and conservation practice as a foundation for change (Ballard et al., 2017). CESA incorporates the environmental/sustainability focus of ESA and its grounding in environmental science practice, but drawing on CSA, specifically incorporates a justice orientation.

CSA extends the use of science knowledge and practice for community action by emphasizing how young people's application of science is linked to justice and can take a political stance (Ballard et al., 2017; Gyles, 2024; Schenkel & Calabrese Barton, 2020). It is positioned as a form of agency wherein young people individually and collectively use their scientific knowledge and practice, along with other forms of expertise, to investigate and address injustice in their lives and communities (Basu et al, 2009; Schenkel et al, 2019; Schenkel & Calabrese Barton, 2020). In developing CSA, students deepen their understanding of scientific concepts and inquiry and build the capacity and motivation to act at both individual and community levels on justice-oriented issues they identify (McNeil & Vaughn, 2012; Basu et al., 2009). CESA incorporates the justice orientation of CSA but focuses specifically on socio-environmental and EJ issues.

CESA brings these constructs together in the specific context of socio-environmental decision-making. It emphasizes students' capacity to use environmental science and civic practices to collectively participate in decisions about community environmental conditions. CESA also involves young people's ability to leverage civic knowledge, skills, and dispositions. Thus, I also draw on civic and political efficacy in its conceptualization, i.e. the belief that individual and collective efforts can impact civic and political life (Bandura, 2000). CESA therefore includes: knowledge of human interdependence with natural and built environments; an intentionally collective approach to action; understanding of institutions and decision-making processes; civic and political efficacy; and using scientific and civic knowledge and practice to work toward more just and sustainable communities.

The decision-making focus of CESA matters because socio-environmental challenges are not only problems of knowledge or behavior; they are also problems of governance, infrastructure, policy, accountability, and power. Students may understand water quality, flooding, pollution, or heat exposure scientifically without understanding who has authority over these issues or how communities can intervene in their solutions. CESA therefore encompasses scientific competence, civic competence, collective efficacy and sociopolitical control and names a form of agency in which students begin to connect environmental evidence to community well-being, institutional responsibility, and collective action.

In socio-environmental contexts, agency becomes justice-oriented when students enact their rights to participate in decision-making and to ask who is harmed, who benefits, who decides, whose knowledge counts, and which institutions are responsible for change. This orientation matters because environmental harms and protections are distributed through policy, infrastructure, public investment, regulation, and political voice. A student may develop environmental knowledge without developing a critical understanding of how environmental conditions are produced, maintained, or governed.

The justice orientation of CESA is important for two related reasons. First, injustice is widely recognized as a root cause of many socio-environmental challenges (Martin et al., 2020), including the injustice of the exclusion of marginalized voices from participation in environmental decision-making processes. Second, as scholars of CSA have argued, incorporating questions of justice into science classrooms can reimagine science learning through a more critical lens and expand whose scientific knowledge and expertise are recognized and valued (Schenkel et al., 2019; Vossoughi & Shea, 2019). I contend that developing CESA can promote justice in environmental decision-making by evaluating environmental issues from a more critical lens and expanding on whose expertise and insights are valued in community environmental decision-making.

Table 3.1 Comparative Framework of Science Agency Constructs

Construct	Core focus	Justice/critical stance	Action context	Illustrative indicators
ESA	Developing identity, competence, and roles in environmental science to address sustainability	Not inherent; may be present depending on program	Inquiry-to-action grounded in environmental science practice	Rigorous data collection; analysis of social–ecological systems; communicating findings to authentic audiences; seeing oneself

	issues through inquiry and action			as capable environmental investigator (Ballard et al., 2016, 2017)
CSA	Using science learning to analyze and act on inequity; science as political and justice-oriented	Central	Individual and collective action on justice-oriented issues (not necessarily environmental)	Entitlement to voice; critique of inequities; individual and collective action; using science to pursue social change (Basu et al., 2009; McNeil & Vaughn, 2012; Schenkel & Calabrese Barton, 2020)
CESA	Using environmental science + civic practice to address socio-ecological sustainability and environmental injustice in community and policy/practice	Central and explicitly environmental	Environmental science-informed inquiry based collective action and participation in environmental decision-making	Entitlement to voice; Environmental + civic efficacy; analysis of socio-environmental issues; public advocacy using evidence; using environmental science for social change; participation in local community decision-making; EJ-oriented framing (drawing from ESA + CSA)

3.2.2.2 Environmental Civic Science: Theory and Pedagogy

To cultivate CESA in school settings, I offer ECS as a pedagogical framework that integrates the application of environmental science and civic knowledge through community-centered investigation and collaborative action on local environmental issues. The ECS framework draws from scholarship and practice in environmental education, community-driven science, place-based education, and environmental action civics, which focus on students directly engaging in learning and action that address community needs. ECS also shares affinities with justice-oriented science education in that it gives young people opportunities to apply learning to contribute meaningfully to their communities, assert visions for community improvement and challenge injustice (Morales-Doyle, 2017; Schenkel et al., 2019).

I argue that ECS is uniquely suited for developing students' CESA because it incorporates relevant theory and practice from each of the above approaches into a comprehensive pedagogical framework. ECS embraces a community-driven, civic approach to science learning by centering on environmental issues in the spaces and places where students live and learn and the knowledge and motivations that community members (including youth) bring to the process. Its goals are to develop students' environmental and civic literacy and nurture their capacities for and confidence in science-informed collective action (Gallay et al,

2025; Flanagan, et al, 2021). Consistent with the orientation of its predecessor, civic science, ECS emphasizes science for the public good and community involvement in defining relevant issues (Garlick & Levine, 2017; Levy et al, 2021; Trott et al., 2024). ECS also holds promise for advancing environmental political engagement because it positions science as serving civic (common-good) goals and asserts that the residents of a community should have agency in determining those goals.

ECS accomplishes these goals via the following core elements:

1. Local environmental inquiry: Students investigate and gather data on environmental issues in the places where they live, contextualizing environmental issues within their immediate community.
2. Collaboration with community partners: Students work with community organizations, local experts, and community members actively involved in addressing environmental issues.
3. Engagement with local decision-makers: Students identify and engage with people who have authority or influence over environmental decisions in schools or communities.
4. Collective public action with peers: Students work together to apply their data, develop arguments for change, and communicate evidence-based calls to action through advocacy campaigns

3.2.2.3 ECS as an Educational Framework for Developing CESA

Relevant scholarship in community-driven science and community youth development suggests that the core ECS practices should develop CESA in students. For example, students' science agency is strengthened when they apply knowledge to local challenges, collect relevant data, and communicate their findings to authentic audiences (Ballard et al., 2016; Morales-Doyle, 2017). And young people's civic and political efficacy develops when community-based organizations emphasize relationships and structures of shared authority in which young people experience voice and respect (Eccles & Gootman, 2001). The ECS framework intentionally brings these (science and civic) strands together, positioning it as a promising approach for cultivating key aspects of CESA.

Data gathering in ECS emphasizes various kinds of local community-based/driven environmental monitoring and recognizes that the perceptions and experiences of the people (including youth) who inhabit that community hold knowledge that should count in

environmental decision-making. When adults and institutions such as schools treat youth-generated evidence and interpretations as legitimate, youth's voice in their community's environment is reinforced, an element essential to CESA. Therefore, to cultivate CESA, young people need opportunities and support to speak up, be heard, and to get public recognition for their contributions. ECS provides such opportunities, linking science learning with local action, potentially fostering environmental political engagement and supporting students' CESA.

Civic science approaches such as ECS also increase the relevance and credibility of inquiry and strengthen the potential for translating findings into policy and practice (English et al., 2018). In ECS, students' production of evidence is not an endpoint; it becomes a resource for civic work. Applying the data students gathered to advocacy efforts links this evidence to public forums, where others can hear and react to it. As youth generate, interpret, and communicate locally relevant data to decision-makers, they are positioned to use environmental science as a civic resource, making claims, anticipating counter arguments, and justifying proposed solutions in institutional settings. In this way, ECS provides a concrete pathway from environmental science efficacy to civic and political efficacy.

When students engage in ECS, they are practicing collective learning/action; from beginning to end students work in peer teams and with adults from community-based organizations. This emphasis on collaboration is at odds with the typical focus on individual learning in schools. But as noted earlier, a community's socio-environmental challenges are collective action problems that beg the question, "What should WE do". For young people to engage in their community's socio-environmental decisions, they have to identify themselves as part of that "WE", i.e., members of the community who care about and contribute to it. They also need to practice working with others, honoring their experiences, listening to and respecting their perspectives, and finding common ground. Thus, the goal of collective learning/action in ECS is to cultivate students' scientific and civic dispositions, their identities as members of a larger community with motivations to contribute to it, and their skills and confidence in working with others to effect change, all components of CESA (Gallay et al., 2025).

ECS is especially relevant because environmental problems are not only technical or scientific problems. They are also civic, political, and justice-related problems shaped by institutional decisions, public policy, infrastructure, and community participation. To cultivate CESA I contend that young people need opportunities and support to speak out, challenge the

status quo, and experience public recognition for their contributions. ECS therefore provides a concrete educational context for examining whether and how students develop CESA.

Though it holds promise, empirical investigation into ECS as a classroom pedagogy is limited, especially regarding student outcomes. This study addresses that gap by examining whether ECS is associated with the development of CESA and how students enact and express that agency in practice.

3.3 Methods

3.3.1 Study Design

This mixed-methods study examined whether participation in ECS was associated with growth in students' CESA-related outcomes in high school science and social studies classrooms. Because I conceptualize CESA as both outcomes that can be voiced (e.g., efficacy, entitlement to voice) and observed through enactment (e.g., using environmental science process, collective action), this design integrates quantitative data and qualitative data to examine change over time, students' expressions of CESA, and students' enactments of CESA within ECS program experiences.

Random assignment of students was not feasible because participation was based on whether teachers had participated in ECS professional development and implemented ECS in their courses. Thus, a quasi-experimental design was used (Cook & Campbell, 1979) to compare students who participated in ECS as part of their standard science or social studies class with students who received standard instruction in comparison classes in the same schools. Comparison classes served to contextualize and strengthen interpretation of patterns observed for ECS students. Findings are interpreted as associations between ECS participation and differential growth, rather than causal effects.

I aimed to answer the over-arching research question: To what extent and how do students develop CESA through ECS?

Specifically, I ask:

1. To what extent is participation in ECS associated with growth in students' CESA-related outcomes?
2. How do students enact CESA during ECS participation?
3. How do students express CESA as an outcome associated with ECS participation?

3.3.2 Research Context

Prior to the present study, the ECS curriculum/process implemented in this study and its theoretical foundations were developed and iterated over several years by a research-practice team of classroom teachers, community-based nonformal educators, university researchers, student participants, and the Southeast Michigan Stewardship Coalition (SEMIS), a regional leader in place-based education. Before implementation, all participating teachers attended a five-day ECS summer institute that I co-planned and co-facilitated with the ECS research-practice team. The institute introduced ECS theory and guided teachers through the ECS curricular process. Teachers then adapted ECS for their content areas and classroom contexts while maintaining the core elements and overall sequence of the ECS process. Through co-planning sessions, I worked with each teacher to support these adaptations.

This collaborative infrastructure supported my role as a participant-observer (Atkinson & Hammersley, 1998). In addition to co-planning and facilitating professional development, I was present in classrooms during implementation, co-planned sessions with teachers and community educators, supported and occasionally led ECS activities, and documented ECS enactment. As a methodological stance, this orientation reflects recommendations from community-engaged, participatory, equity, and environmental justice scholarship that research be designed through partnerships with community members and grounded in local contexts (Bacon et al., 2013; Calabrese Barton et al., 2020; Israel et al., 2012; Lau & Stille, 2014; Vakil et al., 2021).

My participant-observer role gave me close access to ECS enactment, but it also meant that I was not a detached observer. I helped design, facilitate, and study ECS, and my involvement may have shaped implementation, student participation, and interpretation. To address this, I maintained descriptive notes throughout data collection, triangulated across survey data, classroom observations, and student reflections, and treated qualitative findings as evidence of students' learning and participation rather than as neutral records of program effects.

3.3.3 ECS Implementation

ECS was implemented within standard science and social studies classes as a project-based curricular process that followed an arc from local environmental inquiry toward community problem-solving and public advocacy. In each class, students worked collectively in peer teams and collaborated with adults from community-based organizations to identify and investigate local environmental issues, gather and interpret relevant scientific and civic

information, learn about and interact with local decision-makers and environmental policies, develop solutions through proposed changes in community policy or practice, and engage in advocacy through calls to action in public forums.

In their ECS programming, all teachers incorporated the four core ECS elements: local environmental inquiry, engagement with local decision-makers, collaboration with community partners, and collective public action with peers. However, implementation varied across sites. Some classes emphasized inquiry into school-based water issues and presented to district staff and leaders; others emphasized municipal water governance through City Hall or water utility visits; others emphasized environmental monitoring and community education. These differences matter analytically because they shaped the opportunities students had to identify decision-makers in different roles, apply environmental science knowledge and skills to different contexts, and experience their work as impactful in different ways.

3.3.4 Sites, Sample, and Recruitment

I recruited teachers from four high schools in Southeast Michigan, including one rural, one suburban, and two urban schools. One teacher was part of the ECS iterative development team and had prior experience with ECS; the other four were new to ECS and place-based instruction.

ECS was implemented by these five teachers across four schools in the following subjects: earth science (6 classes), biology (7 classes), experimental science (1 class), world history (5 classes), and environmental justice (1 class). All ECS activities occurred during regular school classes, thus students did not self-select into ECS and participation was not dependent on pre-existing interest.

Student demographic data (based on self-reports) indicated a diverse sample: 50% female, 47% male, and 3% another gender identification; 55% White, 16% Black, 6% Latine, 2% Asian/Pacific Islander, 2% American Indian/Native Alaskan, and 18% two or more race/ethnicity categories.) Students represented grades 9–12 (9th: 28%; 10th: 46%; 11th: 19%; 12th: 7%) and multiple academic levels (advanced, conventional, foundational). Three of the four schools served a majority (>60%) “economically disadvantaged” student population based

on eligibility for free/reduced lunch; the remaining school served a 45% "economically disadvantaged" population.

3.3.5 Data Collection and Measures

3.3.5.1 Quantitative Data

Data Collection. I collected pre/post survey data from students enrolled in ECS classes and from students enrolled in comparison classes in the same schools, grade levels, and subject areas. Surveys were administered in person during regular class time at the start and end of ECS programming. Prior to administration, I explained that the survey was an opinion survey, not a test; that there were no right or wrong answers; that students could decline participation or skip items; and that responses would not affect grades.

Matched pre/post data were available for 310 ECS students and 241 comparison students, for a total matched sample of 551 students. Students who did not complete both a pre and post survey (e.g., absent on one administration day) were excluded from repeated-measures analyses. I examined baseline demographic characteristics for the matched sample and between-group comparisons (ECS vs comparison) at pre- on the variables of interest in this study and found no statistically significant demographic differences between ECS and comparison groups.
Measures. I treated CESA as a multidimensional construct. The survey measures did not capture CESA in its entirety; rather, they assessed four CESA-aligned dimensions: environmental action frequency, competence to address community water issues, sociopolitical control, and capacity to take action for environmental change. Although CESA is conceptualized as justice-oriented, the quantitative measures used in this study primarily captured this justice orientation through sociopolitical control and feelings of collective power and efficacy to act, not through capacities to address issues of justice specifically. I interpret these aspects of CESA as justice oriented because they measure, in part, a marginalized groups' (young people) capability to access resources and actively shape policies. Further justice-oriented dimensions of CESA were examined more directly through qualitative data, including students' references to accountability, rights, institutional responsibility, and demands for change.

All pre/post measures were adapted or drawn directly from previously validated scales selected to tap core dimensions and expressions of CESA. These included environmental action, competence to address community water issues, sociopolitical control, and capacity to take action for environmental change. Each of these constructs was examined through exploratory

factor analysis (EFA) using principal axis factoring, to verify their structure after item adaptation and within the current sample (Netemeyer, et al, 2003). All alphas > .80; all total variance > 60%) Details for each scale are shown in Table 2.

The *Environmental Action* scale was used to assess students' participation in civic actions designed to impact environmental issues. The question stem asked students to report on their environmental action behaviors over the last 6 months, measuring frequency of actions students engaged in before their ECS experiences (at pre) and during/after their ECS experiences (at post).

The *Competence to Address Community Water Issues scale* assessed students' belief in their ability/competence to engage in civic actions to address community water issues, through a skills-based measurement of students' civic efficacy. Insofar as ECS inquiry began with water as a focus, the question stem for this scale was intentionally specific to water issues.

The *Sociopolitical Control/Political Efficacy* scale was used to assess students' perceptions of their ability to influence social and political systems in their community. The intent of ECS is to impact students' sense of agency, including sociopolitical control, across community contexts. The use of this construct reflects an assessment of whether students' CESA development was transferable to community decision-making in general.

The *Environmental Agency/Capacity to take Action* scale assessed students' feelings of competence, drive, and individual/collective power as a measurement of agency regarding environmental issues. This construct and scale were used, in part, because although ECS as practiced in this study focused initially on water issues, students' actions were open to focus on any environmentally related issue. The use of this construct reflects an assessment of whether students' CESA development was transferable to any environmental issue.

Survey items used either: a 7-point Likert-type agreement scale (1 = strongly disagree, 7 = strongly agree) for self-reflection items, or a 5-point frequency scale (0 = never, 4 = very often) for behavioral/action items.

Table 3.2 Quantitative Measures, Response Options, Items, and Reliability (Analytic Sample)

Construct (used in analyses)	**Scale source (adaptation)**	**Response options**	**No. items**	**Representative item**	α	**% variance explained**

Environmental action (enactment)	Environmental Action Scale (Alisat & Riemer, 2015) + items added to reflect ESA-aligned actions	4-point frequency: 0 = *Never* to 3 = *Very often*	9	"In the past six months, how often have you participated in environmental actions (like planting trees or testing water)?"	.83	62.16%
Competence to address community water issues (civic skills/ability)	Competence for Civic Action (Flanagan et al., 2007) / California Civic Index (Kahne et al., 2005), adapted to water issues	7-point agree: 1 = *Strongly disagree* to 7 = *Strongly agree*	5	"How likely could you gather information about the water problem?"	.89	64.81%
Sociopolitical control (political efficacy)	Sociopolitical Control Scale Youth, policy control dimension (Peterson et al., 2011), items deleted	7-point agree: 1 = *Strongly disagree* to 7 = *Strongly agree*	6	"I am able to participate in decisions that affect my community."	.92	65.62%
Capacity to take action for environmental change	Civic Agency Measure (Wegemer et al., 2025), adapted to environmental issues	7-point agree: 1 = *Strongly disagree* to 7 = *Strongly agree*	11	"Groups of young people like me have the power to address environmental issues in my community."	.95	65.44%

Note. SD = strongly disagree; SA = strongly agree. Factor fit/variance refers to the total variance explained by a single-factor solution via Principal Axis Factoring. Scale scoring followed original authors' guidance.

3.3.5.2 Qualitative Data

Data collection. Qualitative data sources included (a) participant-observation fieldnotes (Atkinson & Hammersley, 1998) from approximately 90 sessions and (b) students' responses to three open-ended reflection prompts. Field notes of observations were collected throughout the ECS programming implementation, and reflection questions were collected after completion of all ECS programming.

Measures. Observational field notes incorporated classroom and field-based sessions, including presentations of students' public call-to-action advocacy campaigns. Students' open-ended responses answered the following prompts:

1. "What are some ways this way of learning was different from other science or social studies classes you have taken?" (n = 251)
2. "What are some things you and other young people could do about the problem?" (n = 297)
3. "In your opinion, what are the most important things you've learned and why do you think they're important?" (n = 76)

*3.3.6 **Analytic Approach***

3.3.6.1 Quantitative Analysis

To address my first research question (to what extent is participation in ECS associated with growth in students' CESA-related outcomes) I used a longitudinal pre–post comparison design with condition (ECS vs. comparison) as a between-subjects factor and time (pre vs. post) as a within-subjects factor. I treated the analysis as a two-group repeated-measures design and used repeated-measures general linear modeling (GLM) to provide an estimate of average treatment (ECS) associated change. For each dependent variable (environmental action, civic skill ability, sociopolitical control, capacity to take action for environmental change) I compared the ECS program intervention in relation to the (non-intervention) comparison group. The focal test in each model was the Time × Condition interaction, which estimates whether change from pre to post differs between ECS and comparison students.

This design allowed me to (1) assess whether students in the ECS and comparison classes differed at baseline (pre-survey); (2) observe the growth in student outcomes for students in the ECS and comparison classes over time (from pre-to post survey) and (3) compare the pre/post changes or growth over time between ECS and comparison classes (Time x Condition interaction). GLM was used for intervention effect analyses because it is more flexible than ANOVA/regression and can manage non-normally-distributed outcomes (Stroup, et al, 2024; Thompson, 2006).

The repeated-measures GLM models accounted for repeated observations over time within students, but they did not account for nesting of students within classrooms, teachers, or schools. Multilevel models were considered but could not be used because the number of higher-level units was too small and class sizes varied substantially. In the limitations, I return to the implications of nesting and the need for replication with larger numbers of classrooms/teachers.

I evaluated assumptions relevant to repeated-measures GLM including: independence of observations, normality of residuals, homogeneity of variance and sphericity. I inspected distributions and residual plots; no departures were observed that warranted transformation (Thompson, 2006). I compared group variances at pre and post with a mixed-design ANOVA. Given the similarity of variances across conditions, I retained the standard GLM specification. Because the within-subject factor (time) has only two levels, sphericity is automatically satisfied.

I used $\alpha = .05$ $(p - value)$ for significance tests and report partial eta-squared (η_p^2) as an effect size for the Time × Condition interaction. I interpret η_p^2using conventional benchmarks (Cohen, 1988) (approximately .01 small, .06 medium, .14 large).

3.3.6.2 Qualitative Analysis

To address Research Questions 2 and 3, I analyzed field notes and students open-ended reflection responses through an iterative process combining inductive and deductive coding, moving between field notes of observations and student reflections to generate and refine themes (Kushnir, 2025). Across data sources, I used multiple rounds of reading, memoing, team discussion, theme generation and code refinement.

First, I read across field notes and open-ended responses and wrote analytic memos to identify initial patterns in students' observed and described actions and interpretations of their experiences. These memos attended to moments when students used science and civic practices, demonstrated or expressed scientific and civic understanding, worked collectively, identified decision-makers, expressed efficacy power and agency, noted their civic or scientific skill ability, or connected environmental issues to community concerns.

Next, I used open coding to segment themes from the memos into initial categories (Braun & Clarke, 2006), including both CESA-related and non-agency-related themes. Initial coding for field notes included environmental monitoring, campus observation, neighborhood documentation, interviewing, teamwork, public speaking, identifying decision-makers, expressing efficacy, taking collective action, and connecting evidence to advocacy. Two members of the research-practice team generated an initial list of emergent categories identified in student reflections including: firsthand/local experience, hands-on learning, references to the value or usefulness of the students' project work to the real world, valuing teamwork, collective efficacy, being heard, community connection, community partners/social capital, human impact/interdependence, using/applying science, science understanding, confidence, indications of civic learning, expressions of scientific knowledge; and connections to justice.

Agency emerged as a major organizing theme, and subsequent coding incorporated deductive categories drawn from the theoretical dimensions of CESA. These included environmental science practice, civic competence, sociopolitical control, collective efficacy, decision-making knowledge, motivation, and public advocacy. This deductive coding helped

connect emergent student language and observed practices to the theoretical dimensions of CESA.

I used axial coding to organize my interpretation of student data into broader analytic themes, merging some of the codes and collapsing others to categorize student learning in themes relevant to this paper. For example, codes such as “water testing,” “campus observation,” “mapping,” and “comparing to official data” were grouped under “environmental action: generating evidence of local environmental conditions.” Codes such as “talk to the school board,” “city hall,” “who makes decisions,” and “people in charge” were grouped under “sociopolitical control: identifying civic pathways and decision-makers.” Multiple rounds of coding refined categories and supported the development of final analytic themes reported in the results section (Kushnir, 2025; Miles & Huberman, 1994).

Finally, I developed claims by examining whether themes were supported across data sources. For example, the claim that ECS appeared to support students’ sociopolitical control was grounded in student reflections naming decision-makers, observation notes documenting decision-maker engagement and student advocacy targeting specific audiences as well as growth in quantitative measures of sociopolitical control.

3.4 Results

Results are organized in two parts. First, I report quantitative evidence of differential pre/post change between ECS and comparison students across the four CESA-aligned outcomes. Second, to support and expand on these quantitative results, qualitative findings are presented in four categories that map to the quantitative outcomes but also capture additional dimensions of CESA expression that do not fit neatly within the survey constructs. These qualitative findings both triangulate the survey results and extend them by showing what CESA looked like in practice. These themes illustrate (a) students enactment of CESA, including how they used/leveraged science in civic inquiry through environmental action, and (b) how students expressed their own agency for action, including their skills and abilities in the procedures of civic engagement, understanding of civic pathways and decision-making, reasoning about power and accountability and expressing collective capacity.

3.4.1 Quantitative Results

3.4.1.1 Results of Repeated Measures GLM for Students in ECS and Comparison Classes

As reported in Table 3, across all outcomes, ECS and comparison students showed similar baseline (pre-test) means; none of the pre-test group differences were statistically significant. This baseline equivalence strengthens the interpretation of the Time × Condition interaction as reflecting differences in growth over time associated with ECS participation.

At post-test, ECS students exhibited positive change over time, reporting significantly higher mean levels than comparison students on all outcomes. Notably, in one case (civic skill ability), comparison students showed slight declines (though not significant) over time while ECS students increased significantly. There was a statistically significant interaction effect between time and group (Time × ECS Condition) for all dependent variables, as reported in Table 3 and in outcome-specific results below.

3.4.1.2 Outcome-Specific Results

Environmental action frequency. The Time × Condition interaction was statistically significant, $F(1,536) = 58.02$, $p = <.001$, $\eta_p^2 = .10$, indicating that ECS participation was associated with greater growth in students' reports of environmental action frequency when compared to pre/post change in the comparison class. By conventional benchmarks (Cohen, 1988), this partial eta-squared ($\eta_p^2 = .10$) reflects a medium-to-large effect suggesting meaningful differential growth associated with ECS participation.

Competence in addressing community water issues (civic skill ability). The Time × Condition interaction for this outcome was statistically significant, $F(1,541) = 50.30$, $p = <.001$, $\eta_p^2 = .09$ indicating that, compared to pre/post change in the comparison classes, ECS participation was associated with greater growth in students' feelings of civic efficacy around water issues, i.e., students' belief in their ability to accomplish civic-engagement tasks associated with water. This partial eta-squared ($\eta_p^2 = .09$) represents a medium effect.

Sociopolitical control (political efficacy). The Time × Condition interaction was statistically significant, $F(1, 540) = 34.43$, $p < .001$, partial $\eta^2 = .06$, indicating that participation in ECS was associated with significantly greater growth in students' perceived ability to influence social and political systems in their communities when compared to pre/post change in the comparison classes. The effect size ($\eta^2 = .06$) is in the medium range.

Capacity to take action for environmental change. The Time × Condition interaction was statistically significant, $F(1, 540) = 29.82$, $p = <.001$, partial $\eta^2 = .05$ and demonstrated a small-to-medium effect. These results indicate that participation in ECS was associated with greater growth in students' capacity, including their competence, drive and power to take action for environmental change.

Table 3.3 Means, Standard Deviations, and Repeated-Measures GLM Time × Condition Effects by Outcome

Outcome	Group	Pretest *M (SD)*	Posttest *M (SD)*	*F* (1, df)	*p*	ηp²
Environmental Action	Comparison	0.75 (0.64)	1.04 (0.82)	58.02 (1, 536)	< .001	.10
(0-3 response scale)	ECS	0.91(0.79	1.84 (0.94)			
Civic skill ability	Comparison	3.68 (1.29)	3.49 (1.25)	50.30 (1, 541)	< .001	.09
(1-7 response scale)	ECS	3.79 (1.27)	4.48 (1.34)			
Sociopolitical Control	Comparison	3.38 (1.25)	3.49 (1.28)	34.43 (1, 540)	< .001	.06
(1-7 response scale)	ECS	3.52 (1.24)	4.34 (1.36)			
Environmental Agency	Comparison	3.29 (1.30)	3.45 (1.26)	29.82 (1, 540)	< .001	.05
(1-7 response scale)	ECS	3.48 (1.26)	4.29 (1.35)			

Note. Time × Condition effects are from repeated-measures general linear models (GLM) with Time (pre/post) as the within-subjects factor and Condition (ECS vs. comparison) as the between-subjects factor. ηp² = partial eta squared.

3.4.2 Qualitative Results: What CESA Looked Like

Qualitative data provided information about how students enacted and expressed CESA during ECS. Empirically, CESA appeared in both student practice and student reflection. In practice, students enacted CESA when they collected local environmental data, interpreted that data in relation to community concerns, identified people or institutions with decision-making authority, and used evidence to develop public calls to action. In reflection, students expressed CESA when they described themselves and their peers as capable of gathering information, making proposals, contacting decision-makers, mobilizing others, and advocating for changes in policy or practice. Thus, CESA was analyzed as a practiced form of agency visible through students' participation in inquiry, collaboration, civic navigation, and public advocacy.

Across observations and open-ended responses, students descriptions and demonstrations of CESA are organized under five interrelated themes: applying environmental science practices to local issues, connecting scientific evidence to public problems, using evidence in civic advocacy, developing confidence in civic skills, expressing sociopolitical control and identifying pathways of decision-making and expressing collective agency and power.

3.4.2.1 Applying Environmental Science Practices to Local Issues

Classroom observations showed students applying environmental science knowledge and practices to issues in their schools, neighborhoods, and communities. Early in the ECS process, every class took an observational walk of their school campuses to look for evidence of water issues. Observational field notes detailed students documenting standing water, erosion, stormwater infrastructure, mineral staining, litter, and other signs of water-related issues. In this way, students enacted CESA by generating evidence of community environmental concerns, actively engaging in recording real-world scientific data.

Students in three classes also documented evidence of water issues in their neighborhoods and around town. In one case, a student connected their observations directly to lived experience, noting, “I live right by the river and it smells kind of like fish.” This kind of statement matters for CESA because it shows how environmental science practice became tied to students’ own places, observations, and concerns. The act of documenting water issues in students’ own neighborhoods, representing their lived realities, signals autonomy and authentic concern and reflects students’ application of environmental science to their local context. Students were not studying generic water issues; they were investigating environmental conditions they could see, smell, use, and experience.

Half of the classes also collected samples from school water fountains and local surface water, conducted water-quality analyses and compared their results to official standards or reports. Students noted findings such as “The oxygen is low” and “The water is safe but it tastes bad”. In this way students practiced community-based monitoring, exercising agency and connecting to the critical component of CESA as they chose where to monitor and what to look for. These activities mattered because they positioned students not only as learners of environmental science content, but as producers of scientific evidence about places they knew, providing oversight or acting as watchdogs of community conditions.

Student reflections suggest that this local documentation and generation of evidence of environmental concerns changed how students understood their role in science learning. One student wrote, “We actually went out and collected data outside of the classroom.” Another explained, “We also worked hands on by doing experiments and going outside to observe issues within our school.” These responses show students identifying their own participation in environmental science practices rather than acting as only recipients of scientific information. These statements also show that students recognized themselves as people who could generate situated knowledge about local environmental conditions. This matters for CESA because agency began from students’ own relationship to place and their decisions about what evidence mattered.

3.4.2.2 Connecting Evidence to Public Problems

Students also enacted CESA by connecting environmental evidence to public problems. Across all classes, students interpreted why their findings mattered for people, institutions, and community well-being. For example, students in biology classes investigated the water quality of their school retention pond by making observations and conducting water quality tests, including levels of dissolved oxygen. They then connected the look and smell of the pond to the appearance of the school grounds and the school’s reputation by asking their peers and family members what they thought and felt about the pond and the school. They connected the results from their dissolved oxygen tests to the ponds ecological viability and the effects this had on local wildlife. One student captured this type of connection between investigation and public purpose by explaining that ECS was different because “with our research we actually are pushing for the problem we want to fix.” This response suggests that students understood their research as more than an academic exercise. The evidence they gathered became a resource for action. This interpretive step shows enactment of CESA because, sense that the issues they addressed were real, relevant, and connected to the change they wanted to propose.

3.4.2.3 Applying Evidence to Civic Advocacy

Students’ enactment of CESA was especially visible during their calls to action, when classes presented advocacy campaigns to decision-makers and community members. Students used multiple forms of evidence in advocacy, including water test results, observations, maps, interviews, surveys, official reports, cost research, health information, and community concerns.

In some cases, they presented to people with direct authority over the issue, such as school administrators, facilities staff, superintendents, school board members or city staff. In other cases, they presented to broader public or community audiences. Students selected what evidence to include, how to frame it, and why it mattered, demonstrating scientific reasoning. This required students to combine environmental science knowledge with civic communication, audience awareness, and strategic argumentation.

Students' reflections suggest that this public use of their data as evidence in advocacy mattered. One student reflected that "there were lots of adults in charge looking at our work and commenting on it, thinking about how to do it." These responses suggest that students understood their work as more than classroom inquiry; they saw their evidence as something that could support advocacy and public communication. This shows students enacting CESA as evidence-based public participation. Students were not only learning environmental science or expressing opinions about environmental issues. They were using evidence to make claims in civic contexts.

3.4.2.4 Civic Skill Ability and Procedural Confidence

Students also expressed CESA through growing confidence in specific civic skills. Students noted that they would be able to take the practical actions that are part of and facilitate civic engagement, like information-gathering (data collection, research) and communicating (presenting, written communication), such as the student who noted that to address a community water issue they could "make a proposal, talk to people in charge." Others referenced activist and organizing abilities such as "Make petitions, write emails" or "Start a protest so people will hear us." These responses indicate students' belief in their ability to succeed at specific civic tasks, showing confidence in procedural and collective action skills. These responses suggest that students' agency included procedural knowledge: students could name specific actions they might take to influence environmental issues.

A second, recurring category under this theme addressed students' abilities in coalition building. One student wrote they could "get more young people rallied behind the cause," indicating readiness to speak up and influence others. Some students referenced their abilities through more explicit strategies for building power and visibility, including "Talk to local organizers" and "Try to get media attention" indicating a belief in their capacities for activism at the social and political level.

Finally, many students explicitly connected scientific evidence to advocacy as a key ability, noting they could "Learn about the problem and advocate it to get more people to hear." Another explained they could "Collect information concerning issues within our community and data to prove these issues are of concern. We could build advocacy and get others involved in solving the issue." This response is especially important because it links evidence to civic strategy and reflects students' belief that they can initiate action, recruit others, and contribute to solving community issues. This integration of evidence-building with persuasion and mobilization reflects a CESA-relevant form of efficacy as competence: students' belief that they can do the work of civic engagement and that science strengthens their ability to make a case for change.

3.4.2.5 Sociopolitical Control and Pathways for Decision-Making

Students also expressed CESA through developing sociopolitical control and identifying pathways of decision-making. Across observations and reflections, students named specific decision-makers and institutions involved in water and environmental issues. These included city hall, school boards, facilities staff, principals, superintendents, water utility staff, city council members, ward representatives, and community-based organizations. Students also demonstrated increased knowledge of local civic structures and power relationships. Many students named who was responsible for water decisions in their city or school. For example, students described some of the most important things they learned as "Who's in charge of water in our city" and "Who makes decisions on our water and why." These responses show an emerging understanding of the civic landscape related to environmental issues and reflect a form of sociopolitical control grounded in procedural knowledge of decision-making. They also suggest that building students' CESA involved learning where decisions were made and who had responsibility for the issues they were studying.

Students also identified concrete civic pathways for influence. Some described actions such as "make a proposal, talk to people in charge," "continue to talk to the board members," and "make our own case to Bob," the school maintenance director. These responses show that students were beginning to connect environmental issues to specific audiences, strategies, and institutional entry points. They were learning how responsibility and authority are organized locally and displaying their confidence in engaging with people in positions of power, thus reflecting sociopolitical efficacy.

Students' reflections also indicated an emerging sense that they could participate in and influence the systems where environmental decisions are made. Students referenced using what they learned "to help influence decisions by government," and some described ECS as different because data collection was explicitly linked to policy implications: "It used data collection to gather results and explained how these results can be significant and lead to changes in government policies." These responses suggest ECS supported students' belief that environmental science practices matter in civic and political contexts.

Field notes of classroom observations provide context for these responses. Across ECS implementation, teachers and community partners created opportunities for students to learn about decision-making structures through power-mapping activities, City Hall visits, water utility tours, school facilities discussions, and preparation for call-to-action presentations. In some classrooms, students learned that school water systems were connected to federal drinking water requirements, district maintenance decisions, and school board funding priorities. In others, students learned how city departments, water treatment facilities, and local officials shape water infrastructure, runoff management, lead service line replacement, and public environmental policy.

Some responses directly show a view of civic institutions as responsive to young people and their ideas. One student noted, "City hall … takes input from younger people", reflecting a confidence in navigating sociopolitical systems and views of these institutions as an arena where they can play a role in shaping decisions. At the same time, students' responses reflected a nuanced understanding of power. Many acknowledged that adults and institutions hold formal authority while still asserting that youth can engage those structures: "contact higher up people… give our ideas to people who can do something about it".

Another response pointed to a realistic view of adolescents' role in representative politics, responding to what they could do about environmental issues in their community "we (most) aren't 18… so we technically don't have any power to vote or truly effect anything unless someone else gives us a chance to" acknowledging constraints youth face in the barriers of voting restrictions. The qualifier of being given "a chance" to effect change is important given the context of ECS programming. That qualifier points to a belief that young people can genuinely impact social and political contexts when they are not disempowered. Another student wrote, "I can't really do anything about it since I'm just a kid… go to someone who can actually

do something about it." These statements complicate the evidence of students' sense of sociopolitical control. They show that students were beginning to understand real power relations, not imagining unlimited power. Rather, some were recognizing both possible pathways for influence and the barriers that shape youth participation.

Taken together, these data show that students' CESA appeared in their ability to identify who makes decisions, where responsibility lies, and how young people might use evidence, proposals, and public advocacy to enter those decision-making spaces.

3.4.2.6 Capacity to Take Action for Environmental Change: Drive, Efficacy, and Collective Power

Evidence for students' capacity to take action for environmental change centered around three interrelated elements: drive (responsibility/motivation), efficacy/capacity, and collective power.

Drive (motivation/responsibility). Students often expressed an ethic of responsibility and a reason to act, linking their work to community well-being. For example, one student responded that their project was important because "it has a positive impact on EVERYONE in our community and the environment. I want the best for us and the world." Another described their collective motivation, stating "we all just wanted to do this for our community." Along with feelings of responsibility, student responses indicate their drive or motivation to contribute to community environmental well-being. Another student made an important distinction between learning *how to do* something (i.e. gaining the necessary knowledge and skills) and learning *to do something.* The student's statement that the most important thing they learned was *"*Learning to advocate for myself and my community" underscores their intentionality and commitment to changing community conditions.

Efficacy as ability. Students also consistently articulated feelings of efficacy, or a belief in their ability to effect change, with one commenting that "I learned I could make change and take action." Another student wrote, "We were able to actually speak and be heard." A third student specifically connected these feelings to their ECS efforts and the feelings of efficacy that engaging in ECS engendered*: "*It felt to me like our opinions actually could make a difference to the community." These responses align with the quantitative gains in capacity to take action for environmental change. They also help explain what those gains may have meant to students: not

simply feeling more confident in general, but feeling that their ideas, evidence, and collective work could matter beyond the classroom and could influence community change.

Students also explicitly invoked the power of the collective, exemplified by the student who stated, “I learned that when you come together as a team you can have a voice and be heard”. Another student’s response embodies the essence of collective community efficacy and reflects their belief in community-led efforts, “We could also do things ourselves within our community with neighbors and friends to fix any community or local problems.” This statement indicates a belief in their ability to self-organize and directly address environmental issues, underscoring a proactive and empowering vision of their agency.

Collective power. Students frequently referenced their power, and importantly, situated their collective power as an aspect of their identity as “youth” or a younger generation, such as the student who stated “I believe we are a more powerful generation.” Not only do students see themselves as agents of change, they also acknowledge their generation’s collective strength: “I learned that we can actually make a difference in our community... That's important bc as a teenager it's easy to forget the power you hold.” Another student noted “We could come together as a community and fix the problem and have more impact because we are the youth” indicating their belief in the unique power young people as a group hold but also that they view themselves as important players in community-wide efforts. These responses show that students were developing concepts of themselves as actors *with* power. This was explicitly stated by the student who commented that the most important thing they learned was “the effect we can have because it shows how much power we hold” summarizing this sense of collective power directly. These statements suggest that ECS appeared to support agency as relational and collective rather than purely individual. Students located power in working together, mobilizing others, and being recognized by public audiences.

Signaling a belief in their capacity to exert influence over school leaders, one student responded that they could “help pressure the principles.” The term “pressure” here connotes an active, deliberate exertion of agency, positioning students as agents with the ability to shape outcomes, rather than passive recipients of decisions made by authority figures. Another student mentioned that they could “demand it from the people in charge.” This language, that is central to community organizing and social change work, speaks to their sense of power vis-à-vis people who hold power.

Another student commented "We are able to force our ideas on the government." This response shows confidence in young people's ability to influence legislative or governmental processes, central to the environmental justice and civic dimensions of CESA. Another student extends their perceived power to the realms of economic and environmental justice, identifying influential actors and envisioning mechanisms for accountability: "force billionaires to pay a tax for carbon emissions." Taken together, these statements demonstrate students' perceived power to disrupt, challenge, or reform societal structures. They suggest emergent justice-oriented agency: students were beginning to imagine themselves and other young people as people who could apply leverage and press for change, not only ask for it.

Additionally, a few of the responses reflected perceived constraints on students capacity for change such as the student who said they could: "Delude ourselves into thinking we can make a difference." Views like this about constraints on student agency or capacities to make change are important because they both speak to the real restrictions and uneven access to decision-making students experience and show that CESA is not a guaranteed outcome of ECS. Finally, while not reported in detail here, some students' reflections did not reference any aspects of CESA, but instead referenced: human/nature interdependence, hands-on learning, working with community partners, collective/teamwork and affective learning.

Together, the findings show students' CESA as both collective and power-aware. Students expressed motivation, efficacy, and responsibility, but they also began to recognize that environmental change requires working with others, identifying people with authority, and navigating real constraints.

3.5 Discussion

This study examined whether participation in ECS was associated with growth in students' CESA-related outcomes and how students enacted and expressed CESA through participation in ECS. Across quantitative and qualitative data, ECS students showed stronger gains than comparison students in environmental action, civic skill ability, sociopolitical control, and capacity to take action for environmental change. Qualitative findings further suggest that students enacted and expressed CESA by generating local environmental evidence, identifying civic pathways, engaging decision-makers, and participating in collective public advocacy.

3.5.1 ECS Participation and Growth in CESA

In relation to my first research question, "To what extent is participation in ECS associated with growth in students' CESA-related outcomes?", ECS students showed significantly greater pre–post growth than comparison students across all measured outcomes. Effect sizes fell in the moderate range, suggesting meaningful differential growth (Cohen, 1988). These effects are consistent with, and slightly larger than, those reported in a meta-analysis of inquiry-based science education, where average effects were in the small-to-moderate range (Furtak et al., 2012).

These patterns suggest meaningful growth in students' CESA. Because this study used a quasi-experimental design, the findings should not be interpreted as causal evidence that ECS produced the observed changes. However, several features strengthen the interpretation that ECS participation was related to the differences observed. First, ECS and comparison students were drawn from the same schools, grades, and subject areas (science and social studies). Second, there were no significant baseline differences between the two groups on measured outcomes, i.e., the two groups had similar levels on environmental action, civic skill ability, etc. at the beginning of the study (before students in the ECS classes began their ECS work). Third the two groups were demographically similar in age, gender, race/ethnicity. The difference between the two groups was that one group of students engaged in ECS activities as part of their standard science and social studies classes and the other (comparison) group engaged only in standard science and social studies pedagogy.

The quantitative results in this study align with critical and justice-oriented science education scholarship, which argues that agency develops when students are positioned as legitimate participants whose scientific work matters beyond the classroom (Calabrese Barton & Tan, 2010; Schenkel & Calabrese Barton, 2020). Drawing from sociocultural perspectives (Wertsch et al., 1993), the results support an understanding of agency as *not* simply an internal trait that students possess but as developed through participation in activities through which students can have an impact and assess that impact. In short, youth develop CESA through their engagement in ECS work that impacts their communities and their own self-concepts.

3.5.2 Students' Enactment of CESA During ECS

In relation to my second research question "How do students enact CESA during ECS participation?" students enacted CESA through three interrelated forms of participation:

1. generating local environmental evidence

2. identifying and navigating civic pathways, and
3. engaging in collective public advocacy.

First, students enacted CESA by applying environmental science practices to local community concerns that they identified. They participated in observation walks, neighborhood documentation, mapping, water sampling, and water-quality analysis. Importantly, these practices were not framed only as skill-building exercises. They were connected to students' efforts to understand local problems and to develop evidence for public advocacy. These linkages matter because in ECS data collection is part of a broader civic and decision-making process rather than an isolated classroom activity.

Similarly, environmental monitoring has been framed by Indigenous and activist-scholars not simply as data collection but also as an assertion of governance and a practice that underscores the relevance of local experience and knowledge (Wilson et al., 2018; Zavala & González, 2022). Interpreted in that light, student monitoring in ECS can be understood as participating in a broader tradition of community-based and community-driven evidence that can be used to challenge inequities in environmental decision-making (Basile & Roth, 2022; Birmingham & Calabrese Barton, 2012). When students generated local evidence and used it in public forums, they were positioned as science learners as well as producers of knowledge that could inform collective decisions. This repositioning of students as agents of their learning/action is central to CESA development. Students are not doing an inquiry that is assigned to them; rather, *they are the authors* of the inquiry and their insights and knowledge matter for the definition and solution of the problem.

Second, students enacted CESA by identifying civic pathways for enacting change. Student reflections showed that they learned who was responsible for water issues in their schools and communities, including school boards, facilities staff, city officials, and other local decision-makers. These findings suggest that ECS appeared to support what might be called decision-making or civic systems literacy: students were learning not only about environmental systems, but also about the institutions and processes through which environmental decisions are made. This is significant relative to environmental education approaches that emphasize individual behavior change. ECS frames environmental issues as collective action and decision-making problems. Rather than asking only what students can do personally, ECS asks who has responsibility, what evidence matters, who should be engaged, and how collective action can

influence policy or practice. These foci are foundational to CESA development because environmental problems are shaped not only by individual choices, but also by institutions, infrastructure, policy, and public accountability.

Third, students enacted CESA through collective public advocacy. Calls to action required students to synthesize evidence, develop arguments, divide responsibilities, communicate with audiences, and propose changes in policy or practice. Not only were students saying they cared about environmental issues; they were demonstrating their environmental civic engagement capacity by using evidence, working with others, and communicating publicly about possible solutions.

These enactments resonate with justice-oriented and critical science education scholarship. According to that work, learning becomes transformative when disciplinary practices are mobilized to interrogate and address lived problems, and when students' work is oriented toward changing conditions rather than solely demonstrating competence to earn a grade (Birmingham & Calabrese Barton, 2012; Morales-Doyle, 2017).

3.5.3 Students' Expressions of CESA as an Outcome of ECS

In relation to my third research question, "How do students express CESA as an outcome associated with ECS participation?", after participating in ECS, students reported an increased confidence in specific civic processes, a clearer understanding of local decision-making, stronger beliefs in their collective voice, and an emerging awareness of power and constraint. These reports suggest that students were developing CESA as a collective and power-aware construct.

Students' civic competence and beliefs in their capacities were evidenced in qualitative responses in which students named or listed environmental civic tasks as things they could do. The fact that students were aware and could list the skills they had gained to educate, communicate, and mobilize others suggests that engaging in ECS activities developed their procedural confidence. A plausible explanation for these results is the repeated opportunities in ECS work to practice the procedural tasks that constitute civic engagement: gathering information, developing proposals, communicating to officials, and recruiting others. This matters for theory development insofar as CESA related efficacy is framed as inseparable from how students' might develop it in ECS, e.g. not via individual rumination or via a discussion of issues detached from their lives but through scaffolded opportunities to practice civic action in their own communities with support and feedback from fellow community members. Students'

reflective language suggests that they were acquiring a repertoire of civic moves and at least considering how they could apply those moves (or were actually applying them) to address a real local issue that they had identified.

Students' recurring emphasis on learning "who's in charge of water in our city," "who makes decisions… and why," and references to city councils and school boards point to a decision-making-centered form of CESA. Their responses suggest that sociopolitical efficacy involved more than believing they could make a difference; it also involved learning where decisions are made, who holds responsibility, and how students' evidence could be brought into those spaces. Identifying responsibility and organizing direct encounters with authority structures can convert students' understanding of "government" or "decision-makers" from an abstract entity into a set of navigable roles and processes. This concrete and personal experience of how decisions with local environmental impact are made aligns with justice-oriented science education arguments noting that community-based investigations are most transformative when they connect local issues to systemic decision-making and accountability (Birmingham & Calabrese Barton, 2012; Morales-Doyle, 2017). ECS created conditions for such experiences by pairing students' evidence-making with opportunities for them to engage decision-makers and articulate calls to action. Importantly for CESA development, the "critical" dimension of agency in environmental contexts is often inseparable from institutions because environmental harms and protections are distributed through policy, infrastructure, and regulatory choices. Thus, learning to "do science" without learning how environmental decisions are governed is in opposition to CESA development since it could inadvertently reproduce a depoliticized view of environmental problems.

A consistent feature of students' qualitative responses was their use of "we" language in how ECS (team) work was done and in their references to mobilizing others for environmental awareness and action. This aligns with scholarship arguing that agency in civic and environmental contexts is relational: people exercise influence through networks, partnerships, and coordinated actions with others, not only through individual acts (Flanagan et al., 2015; Krasny et al., 2015; Wegemer et al., 2025). Students' language therefore suggests that they were beginning to locate efficacy in their shared action and coordinated team roles, an important shift from models that position students as isolated individual actors or advocates. Some students also used assertive language about power with references to their own capacities. These statements

can be interpreted as early expressions of learning about leverage and accountability. Rather than imagining themselves as polite (and possibly passive) participants in existing systems, some students were using words to describe their civic action as contesting decisions and holding authorities responsible. This is one place where the justice orientation of CESA became visible because EJ work requires communities to challenge institutions, demand attention, and hold decision-makers accountable which can often include sustained collective pressure and challenges to the status quo.

The few mentions of constraints on youth influence can be interpreted through critical consciousness scholarship, such that the statments reflect developing political clarity rather than resignation or disengagement. Students are recognizing structural barriers that are real but that beg questions about alternative modes of political participation for youth (Freire, 1970; Watts et al., 2011; Hart, 2013).

In CESA terms, these findings suggest that as they develop a sense of agency students can challenge the status quo, recognize structural barriers in their way and also be creative in exploring ways they can have a voice and act. ECS appears to create space for both: students become more capable in navigating institutions while also recognizing the inequities embedded in access to formal political power and the limits of conventional channels of political engagement.

Students' CESA was visible not only when they expressed confidence or took action, but when they connected their action to public problems, community well-being, institutional responsibility, and, in some cases, unequal access or neglect. CESA operated as a practiced form of agency that linked environmental science, civic knowledge, collective action, and public participation. Students enacted CESA through ECS when they generated local environmental evidence, connected that evidence to community concerns, identified decision-makers, developed advocacy strategies, and communicated evidence-backed claims to public audiences. Students expressed CESA when they described themselves and their peers as capable of gathering information, making proposals, contacting people in power, mobilizing others, and advocating for changes in policy or practice.

This matters theoretically because CESA is not just a belief students hold internally. It is a relational and situated form of agency that becomes visible through participation in practices. Taken together, these findings indicate that ECS appears to support CESA as a form of agency

that is simultaneously scientific, civic, and collective, grounded in students' experiences of their capacities to use evidence within real decision-making contexts and to be recognized for their efforts.

3.5.4 Plausible Mechanisms: How ECS May Support CESA

Although this study did not test causal mediation, the alignment between observed ECS practices, student accounts, and survey outcomes suggests three plausible processes through which ECS may support CESA development. First, place-based inquiry made environmental science consequential. Students generated evidence about water, infrastructure, flooding, pollution, or environmental conditions in places they knew. This likely supported environmental action frequency and competence because students practiced concrete environmental science tasks rather than only learning about environmental problems abstractly.

Second, decision-maker engagement made civic pathways visible. Students learned who had authority over the issues they were investigating, including school boards, facilities staff, city officials, water utility staff, and community organizations. This likely supported sociopolitical control because students could connect environmental problems to institutions and decision-making processes.

Third, collective public advocacy made agency public and relational. Students worked with peers to develop claims, divide responsibilities, communicate evidence, and present calls to action. This likely supported capacity to take action for environmental change because students experienced environmental problem-solving as something they could do with others in public-facing contexts.

Taken together, these processes help explain why ECS participation was associated with growth across multiple CESA-aligned outcomes. ECS does not merely add civic activities onto science learning; it organizes a coherent arc from inquiry to advocacy in which students practice using environmental evidence to participate in public life. Evidence without governance knowledge could have remained a classroom science activity. Governance knowledge without advocacy could have remained abstract civics content. Advocacy without evidence could have become expression without disciplinary grounding.

CESA appeared to develop through participation in a structured civic-scientific context. ECS did not ask students to develop agency as an abstract disposition; it organized classroom activity so students could practice agency in relation to real environmental conditions, real

institutions, and real audiences. Students developed agency not simply because they studied environmental issues, but because ECS positioned those issues as local, governed, and actionable. In ECS, students were positioned as environmental investigators, community knowledge producers, collaborators, and advocates. These roles gave students opportunities to experience environmental science as something they could use with others to participate in community decision-making. These contextual features help explain why students' CESA appeared as an outcome in both belief and practice: students described themselves as capable of action, but they also enacted that capacity by gathering data, identifying civic pathways, engaging decision-makers, and advocating collectively. In this sense, CESA was supported through implication and context: the design of ECS implied that students were legitimate environmental knowledge producers and civic actors, and the classroom/community context gave them opportunities to inhabit that role.

3.5.5 Contributions to Theory and Practice

This study contributes to science education theory by conceptualizing CESA as a decision-making-centered, collective, and justice-oriented extension of ESA and CSA. CESA specifies a form of agency especially salient in environmental contexts, where harms, benefits, and protections are shaped through institutions, policies, infrastructure, and public decisions. The study also contributes empirically by showing what CESA looked like in student practice: collecting water data, documenting local environmental conditions, identifying decision-makers, developing proposals, working in teams, communicating with public audiences, and expressing collective power. The findings suggest that this form of agency may develop not only through inquiry and action, but also through opportunities to understand governance, engage decision-makers, and practice collective public advocacy. This is what ECS adds to existing approaches: it does not simply ask students to investigate environmental issues or take individual action. It organizes learning around community environmental decision-making, where scientific evidence, civic knowledge, collective work, and justice-oriented accountability can come together.

This study advances the field in three ways: it provides mixed-methods evidence that ECS participation is associated with growth across multiple dimensions of CESA; it identifies ECS practices that may help explain this growth; and it clarifies what ECS adds to existing approaches by centering environmental decision-making, governance, and collective public

action. In doing so, the study offers both a theoretical account of CESA and empirical support for ECS as a pedagogical framework for cultivating CESA.

3.5.6 Limitations

This study has several limitations. First, because students were not randomly assigned to ECS or comparison classes, findings should be interpreted as associations between ECS participation and differential growth, not as causal effects. Although ECS and comparison students were in the same schools and showed similar baseline characteristics and scores on the dependent variables prior to ECS activities, unmeasured differences between teachers, classes, or students may have contributed to observed patterns.

Second, students were nested within classrooms, teachers, and schools, but the repeated-measures GLM models did not account for this nesting. Multilevel modeling was not used because the number of higher-level units (classes) was small and class sizes varied substantially. As a result, standard errors and significance tests should be interpreted cautiously. Future studies with larger numbers of classrooms, teachers, and schools should use multilevel designs (students nested in classrooms) to better estimate classroom- and teacher-level effects.

Third, implementation varied across teachers and contexts. Teachers differed in their prior ECS experience, comfort with place-based instruction, access to community partners, and opportunities to connect students with decision-makers. These implementation differences may have shaped students' experiences, making it difficult to separate ECS-related learning opportunities from teacher and context effects.

Fourth, several outcomes relied on student self-report. Although survey results were reinforced by qualitative evidence from observations and open-ended responses, self-report measures may be influenced by social desirability and students' interpretations of survey items.

Fifth, although CESA is conceptualized as justice-oriented, the quantitative measures did not fully capture CESA justice dimensions. Justice-oriented dimensions were examined qualitatively through references to accountability, rights, institutional responsibility, collective power, and demands for change. Future research should develop measures that more directly assess the justice-oriented dimensions of CESA, including students' ability to analyze inequity, identify affected communities, and connect environmental evidence to questions of power and accountability.

Finally, my participant-observer role provided close access to ECS implementation but may also have shaped classroom activity and interpretation. Analytic memoing and triangulation across data sources helped address this limitation, but future research involving novel observers would strengthen confidence in the findings.

3.5.7 Future Research

Because this paper advances CESA as a multidimensional student outcome related to community environmental decision-making, future research should continue to refine how it is measured. Future measurement work could capture more than students' self-reported confidence, motivation, or dispositions. It should also assess students' demonstrated abilities to identify relevant decision-making systems, use evidence in public arguments, collaborate with peers, develop advocacy strategies, and participate in civic processes. Performance-based assessments, student interviews, and classroom discourse analysis could deepen understanding of what CESA looks like in practice and how it develops over time.

Future research should examine ECS and CESA across larger samples of classrooms, teachers, and schools using multilevel and longitudinal designs. Such studies could account for nesting, estimate teacher- and classroom-level effects, and assess whether CESA-related gains persist beyond the program

Future studies should also investigate which ECS elements are most strongly associated with particular dimensions of CESA. For example, decision-maker engagement may be especially important for sociopolitical control and municipal literacy, while collective public action may be especially important for collective efficacy and entitlement to voice. Research that compares different configurations of ECS elements could clarify which practices are necessary, which are supportive, and how they interact.

Finally, longitudinal research is also needed to examine whether CESA-related gains persist beyond the program. Future studies could assess whether ECS participation relates to later environmental action, civic participation, science identity, community engagement, or justice-oriented advocacy.

3.5.8 Implications for Practice

This study also has implications for education. If schools aim to support students' capacity to participate in community environmental decision-making, then learning experiences

should move beyond environmental awareness or individual behavior change. Students need opportunities to investigate local environmental issues, generate evidence, understand who has decision-making authority, and communicate claims in public settings.

For teachers, CESA-supportive instruction should include three design priorities: place-based inquiry, explicit learning about pathways to civic engagement and decision-making, and collective public action. Place-based inquiry connects environmental science to conditions in students' schools, neighborhoods, and communities. Learning about civic pathways helps students understand who makes decisions, how policies and practices are shaped, and how community members can participate. Collective public action gives students structured opportunities to deliberate, share roles, build coalitions, and advocate with evidence. All of these core affordances of ECS appear to be instrumental in developing CESA.

For schools and districts, supporting ECS may require time, flexibility, and institutional support for community partnerships, field-based learning, and public presentations. Teachers may also need professional learning focused on community partnership-building, facilitation of student-led inquiry, and scaffolding civic communication. Because ECS depends on relationships among schools, communities, and decision-making institutions, implementation cannot rest on individual teachers alone.

3.6 Conclusion

This study examined whether and how participation in ECS was associated with students' development and enactment of CESA. Findings suggest that ECS participation was associated with greater growth across four CESA-aligned outcomes: environmental action, civic skill ability, sociopolitical control, and capacity to take action for environmental change compared with standard science and social studies instruction. Qualitative findings triangulated and extended these results by showing how students enacted and expressed CESA by generating local environmental evidence, identifying civic decision-making pathways, engaging decision-makers, and participating in collective public advocacy.

The study's central theoretical contribution is the articulation of CESA as a decision-making-centered, collective, and justice-oriented form of science agency. Practically, the findings suggest that science and social studies classrooms can support this form of agency when students investigate local issues, work with community partners, learn how decisions are made, and use evidence in public-facing action.

ECS does not simply ask students to learn about environmental problems or take individual action. It organizes learning so students can practice using science as a civic resource in collective efforts to address community environmental issues. In this way, ECS offers a promising framework for designing justice-oriented environmental learning that prepares young people to participate in the environmental decisions shaping their communities.

3.7 **References**

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Chapter 4 “It Made Me Think About How Water Should be a Right”: Student Environmental Justice Learning in Environmental Civic Science

4.1 Abstract

This paper examines Environmental Civic Science (ECS) as a participatory educational approach that can create entry points for students’ environmental justice (EJ) understanding and critical consciousness (CC) development. Drawing on environmental justice education (EJE), CC theory and EJ principles (e.g. distributive justice, rights to participation), the study investigates how teachers’ ECS praxis afforded opportunities for EJ learning and how students articulated EJ understanding and CC. Using an exploratory qualitative design, I analyzed participant-observation field notes from approximately 70 classroom and field-based sessions, student reflections on whether water is a human right (n = 43), and student post-project reflections on whether ECS activities made them think about fairness or justice issues related to water (n = 78). Findings indicate ECS affords opportunities for students to reason about EJ through teachers’ incorporation of explicit EJ content and through ECS core practices: place-based inquiry into local water issues, community-engaged learning with decision-makers and partners, as well as public advocacy via student call-to-action campaigns. Findings illustrate that students framed water as a human right and applied distributional justice reasoning. Students described socioeconomic bases of environmental injustice and articulated structural critiques of injustice (profit, neglect of low-income communities) but also expressed individual and collective agency and their own intentions to act. Students also expressed emerging CC through critical reflection, moral concern, sociopolitical questioning, and participation in public advocacy. However, students did not name environmental racism or rights to participation, even in contexts where local environmental harms were connected to histories of segregation and disinvestment and despite ECS’s participatory structure. The study contributes to EJE and CC scholarship by showing how participatory inquiry-to-action pedagogies can support initial EJ reasoning while also revealing the curricular conditions needed for deeper critical analysis.

4.2 Introduction

Heeding the call that environmental justice organizers and scholars have raised for decades (e.g., Bullard, 1993), awareness has grown that social inequality and power imbalances lie at the heart of environmental degradation (Bullard, 1990; Mies & Shiva, 1993). Associated with that awareness is an increasing recognition that addressing environmental crises requires confronting these root causes. The climate crisis in particular makes addressing environmental injustice urgent. Lower-income and especially communities of color and Indigenous populations (in the United States and across the globe) already experience disproportionate environmental harms rooted in historical and ongoing oppression, with climate change intensifying these inequalities (Routledge et al., 2018). At the same time, younger generations are inheriting a world in which climate impacts will heighten risks and make everyday life more precarious (Thiery et al., 2021).

Education plays a critical role in addressing these inequities *within* and *between* generations, and in progressing toward a more just and sustainable future. To do so, education must move beyond focusing on scientific explanations of environmental issues to also address the cultural, economic, political, and societal roots of environmental challenges (Tannock, 2021). This requires justice-oriented educational approaches that enable students to question the status quo and envision alternative futures. To achieve these goals, education should afford students opportunities to examine: whose voices are represented and whose are excluded in environmental decision-making, how policies and institutions shape unequal environmental conditions, and how communities can and do organize to challenge environmental injustice (Guevara-Herrero et al., 2024; Miles et al., 2025; Schindel Dimick, 2015). In this paper, I introduce Environmental Civic Science (ECS) as a participatory environmental inquiry-to-action framework and examine how participation in ECS may create conditions for high school students' environmental justice (EJ) learning and critical consciousness (CC) development. ECS engages students in investigating environmental issues, connecting those issues to community concerns, engaging decision-makers, and developing public calls to action. Rather than asking whether ECS "works" as environmental justice education (EJE), I ask what ECS might enable: how the participatory learning experiences it affords may help students conceptualize environmental issues as justice issues and begin to develop CC.

Specifically, I ask:

1. What forms of EJ understanding did students articulate in relation to their participation in ECS?
2. How did students express CC, including critical reflection, sociopolitical and structural analysis, critical motivation, and critical action, in relation to their participation in ECS?
3. How did the ECS participatory process and teachers' praxis create conditions for students to connect environmental issues to EJ learning and for CC development, including questions/reflections on rights, inequity, institutional responsibility, power, and collective action?

By addressing these questions, I aim to generate insights into how participatory inquiry-to-action educational processes like ECS may support EJ learning and CC, defined as students' critical analysis of inequality's root causes, motivation to promote social change, and engagement in action to challenge injustice (Pinedo et al., 2024).

Although EJ is not typically incorporated into educational theory or practice (Davis & Schaeffer, 2019; Guevara-Herrero et al., 2024; Miles et al., 2025), some contemporary scholarship has done so (e.g. Cachelin & Nicolosi, 2022; Davis & Schaeffer, 2019; Nxumalo & Ross 2019; Trott, 2023). At the same time, there have been few empirical studies of how education can facilitate students' environmental sociopolitical awareness, their ability to understand and challenge environmental injustice, or their development of CC about socio-environmental issues (Delia & Krasny, 2018; Miles et al., 2025). Likewise, there is limited research on the learning processes and practices through which students come to understand environmental problems as justice problems (Delia & Krasny, 2018; Guevara-Herrero et al., 2024; Wilder et. al., 2023). The current study addressed this research gap by examining how EJ learning and CC may develop through participatory processes in ECS. Because ECS was implemented in standard high school science and social studies classes rather than in courses designed as EJE, this study examines how EJ learning and CC may develop through participatory process, not through explicit EJ instruction.

4.3 Background and Theoretical Framing

4.3.1 EJE Pedagogy

When environmental justice *is* incorporated into educational practice it is typically taught as content: students learn about systemic injustices that drive EJ, like environmental racism, or learn about specific cases like the Flint water crisis that highlight negligent governance and residents' demands for accountability. Such content is important. However, EJE should not only concern *what* students learn, but also *how* they learn and the skills and dispositions they develop in the process. EJE scholars offer clear recommendations for how pedagogy should be practiced: engaging students in critical inquiry, community-centered learning, examination of power and decision-making, and action aimed at disrupting unjust systems (Cachelin & Nicolosi, 2022; Figueroa, 2002; Haluza-Delay, 2012; Miles et al., 2025;).

In practice, this means creating opportunities for students to evaluate and question the social as well as the ecological foundations of environmental injustice. This includes questioning who is represented and who is excluded in environmental decision-making (Guevara-Herrero et al., 2024; Miles et al., 2025) and how choices made by people in power have contributed to environmental injustice. Young people should also know that they have the power to redress environmental injustice. Thus, pedagogies aligned with EJ principles must connect academic knowledge with community-centered experiential learning that positions students as producers of knowledge and engages them in actions to disrupt unjust systems (Haluza-Delay, 2012; Miles et al., 2025; Morales-Doyle, 2017). To learn how to disrupt those systems, students should engage in collective action with community groups that are addressing environmental injustice (Cachelin & Nicolosi, 2022; Dittmer et al., 2018; Morales-Doyle, 2017; Schneller et al., 2022). Partnering with community members in this way moves EJE from theory into lived experience and connects disciplinary learning with real-world EJ concerns.

The current paper takes up these recommendations by examining ECS as a participatory inquiry-to-action process that reflects EJE pedagogy and incorporates practices associated with EJ organizing. Although ECS is not, in itself, explicitly EJE, its structure and core elements provide a participatory process through which students may encounter environmental issues as justice issues. Those core elements include:

1. Local environmental issue inquiry
2. Collaboration and engagement with people and groups in the local community
3. Engagement with local decision-makers and with environmental policy/practice
4. Collective public action/advocacy.

I argue that ECS affords opportunities for EJ learning, in part, because it organizes students' participation around these core elements that mirror the following EJ practices of:

1. Documenting environmental harms/monitoring community environmental conditions
2. Centering community concerns
3. Asserting rights to participation and to holding institutions and authority accountable
4. Engaging in community mobilization and activism.

4.3.2 EJ Principles

Following scholarship in EJE and related fields (e.g. climate justice education) I conceptualize EJE as grounded in the history, practices, and principles of the EJ movement and informed by multiple dimensions and concepts of justice (Miles et. al, 2025; Soysal et. al, 2026; Wilder et. al., 2023). My framing draws on *The Principles of Environmental Justice*, adopted at the First National People of Color Environmental Leadership Summit (1991). It also draws from EJ scholarship that emphasizes EJ's inclusion of accountability, redress, recognition, interaction, transformation of unjust systems, intersectionality, and systems of responsibility (Bullard et al., 2007; Pellow, 2017; Schlosberg, 2007; Whyte, 2018; Wilder et al., 2023). Because students' inquiry in this study centered on water, I also draw on Sultana's (2018) framing of water justice, which includes access and affordability, lived experiences of water insecurity, the burdens created by inadequate water systems, and calls for democratized water governance.

I understand EJ to extend beyond the unequal distribution of environmental harms to include the pillars of rights to: equal protection and to healthy natural systems; prevention of harm; self-determination and participation; and rights of all living beings and ecological systems. In fact, a key principle of EJ is the right of affected communities to participate meaningfully in environmental decision-making as equal partners at every level, including needs assessment, planning, implementation, enforcement, and evaluation. This participatory principle is central to EJ because environmental harms are often produced and maintained through the exclusion of affected communities from decisions about land use, infrastructure, water, waste, and public health. In this study, this principle is particularly important because ECS intentionally positions students to participate in decision-making about community environmental issues, effectively asserting their rights to participation.

Importantly, I understand EJ not only as a set of principles, but also as social movement praxis (Bullard et. al., 2007). To accomplish EJ goals, grassroots organizers engage in

community-based monitoring, public testimony, protest, storytelling, municipal permitting and planning procedures and strategic litigation strategies. For decades the EJ movement has used these concrete practices to document environmental harms, mobilize communities, elevate the experiences of impacted residents, assert their rights to participate in environmental decisions, and demand accountability from corporations and public agencies. This practice-based understanding of EJ is especially important for education because it frames environmental knowledge as inseparable from participation and action.

4.3.3 Injustice and the Development of CC

The construct of CC is closely related to EJE's emphasis on examining power and structural injustice. CC grew out of Freire's (1993) notion of critical pedagogy, which critiques systems of marginalization and oppression and conceptualizes education as a tool for social change. Instead of the "banking model" of teachers delivering knowledge to passive students, Freire advocated for a "problem-posing" approach to learning built on dialogue, critical thinking, and action.

Contemporary scholarship defines CC as the ability to understand, reflect and act on social inequalities and unjust socio-political contexts (Diemer et al., 2016; Morgan & Christens, 2023). CC is commonly understood to develop through critical reflection/sociopolitical analysis, critical motivation, and critical action: students analyze inequality's root causes, develop motivation to promote social change, and engage in action to challenge injustice (Pinedo et al., 2024; Watts et al., 2011). With respect to EJ, developing CC is important in part, because it is associated with youth engagement in social change to realize more just communities (Pinedo et al., 2024).

In practice, students have to analyze systemic injustice and engage in concrete actions to address it. Through practice students develop their skills, beliefs, motivations, and ultimately a sense of their agency and power to address injustice (Diemer et al., 2016; Morgan & Christens, 2023). In environmental contexts, this means students need opportunities to analyze how environmental harms are produced through policy, infrastructure, racism, classism, disinvestment, and unequal political power, while also developing motivation and capacity to act. For example, when comparing flooding across neighborhoods students might notice that flooding frequency is higher in communities of color. That observation can lead them to ask how

infrastructure disinvestment and inequities in political power shape a community's vulnerability. Such analyses can support motivation and action: as students see how inequities are rooted in historical and contemporary policies, they can then use their findings to advocate for increased green infrastructure for stormwater management in effected neighborhoods.

Participatory educational approaches in which students collectively investigate sociopolitical issues and examine power dynamics in their communities are linked to CC development, especially among minoritized youth (Morgan & Christens, 2023; Schindel Dimick, 2015). Approaches in environmental education (EE), including action civics, youth participatory action research, and urban environmental education, offer possibilities for CC development because they engage students in exploring locally relevant issues, researching root causes, and participating in community environmental action (Ballard et al., 2016; Delia & Krasny, 2017; Trott et al., 2024). However, there is limited research on the development of students' CC in the context of EJ. This gap matters because students may recognize environmental unfairness or express concern without developing a structural analysis of the root causes of EJ, including environmental racism, classism, colonialism, or the exclusion of communities from participating in decision-making. This study therefore examines both what ECS afforded and what remained less visible in students' CC.

Taken together, the abovementioned frameworks, principles and practices inform my conceptualization of EJ, EJE and CC, guide my research questions and analysis, and provide the foundation for understanding education as a site for advancing EJ.

4.3.4 Environmental Civic Science

ECS builds on established scholarship and practice in EE, civic science, critical place/land-based education, and justice-oriented science education. It shares with these fields an emphasis on local context, ecological understanding, meaningful engagement, students' capacity to analyze issues, and to act. What distinguishes ECS is its integration of scientific and civic literacy through a focus on policy, governance, and institutional engagement. This focus is meant to promote "action," but also to cultivate the participatory competencies and socio-political understandings required for collective environmental decision-making. This orientation is especially important in EJ contexts because as decisions about infrastructure, land use, water, and public health are almost always made without meaningful participation from youth or other marginalized groups.

I contend that the participatory inquiry-to-action process in ECS affords students opportunities to see how scientific evidence can clarify community problems and promote more accountable decision-making (Gallay et al., 2025). For example, students might assess drinking or surface water quality or investigate how land cover and green infrastructure relate to runoff and heat exposure. Based on their findings, students would identify target audiences to advocate to for policy or practice changes. In the process, students learn to identify stakeholders and decision-makers and to understand constraints to decision-making such as jurisdiction. With those audiences and constraints in mind, students would frame their advocacy arguments using scientific evidence to persuade others to act.

By integrating scientific inquiry with civic participation, the goal of ECS is to prepare students to investigate and address environmental challenges in their own communities (Gallay et al., 2025). This goal, as well as the core elements of the ECS process, align with EJE recommendations, EJ practices, and the CC process. These alignments make ECS a good candidate for examining how participatory inquiry-to-action pedagogy may support EJ learning and emerging CC.

4.4 Methods

In this study, I used an exploratory qualitative approach to examine how students expressed EJ learning and CC in relation to ECS participation and how classroom practices afforded opportunities for such learning. The research detailed here is part of a larger mixed-methods study of ECS as implemented during the 2023–2024 school year by five teachers in high school science and social studies classes across four schools in Southeast/Mid-Michigan (see Gallay, 2026; Gallay et al., 2025 for additional details). Collaboration among educators, community partners, and scholars as well as feedback from students grounded all phases of the project and informed iterative changes throughout the study. This collaborative foundation shaped my methodological approach and is consistent with recommendations from community-engaged, participatory, equity-oriented, and EJ research, which emphasize that research should be designed through partnerships with community members and grounded in local contexts (Bacon et al., 2013; Calabrese Barton et al., 2020; Lau & Stille, 2014; Vakil et al., 2021).

I also took seriously my relationship to place as a scholar, educator, and activist who grew up in and has spent my adult life working to advance EJE in the region where this study took place. I am geographically, professionally, culturally, and socially connected to the

communities with which I worked. I live with the realities, emotions, and politics shaping this landscape (Butt, 2022), including the deindustrialization, disinvestment, and associated environmental harms many communities in the region have faced. In addition, in my work and personal life, I have been intentional about developing "right relations" with land, just as with humans (Jadallah et al., 2024). I acknowledge that my positionality influenced this project by informing my methodological approach and, to some extent, may have influenced my interpretations of the data. Triangulation of data helped to limit this influence.

These foundations and relationships also minimized my status as an "outsider" in the schools and classrooms where the research took place and strengthened my role as a participant-observer (Atkinson & Hammersley, 1998). In addition to my research role, I facilitated planning of ECS implementation with teachers and community educators, led teachers and partners in reflection on implementation, supported and sometimes facilitated ECS activities with students in classrooms and in the field. These roles enabled me to closely observe how teachers engaged students in ECS, what students experienced, and how students expressed EJ learning and emerging CC.

4.4.1 Sites and Contexts

For the current study, I used purposive sampling (Palinkas et al., 2015) to select a subset of classes (from the larger study referenced above) representing communities with a higher likelihood of experiencing environmental injustice. Specifically, I chose schools/classes based on the socioeconomic and racial/ethnic composition of the communities the schools served and on their geographic locations/classifications (i.e., urban and rural locales associated with greater vulnerability to climate crisis impacts and environmental injustice). As discussed below, the majority of students in each school were considered "economically disadvantaged" based on eligibility for free and reduced lunch. In the remainder of the paper, I use pseudonyms for the three schools, the classroom teachers, and community partners.

4.4.1.1 Site 1

The city of Benson faces environmental issues common in Rust Belt cities, including deindustrialization and toxic legacies from large-scale manufacturing. Benson was part of the automotive industrial boom, particularly through metal plating facilities which have contributed to soil and water contamination in the area. A former manufacturing site in Benson qualifies as

one of the nation's most polluted (U.S. Environmental Protection Agency, 2022). At the beginning of the school year (and the ECS programming), Benson students also had first-hand experiences linked to environmental injustice: Benson HS cancelled two days of school, once due to high heat action days and lack of cooling infrastructure, and once due to concerns about toxic pollution in the smoke from a fire in a nearby abandoned manufacturing facility.

The participating history teacher at Benson HS incorporated ECS into her five world history classes (a required course for all students). Students from Benson HS who participated in ECS (n = 114) were mostly 10th graders (82%), with 11th graders (12%), 12th graders (4%), and a small percentage of 9th graders (2%). Based on students' self-reports, 53% were female, 44% male, and 3% selected another gender identification. Slightly less than half (44%) self-identified as White, 26% as Black, 18% selected multiple racial/ethnic identities, 5% as Latinx, and 4% as Asian American. Sixty-seven percent of Benson HS students are considered "economically disadvantaged."

4.4.1.3 Site 2

Community Area High School is in an urban location shaped by environmental harms associated with deindustrialization, though on a smaller scale than in Benson. A particularly visible EJ issue is that most of the city's Black residents live in areas with poorer air quality and more frequent flooding, issues that are due to policies of racial segregation and chronic underinvestment in infrastructure. A salient example occurred one month before the school year began: a poorer, Black-majority neighborhood where many students live, experienced a devastating flood that overwhelmed streets, homes, and infrastructure. More than 1,000 homes and over 3,000 residents were affected, with many facing sewer backups in their homes.

The participating teacher at Community Area HS incorporated ECS into his Earth Science classes. Community Area HS students (n = 17) who participated in ECS were in the highest grade levels: 12th graders (53%) and 11th graders (47%). Female and male students each made up 47% of the sample, with 6% (one student) self-identifying as another gender identification. Most students (47%) identified as Black, 18% as Latinx, 12% as White, and 24% identified with multiple racial/ethnicities. Like Benson HS, Community Area HS served a majority (67%) of "economically disadvantaged" students.

4.4.1.3 Site 3

West Benson Secondary School is the only rural school in this study, and the only community where EJ issues did not emerge as current events during the study period. However, West Benson faces environmental injustice vulnerabilities that many rural low-income communities face: agricultural pollution exposure, limited infrastructure, and weak regulatory enforcement for environmental protections. Local environmental concerns include groundwater pollution, land use and redevelopment, and rezoning for industrial use, including a potential data center.

The participating teacher at West Benson incorporated ECS into her Earth Science and Experimental Science classes. West Benson had 39 students from all grade levels participate in ECS: 12th graders (28%), 11th graders (65%), 10th graders (3%), and 9th graders (5%). Female students made up 44% and male students 49% of the sample, with 8% (three students) selecting another gender identification. Most students (64%) self-identified as White, 8% as Black, 3% as Latinx, and 21% identified with multiple racial/ethnicities; 4% chose not to answer. Of the three schools, West Benson SS served the highest percentage (75%) of "economically disadvantaged" students.

4.4.2 Measurements

I explored data from multiple sources for the purposes of triangulation. Data sources included:

1. Participant-observer field notes from curricular planning meetings and approximately 70 class sessions.
2. Student reflections from an ECS activity that two teachers incorporated as part of their ECS programming, in response to the open-ended prompt, "Is water a human right? Explain" (n = 43).
3. Student reflections after completing ECS programming, in response to the open-ended prompt: "During the past weeks your class learned a lot about water like how humans need to have safe, healthy water to live, how water can cause flooding in some places, how decisions that affect water in your community are made, etc. Did any of the activities your class did, discussions you had, or anything you learned make you think about fairness or justice issues about water?" (n = 78).

These data sources were aligned with my research questions. Field notes were important for documenting what students actually did that could afford opportunities for developing CC and EJ concepts. The two reflection prompts (2 and 3 above) specifically asked students about how they thought of water issues as connected to dimensions of EJ and whether their ECS experiences made them consider issues of justice. In the remainder of the paper, I use the following abbreviations for each data source: FN, field notes of observations; RAA, reflection activity artifact (data source 2 above); and SR, student reflection after completing ECS programming (data source 3 above).

4.4.3 Analysis

Analyses across all qualitative data followed an iterative process that combined deductive and inductive coding. I began with an overall reading and analytic memoing across data sources to explore what emerged, generate high-level understanding and to identify patterns across the data (Kushnir, 2025). In my field notes, I looked for evidence of students' CC, including their critical reflection, sociopolitical and structural analysis, critical motivation, critical action, and agency. I also attended to students' EJ learning through their participation in ECS experiences in ways that aligned with my conceptualization of EJ practice, especially participation in community environmental decision-making, community-based monitoring, community engagement and knowledge-gathering, and public advocacy. At the same time, I remained attentive to emergent forms of EJ-related engagement and CC development and learning in classroom activities and discourse.

In the first cycle of coding, I applied deductive codes drawn from EJ principles, CC theory, and ECS/EJE praxis. EJ understanding codes included rights-based justice, distributive justice, procedural justice, recognitional justice, ecological justice, participation rights, accountability, and institutional responsibility. CC codes included critical reflection, sociopolitical or structural analysis, critical motivation, and critical action. EJE praxis codes included community monitoring, community-engaged learning, decision-maker engagement, explicit EJ content, and public advocacy.

I also used inductive coding to capture themes that emerged from students' own language. These included water as survival, water affordability, distrust or skepticism toward decision-makers, "poorer communities," government responsibility, corporate responsibility, care for ecosystems, and students' own intentions to act. Inductive coding was especially important

because many students did not use formal EJ language, but they did reason about fairness, responsibility, access, and accountability in everyday terms.

In the second cycle of coding, I refined and grouped codes into broader analytic categories. For example, statements such as “water should be free,” “everyone deserves water,” and “water is necessary to survive” were grouped under rights-based justice. Statements about “richer cities” having better water, “poorer areas” being ignored, or unequal infrastructure were grouped under distributive and socioeconomic justice.

Claims were developed by comparing patterns across data sources and attending to both presence and absence. For example, the claim that students developed rights-based and distributive EJ reasoning was grounded in recurring patterns across the water-rights reflection and the post-project justice reflection. The claim that ECS made governance visible was supported by student reflections naming city hall and decision-makers, field notes documenting teacher-led discussions and field trips, and observed student advocacy activities.

Ultimately, I integrated the analysis into refined coding categories organized around: (a) references to EJ principles; (b) references/displays of CC and agency; and (c) instances of EJ and EJE praxis (content, experiences, practices). These categories and associated subcodes are presented in Table 1.

Table 4.1 Superordinate EJ and CC Themes and Subordinate Coding Categories (subcodes)

Superordinate Theme	Subordinate Coding Categories (Subcodes)
EJ principles	*Rights-based justice:* water as human right; right to healthy environment; right to protection from harm. *Distributive justice:* unequal access, affordability, infrastructure, exposure, benefits/burdens. *Procedural justice:* decision-making, transparency, accountability, institutional responsibility. *Participatory justice:* rights to meaningful participation in environmental decision-making at all levels and phases. *Recognitional justice:* whose knowledge, voice, experience, and community concerns are valued. Ecological justice: more-than-human life, ecosystems, human-nature reciprocity. Structural/socioeconomic justice: classism, disinvestment, profit, institutional neglect, racism/environmental racism
CC	*Critical reflection/sociopolitical analysis:* understanding sociopolitical systems; recognition of decision-making structures, identifying mechanisms of power; awareness of inequality/inequity questioning accountability.

Superordinate Theme	Subordinate Coding Categories (Subcodes)
	Critical motivation: urgency, efficacy, moral concern, fairness reasoning, hope, desire to change *Critical action:* civic engagement, justice-oriented actions, connecting monitoring to civic oversight, collective public action, demanding action from decision-makers *Agency as part of critical action, not primary outcome:* shared responsibility; belief in collective and individual power; intentions and strategies to act.
EJ and EJE praxis	*Explicit EJ content*: environmental racism/classism; historical and contemporary EJ cases/events; EJ movements EJE and EJ-aligned experiences: participation in community environmental decision-making (asserting rights to participation), engaging with decision-makers/authority structures (City Hall visits, water utility visits, school facilities and administrator engagement, communicating recommendations) community-engaged learning with affected communities (surveys and interviews with school/community members, engagement with community partners, centering community concerns; students' own lived experience as knowledge) EJ practices: organizing (developing goals, strategies, allies, target audiences) mobilizing (gathering community support, public education), monitoring/oversight (school/neighborhood walks, water sampling and water quality analysis, identifying water-related issues) advocacy (call-to-action campaigns/advocacy presentations, presenting to authentic audiences)

4.5 Results

I present results organized around the three research questions guiding this study. First, I report evidence of students' EJ understanding as connected to EJ principles. Next, I report evidence of students' CC. Finally, I report instances of teachers' praxis of the ECS process that afforded opportunities for students to understand environmental issues as EJ issues and to develop CC. Within each of these sections, I organize results in line with the subcodes associated with each superordinate coding theme. Data sources are listed after each reported finding and quotes are reported verbatim.

4.5.1 Students' EJ Understanding Connected to EJ Principles

Students articulated multiple forms of EJ understanding. These included rights-based understandings of water, distributive justice claims about unequal access and infrastructure, socioeconomic analyses of environmental inequality, procedural justice concerns about government and policy responsibility, and ecological justice orientations that extended concern beyond humans to water, animals, and ecosystems.

4.5.1.1 Rights-Based Understandings of Water

Students invoked rights-based EJ principles, particularly the right to access and non-exclusion. Their reasoning connected water to survival, health, and dignity.

In response to the question "Is water a human right?" students unanimously asserted that water is a human right, with their explanations rooted mainly in the essential nature of water for survival and daily life. For example, one student asserted, "Water is a human right. You need it to survive and I believe if it's truly necessary it should be a right" (RAA). Another student explicitly invoked the equal nature of this right tied to a universal need: "the entire world relies on water so it is a world wide right" (RAA).

Several students also framed this right in relation to the commodification of an essential resource, including the student who offered an elaborate argument that incorporated rights-based reasoning around non-exclusion and rights to a healthy environment:

> "I think that one fairness about water is that it should be free for everybody. Water is life, without it animals, plants, and we could not live. There are countries where water is limited in many communities due to contamination or lack of water. Water is a right for everybody and it should be available for anybody without cost" (SR).

This student's response goes beyond a rights-based framing, to allude to ecological and distributional justice, showcasing multidimensional EJ understanding.

4.5.1.2 Distributive Justice: Unequal Access, Affordability, Infrastructure, and Responsibility

Students articulated EJ understanding with distributive justice claims about unequal access, environmental burdens, resources, affordability, and infrastructure. In some instances, students' call-to-action campaigns included policy and practice solutions that revealed their EJ understanding concerning fair distribution. Thus, they were not only noting or describing inequality but were applying distributive justice reasoning to a concrete policy/practice issue. For example, one group of students advocated for air conditioning to be installed at Benson HS. Their campaign built on the planned school improvement bond scheduled for a vote in the district with students arguing that equity should be applied across the proposed building improvements. Adopting a distributional justice perspective, students advocated for the "most urban schools" to be equipped with air conditioning first, noting that the older school buildings in some neighborhoods lacked the necessary infrastructure to provide a healthy learning environment and therefore should be first in line for improvement (FN).

Some students' reflections emphasized a distributive justice orientation tied to affordability, noting that circumstances should not be a barrier to people's access to water. For example, one student wrote, "I think every human should be able to use water, even if they aren't paying for it" (RAA), alluding to the idea that water should not be withheld or limited due to one's status or ability to pay.

Finally, one student broadened justice beyond immediate distribution to include intergenerational distribution of harms and responsibility: "It's not fair that so much of our environment was broken by the generations before us and now no one is taking it seriously" (SR). This student articulates the idea of intergenerational justice, alluding to both restorative justice in ascribing responsibility for past environmental degradation, and distributive fairness in that present generations should protect natural systems to ensure future generations inherit a healthy planet.

4.5.1.3 Socioeconomic Environmental Justice: Understanding Environmental Classism

In addition to noting the injustice of unequal environmental outcomes, students also connected those outcomes to inequalities in political responsiveness and investment. Their reflections revealed an awareness that fairness is shaped by systemic, structural causes that prioritize the needs of some groups over others. Many students referenced inequities between wealthier and poorer communities, noting that poorer areas often have worse water quality and fewer resources. For example, one student explicitly referenced the injustice of water access being tied to social class or economic status, stating that "clean water should be accessible to all, regardless of economic status" (SR).

In one instance, a student expanded socioeconomic justice to a global level, linking scarcity, development, conflict and connecting water conditions to socioeconomic status, health, ecosystem harm, and social stability:

> "the activities and discussions we had made me think about fairness and justice issues related to water. We discussed how water scarcity affects people in developing countries and how it can lead to conflicts over water resources. We also talked about how water pollution affects the health of people and ecosystems, and how it disproportionately affects low-income communities" (SR).

Other students' responses moved beyond a lack of resources to tie neglect to inequitable political attention and political choices made by decision-makers. This appeared as broad pattern

recognition, such as the student who pointed out that “i feel like richer cities get better water and no one cares abt the smaller/poorer cities and their water” (SR). Another student included a causal attribution, articulating explanations of power and profit incentives: “Poorer areas water quality needs are often ignored, especially if it's profitable for people in charge” (SR).

4.5.1.4 Government and Policy Responsibility: Procedural Justice

Students articulated procedural justice understandings as related to power, transparency, decision-making, and accountability. In their reflections, students showcased understandings of how governmental decisions are made, by whom, and how such decisions impact community outcomes.

Some students explicitly connected procedural justice questions to trust and accountability. For example, one student stated, “it made me think about who makes the decisions about our drinking water and do they have our best interest in mind” (SR). This statement alludes to a healthy skepticism about water governance and procedural justice as it pertains to accountability and legitimacy. It shows more than curiosity about government structure. It raises the question of accountability and legitimacy: are decision-makers serving the people affected by their decisions? Another student summarized institutional decision-making related to water governance, stating, “Water in certain communities and the status of its cleanliness are heavily dependent on the decisions made by important members of the community” again connecting environmental conditions to human decision-making rather than treating them as natural or inevitable (SR). Taken together, these responses show that students identified the roles of government and policy making in community water management and questioned whether decision-makers serve (all members of) the public’s interest. These responses suggest that ECS appeared to support students’ emerging understanding of environmental governance as a justice issue. Another student reasoned through the relationship between profit, governance, and universal access, capturing a shift from describing inequity to proposing institutional redesign to address inequity:

> “I feel like learning just how important water is raises questions about ideas like ‘Should water be free for everyone?’ I get that the water companies need to make money, but if they were fully government sanctioned, then everyone could have free, accessible water. It would solve a lot of problems” (SR).

This response does not simply name water as important, it questions whether the current organization of water provision serves justice and imagines an alternative governance arrangement. This student is not just questioning the status quo but proposing a vision for a different, justice-oriented future.

A few responses also connected water justice to corporate responsibility, reflecting concern about pollution and waste from large companies. One student questioned who should be carrying the burdens of water pollution, invoking restorative justice by asserting that polluters should be held accountable, stating that "some big companies should have bigger responsibilities for their water waste and pollution" (SR). This framing also positions injustice not only as municipal capacity or institutional decisions, but also as obligations proportional to industrial impact. Together, these reflections suggest that ECS helped some students connect water justice to institutional and corporate responsibility, although their analyses generally remained broad.

4.5.1.5 Ecological Justice

Several students framed justice as inseparable from ecosystem health and the prevention of contamination of natural systems. These responses reflect an ecological justice orientation in which harms to water are also harms to more-than-human communities, as well as to people, and their shared futures. One student connected pollution of waterways to justice, writing, "I learned in class 2 weeks ago that water is often very contaminated when they go into freshwater bodies like lakes and rivers. This made me think deeply about the justice and safety of water" (SR). A few students extended water as a right to all living beings, not just humans. One student responded, "I think water is for all animals not just us" (RAA), reflecting the rights of nature and a moral consideration for more-than-human life.

4.5.2 Students' Displays of Emerging CC

Students expressed CC through critical reflection and sociopolitical analysis, critical motivation, and critical action. Their responses showed evidence of critical thinking and questioning about water access, recognizing inequity in unequal exposure to water-related harms, identifying decision-making structures, expressing moral concern and urgency, and participating in civic and advocacy-oriented actions.

4.5.2.1 Critical Reflection and Sociopolitical Analysis

Evidence of students' critical consciousness development through sociopolitical analysis was seen during class discussions and activities. Students were able to identify civic institutions,

government jurisdictions, and decision-making power in their communities. They recognized multiple levels of authority and power, such as the mayor, city commissions, city ward representatives, school facilities staff, water department staff, and water treatment plant staff (FN). Their sociopolitical analysis could be seen in students' growth in aspects of sociopolitical literacy. For instance, at the beginning of ECS programming, students did not know of some specific institutions with authority over community water issues (e.g. Community Area Water Utility Authority; Benson Sustainability Commission). At the end of ECS programming, students were not only able to name these institutions, but knew how they functioned, what power they held and how their roles helped shape community water issues, or their solutions (FN).

Critical reflection was also evident in students' responses, particularly in their use of explanatory statements (e.g. it made me question) in reference to how students' ECS experience made them confront, reflect on, and question water justice. Students' critical reflection appeared most clearly in moments when they moved from noticing water issues to questioning access, responsibility, and decision-making. For example, student described heightened consciousness about water systems in the community, stating, "it made me be more conscious about where the water is going and how it gets there" (SR). Another reflected, "I realized that some people can't get water as easy as some other people. I think they should find a way to get water for cheaper and easier for everyone" (SR). This student's statement is especially important because it moves from recognition of inequality to a claim that something should be done. Recognizing that something is unjust and that something should be done about it is a crucial step in developing CC. These responses show students beginning to interpret water access as unequal and changeable.

At the same time, these reflections show emerging rather than fully developed CC. Students often recognized unfairness and institutional responsibility, but they less often explained the historical or structural mechanisms that produced unequal water access. Thus, ECS appeared to support initial critical reflection, especially around rights, access, and governance, while deeper structural analysis required more explicit scaffolding.

4.5.2.2 Critical Motivation

Students' emotional engagement and moral reasoning about the (un)ethics of exclusion provide evidence of critical motivation. One student wrote, "To withhold water from a person is inhumane" (RAA), while another argued for the rights of all people to have their needs met: "I

think everyone deserves a basic need for life, without it we would die, so how is it not a basic human right?" (RAA). Others framed motivation through environmental protection norms and collective responsibility, with one student asserting, "We just generally need to make our water clean and protect our environment" (SR).

4.5.2.3 Critical Action and Agency

Students' call-to-action campaigns provided evidence of participation in practices associated with critical action. Across classes, students conducted research, developed goals and strategies, identified allies and target audiences, gathered community input, synthesized findings into public narratives, and presented advocacy campaigns to school administrators, local officials, community partners, or public audiences (FN). These practices resemble elements of EJ organizing, including documenting conditions, building support, identifying decision-makers, and making public claims for change.

However, participation in these practices did not always mean that students explicitly framed their action as EJ work. Some students understood advocacy as a way to improve water, infrastructure, or environmental conditions; fewer, however, explicitly connected advocacy to structural inequality. This distinction matters for interpreting CC development: ECS gave students opportunities to practice action, but students' justice interpretations of that action varied.

4.5.3 EJ/EJE Aligned Praxis: ECS Participatory Process and Teacher Practice

4.5.3.1 Incorporation of Explicit EJ Content

Although not a core element of ECS, EJ content was integrated in all classes in this study through videos, articles and class discussions (FN). The amount and depth of direct delivery of EJ content varied by teacher/class context: some teachers introduced content in response to student comments during class discussions of related topics, others formulated lessons around these topics. The most introduced form of EJ content was examples of well-known cases of environmental injustice, and the resulting community activism and organizing of residents. Across classes, teachers incorporated examples of national, regional, and local EJ cases, including the Love Canal toxic waste contamination in Niagara Falls, NY, Nestle's water extraction and privatization of groundwater in Michigan, the "ecocide" of the Aral Sea and the Flint water crisis. Two of the teachers also shared examples of communities practicing civil disobedience (e.g. peaceful marches) as part of class discussions about these issues. Finally, one teacher also shared maps that overlaid flooding frequency with historically redlined and racially

segregated neighborhoods, connecting water issues to histories of racism, disinvestment, and uneven environmental risk.

4.5.3.2 Local Environmental Inquiry and Community Monitoring

ECS as practiced by all teachers centered on place-based environmental inquiry, with students acting as observers of and for their communities. Students took walks through their schools and neighborhoods to identify water-related issues, made observations, gathered relevant data, conducted water sampling and water quality analysis to use as evidence in their advocacy campaigns aimed at influencing local policy and practice (FN). Students also connected their water quality monitoring to institutional oversight and regulations. Students compared their data and findings to federal surface and drinking water quality standards, as well as to other locally generated data, like the results from mandated drinking water quality reports sent out by the utility authority (FN).

Teacher's praxis influenced what students looked for in these community investigations, by way of the observational prompts used and community partner guests who acted as interpretive guides of the landscape. In some cases, this skewed the focus to an ecological perspective, which centered ecosystem, plant and animal health and safety. For example, "the river guy" from a local watershed organization guided students to think about how what they saw might affect the oxygen levels in a nearby stream and therefore any animals living in it. In other cases, a historical and sociopolitical perspective was employed, which incorporated observations about how community spaces are used and whose decisions shaped their conditions. For instance, worksheet prompts asked students to record what kinds of land use they saw around them (e.g. housing, school buildings) and to look for literal signs (e.g. Benson City Park; Community Area neighborhood association) that might show who managed these public spaces (FN).

One student reflected that these experiences made them think about the importance of producing community-based knowledge and acting as a watchdog of local environmental conditions: "it educated me on how important monitoring my water is and finding out where it comes from and how" (SR). This reflects a step in informed participation, positioning learning and self-determined oversight as part of one's responsibility.

4.5.3.3 Community-Engaged Learning: Centering Community Concerns

As they conducted investigations and proposed solutions to community environmental issues, all students collaborated in some way with local experts, community members, community organizations, and policymakers. Students gathered survey and interview data from school and community members about local water concerns, eliciting community perspectives and building power to support their advocacy positions (FN).

In two teachers' classes, students met with Ms. D, a community member/activist and "ambassador". Ms. D's work addresses environmental injustice by connecting "often neglected" residents and bringing their voices into sustainability issues (FN). In her discussions with students, Ms. D emphasized that residents deserve to "take up space" but have often had their perspectives and concerns ignored. She described her work as learning what community members felt would sustain themselves and their neighbors long-term, rather than accepting what the city or outsiders thought. She identified water affordability, access, and the threat of municipal water cut-offs as central community concerns raised in these discussions. Ms. D. also was clear in asserting her position, i.e., that water is a human right, and encouraged students to engage community members to learn about and address their concerns. Ms. D. modeled community-centered EJ praxis and recognitional and interactional justice by centering students' and residents' experiences and expertise as legitimate knowledge (FN).

4.5.3.4 Opportunities for Reflection on Fairness, Justice, and Water

Student responses to the prompt, "Did any of the activities your class did, discussions you had, or anything you learned make you think about fairness or justice issues about water?" provide evidence that teachers' ECS praxis supported EJ reflection. The majority, 72%, indicated that their ECS experience made them think about issues of environmental injustice in some way (SR).

Through various activities, all teachers asked students to consider questions of water access, drinking water safety, and pollution such as: Where does your drinking water come from? Should water be free? Or paid for? Do you think water availability is a community issue? and Is water/access it to a right? One teacher did this by incorporating these types of questions into class discussions. In two teachers' classes, students responded to these questions by writing their answers on posters around the room and took a "gallery walk" to read others' answers alongside their own. These activities served as opportunities for critical reflection, especially by

allowing students to activate critical thinking both in response to the questions and in contemplating other perspectives, activating their critical thinking.

4.5.3.5 Engagement with Decision-Makers and Authority Structures

The participatory process also included opportunities for sociopolitical analysis through class discussions about community decision-making. Teachers' praxis shaped these discussions, which were led by questions that support EJ learning and CC development, such as: Who are the decision-makers in our community? Who controls water in our community? Who is responsible for environmental decision-making?

Students were then able to conduct a form of power analysis in relation to the water issues they chose to address. They identified entities and roles that might hold authority or influence over these issues such as: the mayor, Department of Environmental Quality, City Council ward representatives, principals and school facilities staff. This is one example of where teachers were intentional about making visible the role that government and other authorities play in the context of students' lives and community environmental conditions (FN).

In two teachers' classes, students' understanding of governance and decision-making was bolstered by trips either to City Hall or to the community water utility facility. In Community Area High School classes, students toured the municipal water treatment plant, learning and experiencing how water is treated and processed. This provided students with new understandings about what goes into the management of water systems, especially in relation to drinking water and wastewater. Staff also informed students about, and encouraged their families to take part in, the utility authority's EPA sponsored initiative to "get the lead out" by identifying and replacing lead service lines to homes within its service area (FN).

During the field trip to City Hall, Benson High School classes toured operational departments and discussed city environmental policies, including initiatives to replace old lead service lines and strategies for stormwater runoff management. Students learned about roles in municipal governance, such as water system infrastructure, about governmental decision-making, and how the public can participate in environmental management and decisions at the municipal level. Their teacher stressed that the people students met with were the people making decisions that impact the places they live and care about, drawing a direct and personal connection between governmental actions and community consequences (FN). City staff also

stressed that their role was to serve the needs of residents, stating “We answer to you”, underpinning that civic institutions can be held accountable by community members (FN).

In response to the reflection prompt that asked students if ECS made them think about fairness or justice, students referenced these activities directly as opportunities for sociopolitical analysis. One student wrote, “We went to city hall and learned who makes the decision about water in our city” (SR). Another student, after the visit to City Hall, asked the class about their “call to action” campaign, “what if the things we decide to target aren’t the right things to target?” This student gave the example of fixing roads, a community issue that the class had discussed, but then wondered if spending money to fix the roads was the right thing when there are “homeless people on the street and the roads will just get messed up again” (FN). This moment reflects students’ developing ability to reason about policy priorities, resource allocation, and the complexity of public decision-making.

4.5.3.6 Organizing, Mobilizing, Advocacy, and Public Action

Finally, ECS created conditions for EJ learning by structuring student participation around practices that resembled EJ movement work, primarily through experiences that supported their development of “call to action” advocacy campaigns. Students developed goal and strategy statements, identified allies and target audiences, conducted research, gathered community support, synthesized their findings into data-driven narratives, created public education materials, engaged in storytelling and finally advocated for change. In these ways, students enacted the practices of EJ.

4.6 Discussion

Across classroom observations and student reflections, participation in ECS appeared to provide students with multiple entry points into EJ learning. Students understood water issues not only as ecological or technical issues, but also as matters of rights, unequal access, institutional responsibility/accountability that can be influenced by people’s collective action. Through ECS’s inquiry-to-action process, students investigated local environmental conditions, interpreted those conditions using their community knowledge and applying questions of fairness. Students identified institutional actors and decision-making structures and used evidence to advocate for changes to people in positions of authority.

This discussion is organized first around students’ multidimensional EJ understanding and emerging environmental CC that was afforded by the ECS process overall. The discussion

then turns to the specific aspects of the process, community-based inquiry and monitoring, community expertise and recognition, governance and sociopolitical visibility, and collective action/youth agency as affordances. Finally, it addresses teacher praxis, the limits of inquiry alone and a summary of the study's main contributions.

4.6.1 Learning Across the ECS Inquiry-to-Action Process

My first research question asked what forms of EJ understanding students articulated in relation to their participation in ECS. Rather than treating students' responses as evidence that they had acquired a single definition of EJ, the findings are better understood as evidence that students engaged EJ as multidimensional and used aspects of these dimensions to make sense of water issues. This multidimensional understanding of EJ did not result from one ECS practice or learning opportunity. Instead, it appeared to emerge across the entire inquiry-to-action process as students moved between local observation, data collection, community engagement, decision-maker analysis, and advocacy.

In developing their concepts of justice students incorporated rights-based reasoning, distributive justice, procedural justice, recognitional justice, and ecological justice. Rights-based reasoning emerged the strongest when students were prompted to consider water as a human right. Distributive reasoning became more concrete when students examined unequal infrastructure, access, and environmental burdens in familiar places. Procedural justice became visible when students asked who makes decisions about water, schools, utilities, and public infrastructure. Recognitional justice was enacted throughout the process when community knowledge and students' lived experiences were treated as legitimate sources of environmental evidence. Ecological justice appeared when students connected shared environmental conditions and futures to the well-being of waterways, animals, and ecosystems.

The significance of these findings is not simply that students articulated these dimensions, but that ECS created a process through which students could encounter these dimensions in relation to one another. Students were not memorizing definitions of rights, distributional justice, participatory justice, recognitional justice, or accountability. Instead, they were engaging questions such as: Who has clean and affordable water? Who is affected when infrastructure fails? Whose knowledge counts in defining environmental problems? Who has authority to make decisions? What responsibilities do institutions have to communities? These

questions are central to EJ learning because they help students move from environmental awareness toward justice-oriented interpretations and actions.

My second research question asked how students expressed CC, including critical reflection, sociopolitical and structural analysis, critical motivation, and critical action. The ECS inquiry-to-action process-level finding also helps explain students' emerging CC. ECS provided a context for what might be called environmental CC: the developing capacity to interpret socio-environmental conditions as unjust, to understand their institutional or structural roots, to feel motivated to address them, and to participate in actions aimed at community change for a more just future. This learning cannot be attributed to a single field trip, lesson, monitoring activity, or advocacy presentation. Rather, it appeared to develop through the cumulative movement from inquiry to interpretation to action.

This suggests one possible pathway to CC development: local environmental inquiry makes conditions observable; community engagement connects those conditions to lived experiences and collective concerns; decision-maker analysis makes governance and accountability visible; and public advocacy gives students a structured opportunity to act on evidence and moral concern. Through this sequence, students can connect their environmental knowledge to sociopolitical analysis and civic agency.

At the same time, I cannot conclude from these findings that a multidimensional understanding of EJ or CC develops automatically when students engage in ECS. The reasoning that students articulated about justice in relation to water issues and their ECS experiences was more developed in some dimensions than others. Rights-based water access and distributive justice claims were more prominent than assertion of rights to participation or structural analyses of environmental racism, colonialism, or political economy. Many students articulated moral concerns and rights-based motivations; some connected environmental conditions to institutional neglect, profit, or unequal political attention. Fewer explicitly named historical disinvestment or regulatory failure. This unevenness suggests that ECS can create entry points into EJ learning, but those entry points are likely to require intentional curricular support if students are to develop deeper explanations of how environmental injustice is produced and can be rectified.

ECS appeared to support CC development when students were invited to ask why conditions differed across communities, who had decision-making authority, what interests were being served, and how evidence could be used to demand change. In this sense, ECS helped shift

environmental learning from “What is the problem?” to “How did this problem come to be, who is responsible, and how might collective action address it?”

For these reasons, this study’s claims are intentionally modest. I can assert that ECS afforded opportunities for emerging CC but cannot claim that all students developed robust structural analyses of environmental injustice causes through their ECS participation. The results, however, do suggest that the value of ECS is in creating conditions through which students’ critical reflection, motivation, and action could begin to cohere around environmental issues.

4.6.2 Affordances of ECS Process Elements

4.6.2.1 Community-Based Inquiry and Monitoring as EJ Learning

One affordance of ECS was its focus on community-based environmental inquiry and monitoring. Students observed local environmental conditions, gathered data, conducted water quality analysis, and used that evidence to interpret environmental problems in their own communities. The ECS practices positioned students as knowledgeable and respected participants in community-based monitoring and environmental oversight. In this way, students were situated not only as learners of environmental content, but also as participants in knowledge production about local environmental conditions.

This ECS affordance supported EJ learning by making local environmental conditions observable and open to interpretation. Students could see, measure, and document aspects of the environmental problems they were studying. In particular, observing and analyzing local water conditions made distributive and ecological justice issues concrete and meaningful in students’ own experiences. Students were able to examine how environmental burdens, infrastructure, and access differed across places that were familiar. By focusing attention on environmental conditions in the places they knew and cared about, students could make connections between human well-being and the waterways, animals, ecosystems, and environmental futures they shared.

Community monitoring also supported emerging CC because it transformed observation into civic and justice-oriented inquiry. Students did not simply document water quality, flooding, pollution, or infrastructure problems; they were prompted to ask what those conditions meant, who was affected, who was responsible, and how evidence could be used to advocate for change. Because monitoring occurred in familiar school and community spaces, students could connect

environmental data to lived experience and community well-being. Because monitoring was connected to decision-maker analysis and public advocacy, students could also see environmental conditions as governed rather than natural or inevitable.

This matters because noticing a problem is not the same as understanding it as unjust or changeable. Students may observe litter, flooding, contamination, or inadequate infrastructure without asking how those conditions came to be, who benefits or is burdened, or whether institutions could respond differently. ECS monitoring created structured opportunities for students to move from "this is what we see" to "this is what this condition means for people and communities" and then toward "someone made or failed to make decisions that shaped this condition."

This matters theoretically because environmental monitoring is not only a scientific practice. Indigenous and activist-scholars have described monitoring as an assertion of governance and of whose knowledge counts (Wilson et al., 2018; Zavala & González, 2022). In this light, student monitoring in ECS can be interpreted as a classroom-based version of community-driven science practices used to challenge inequities in environmental decision-making (Ballard et al., 2023; Basile & Roth, 2022; Haq et al., 2024). Instead of just learning about the local environment, community monitoring became a way for students to produce and share their local environmental knowledge and to participate in environmental oversight.

The findings therefore suggest that inquiry and monitoring were important not because they independently produced students' EJ understanding, but because they grounded that understanding and reasoning in evidence from local environmental conditions. Monitoring and water issue inquiry provided students with concrete bases for interpreting water issues as public, justice-laden problems.

4.6.2.2 Community Expertise, Recognition, and the Social Landscape of Environmental Problems

A second affordance of the ECS inquiry-to-action process was the incorporation of community expertise and community concerns. My third research question asked how the ECS participatory process and teachers' praxis created conditions for students to connect environmental issues to EJ learning. Aligning with justice-oriented science education (Morales-Doyle, 2017), one way that ECS created these conditions was by positioning community knowledge as a legitimate source of environmental understanding and evidence of EJ issues.

Community engagement helped students understand that environmental problems are not defined only by agencies, textbooks, or scientific instruments; they also are, and from an EJ perspective should be, defined by the people who live with their consequences. This does not reject scientific or regulatory knowledge. Rather, it recognizes that technical data are incomplete without community knowledge about how environmental conditions are experienced. For example, official water-quality reports might define school drinking water as safe, while students' experiences showed that taste, access, and trust also shaped whether the water system met students' needs. Similarly, flooding can be measured through rainfall, drainage, and sewer capacity, but residents' experiences reveal the lived burdens of flooding: damaged homes, sewer backups, unsafe streets, financial loss, and unequal institutional response.

Community partners such as Ms. D modeled this orientation by emphasizing that residents deserve to "take up space" in sustainability decisions and by identifying water affordability, access, and shutoffs as concerns that residents themselves had named. These examples reflect recognitional justice, procedural justice, and civic science perspectives, all of which argue that affected communities should help define environmental problems, determine what evidence matters, and shape the solutions pursued. ECS community engagement helped students see that scientific data can identify environmental conditions, but community experience helps define their significance. This reflects an environmental justice perspective: people who live with environmental harms should have a role in naming the problem, determining what evidence matters, and shaping the response. The environmental justice movement has long argued that affected communities should not be studied, regulated, consulted after decisions are made, or spoken for by experts. They should be central in defining environmental problems, identifying harms, setting priorities, and shaping solutions.

Recognizing and respecting local knowledge and expertise also supported CC development by connecting environmental conditions to lived experience and collective concerns. ECS helped students interpret water issues as social and political problems in addition to ecological or technical ones. By incorporating the social landscape of their communities into their investigations, students centered community concerns and connected those concerns to their own environmental observations as well as to arguments for community change. Through this process, students could ask whose concerns had been neglected, whose knowledge had been

taken seriously, and whose experiences should and could play a role in local environmental decision-making.

The findings therefore suggest that ECS supported EJ understanding through the participatory practices students enacted. Community engagement became a way to practice recognition and to understand whose concerns have been neglected. This process helped students move from viewing environmental problems as isolated local issues to understanding them as connected to community knowledge.

4.6.2.3 Governance, Sociopolitical Visibility, and Procedural Justice

Taken together the results suggest that ECS made environmental governance visible. I use the term environmental governance broadly to refer to formal political institutions, agencies, utilities, school districts, infrastructure systems, corporate actors, community organizations, policies, norms, and decision-making processes that play a part in impacting environmental conditions. By emphasizing students' local knowledge, insights, and their interactions with decision-makers, ECS supported students' understanding of environmental issues as public problems governed through multiple institutions and decision-making processes.

This governance orientation supported students' EJ understanding in relation to the first research question. Procedural justice became visible when students asked "who makes decisions" about water, schools, utilities, and public infrastructure. Distributive justice also became more concrete when students connected unequal access, infrastructure, and environmental burdens to the decision-making process. In ECS students' learning went beyond ecological and scientific understanding to also include sociopolitical and civic systems reasoning, i.e., their capacity to recognize how environmental conditions are shaped by infrastructure, policy, funding, regulation, jurisdiction, authority, and accountability.

In relation to my second research question, the governance orientation of ECS also supported emerging CC. ECS appeared to support CC development when students were invited to ask questions that included why conditions differed across communities, who had decision-making authority over specific environmental issues, whose interests were being served by the decisions, along with how the students' own evidence could be used to demand change. Field trips and follow-up discussions created opportunities for sociopolitical analysis: students had face-to-face interactions with people who were in roles or who made decisions that impacted the environmental conditions in their community. Interactions with officials and other people who

had influence over the issues students were investigating demystified governmental authority. Rather than understanding government, utilities, or public agencies as abstract institutions, students were able to recognize that there are real people in positions of power whose decisions affect environmental conditions in their communities. These interactions helped students view environmental problems as not inevitable or merely technical, but as produced through human decisions and therefore open to collective (including their own) challenges. Understanding the local environmental civic landscape is critical for students' to have an impact.

The inclusion of governance, policy, and decision-making authorities differentiates ECS from forms of EE that emphasize individual stewardship or behavior change. Students were not only encouraged to conserve water, recycle, or make environmentally responsible choices. They were also positioned to ask what decision-makers, those in positions of authority, should do. This shift from individual responsibility to institutional and collective responsibility is essential for EJE because environmental injustice is produced through systems of power. In fact, the lack of focus in EE on collective action to address root causes can distract from the systemic, structural, and cultural changes needed to address environmental crises and can absolve the state of responsibility for the environmental public good (Dimick, 2012; Kluttz & Walter, 2018).

The governance-focused learning in ECS also addresses my third research question by showing how ECS's participatory process created conditions for students to connect environmental issues to EJ learning. Decision-maker engagement became a way to analyze community sociopolitical conditions and understand procedural justice and institutional responsibility. ECS's attention to decision-makers, target audiences, and policy/practice change encouraged students to see the layers of authority and accountability that shape local environmental conditions. Demystifying the sociopolitical context of young people's communities by making it concrete and accessible can help young people imagine how they can have a voice in environmental decision-making (Knowles & Clark, 2018; Schenkel & Calabrese Barton, 2020).

The governance focus in ECS matters for EJE because environmental injustices are rarely produced by a single actor or event. They emerge through layered decisions about where infrastructure is built or neglected, which communities receive investment, how regulations are enforced, whose complaints are taken seriously, how risks are communicated, and which futures are imagined as possible. In this sense, ECS's participatory process supported EJ understanding

by helping students learn that environmental systems are governed systems and that governance can be questioned, navigated, pressured, and potentially changed.

4.6.2.4 Collective Action, Youth Agency, and Public Advocacy

Another affordance of ECS was that it created opportunities for collective action and youth agency. ECS's justice-oriented potential depends not only on students identifying decision-making systems but also on students experiencing themselves as people who can participate in those systems. CC requires agency: the belief and capacity to analyze injustice and participate in efforts to change it. ECS appeared to support this by positioning students as observers, knowledge producers, community researchers, advocates, and civic actors.

Through their public advocacy students could connect evidence of an environmental issue with their moral concerns and with institutional accountability. Through their advocacy presentations, students also experienced their own identities as part of a collective and their own capacities to engage in critical action in their communities. Public advocacy became a way for them to practice participation, accountability, and critical action. Students' call-to-action campaigns were therefore not simply culminating projects. They were opportunities to practice dissent, within environmental governance systems (O'brien et al., 2018).

To address my second research question, ECS appeared to support emerging CC by giving students a structured opportunity to act. Their collective actions also deepened students' EJ understanding. Their advocacy campaigns required students to frame environmental issues as public concerns, to identify audiences with responsibility or authority, and to make claims about what should change. This helped students understand environmental issues as matters of rights, unequal access, institutional responsibility, public accountability, and collective action. It also supported procedural justice because students practiced addressing individuals and institutions with decision-making power.

This affordance of ECS resonates with previous work on agency in EE, civics, and science education, which shows that young people develop civic and science agency when they investigate issues affecting their communities, and act publicly on the issues they uncover (Ballard et al., 2017; Morales-Doyle, 2017). In reflections on ECS projects documented in my prior work, students consistently mentioned the power of their voice and the impact they can have on community decision-making, including influencing those in positions of power (Gallay

et al., 2021; Gallay et al., 2022). Experiences of collective action and public advocacy can help young people communicate their ideas and effect change (Buckland et al., 2018).

Certainly, students' calls to action can be denied or even ignored by decision-makers (Pena-Vega et al., 2022). Although this is true, I contend that it is important that students have opportunities to practice the skills of advocacy. The ECS process affords students such opportunities with the guidance and support of adults (teachers and community partners) who are in their corner. These intergenerational relationships scaffold students' learning, enabling them to develop capacities that are foundational to advocating for community environmental change. In this way, ECS afforded students opportunities to practice forms of democratic participation and collective action that are necessary for EJ work.

Finally, the action components in ECS position youth as legitimate participants in matters that affect their schools, neighborhoods, health, and futures. That stance (recognizing and respecting youth as worthy partners in decision making) is itself justice-oriented given that youth are often excluded from environmental decision-making that directly impacts them.

4.6.3 Teacher Praxis and ECS Affordances

Although ECS provided a structure that afforded students opportunities to participate in community change and decision-making at multiple levels, its EJ affordances were further shaped by teacher praxis. Teachers made consequential decisions about what examples of environmental (in)justice to introduce, which questions to ask, how to frame local environmental issues, when to name injustices, how to discuss race and class, and how to connect students' observations to broader histories and structures. In other words, ECS recognizes that teachers are curricular-instructional gatekeepers whose choices shape how students encounter content and practice.

Recognizing the authority and decisions of teachers as they interpret and incorporate ECS into their classes is critical because ECS is not a cookie-cutter curriculum but rather an intentionally flexible process. Flexibility in ECS implementation allowed teachers to adapt ECS to different classes, disciplines, local contexts, and community concerns. It also allowed teachers to incorporate EJ examples and reflection prompts that were responsive to their students and settings. That said, the flexibility of ECS enactment means that teachers may leave out important elements. For example, if teachers do not explicitly scaffold structural analysis of the

environmental issues students address, students may recognize unfairness without understanding its root causes.

The findings suggest that teacher praxis shaped the level of analysis students reached. When teachers asked broad questions about fairness, students often generated rights-based or distributive responses. When teachers made governance visible, students began to ask who decides and who is responsible. However, when race, historical disinvestment, or environmental racism were not explicitly named and revisited, students did not introduce those frameworks on their own. This pattern suggests that students may need more than exposure to local environmental inequity; they need repeated opportunities to practice using structural concepts to interpret local evidence.

While the inquiry-to-action process affords opportunities for students to confront these realities on their own, they are likely to need guidance and scaffolding. For example, the students who focused their advocacy campaign on cooling infrastructure at their high school were addressing an EJ issue, although they did not directly articulate it as such. In their campaigns these students invoked a distributive justice perspective, but they did not tie the fact of older school buildings lack air conditioning to municipal underinvestment in lower-income communities. To make EJ connections clearer, teachers could name this as environmental classism or racism, or even simply as an issue of justice. They could have students research urban heat islands and the fact that low-income communities and communities of color historically experience less urban tree canopy and more concrete, and thus significantly higher temperatures and worse air quality.

This conclusion is consistent with scholarship that contends that EJE should focus on both content and process (Miles et al., 2025). Participatory inquiry is powerful because it situates learning in local questions, community relationships, and action. However, students also need explicit concepts, historical examples, and analytic tools to frame and interpret what they encounter. Content matters because students need language for naming environmental racism, classism, colonialism, disinvestment, privatization, procedural exclusion, and unequal enforcement. Process matters because students need opportunities to apply that language to lived and local conditions and to collectively? act with others.

The implication is that ECS should be understood as a pedagogical architecture that becomes more EJ-oriented when teachers intentionally connect inquiry to structural and root-

cause analysis of the issues students investigate. For example, investigating flooding can become an inquiry into stormwater infrastructure, zoning, land use, redlining, and climate adaptation. Studying water affordability can become an inquiry into shutoffs, municipal finance, privatization, and water governance. Monitoring water quality can become an inquiry into regulatory systems, public trust, unequal enforcement, and community oversight. Making these connections requires teacher preparation and curricular support.

4.6.4 Participation Rights: Present in the Framework, Not in Student Reflections

Meaningful participation in environmental decision-making is a central EJ principle. Although students participated in advocacy through ECS, they did not explicitly articulate participation as a right. This distinction between participating and naming participation as a justice claim is important for interpreting the limits of students' EJ understanding in this chapter. Students did not say that community members, youth, or residents have a right to participate in water governance or environmental decision-making. This absence is one of the most important findings of this study. It suggests that although ECS created opportunities for students to participate in naming environmental issues, collecting evidence to document those issues and support advocacy and participating in decision-making structures, they did not frame participation itself as a justice claim.

Some student responses placed responsibility for participation and protection primarily on authority figures. These responses show emerging awareness that water issues are governed, but they still locates decision-making authority with authority figures as decision-makers, rather than asserting community members' right to participate in those decisions. Student responses also expressed agency, collective responsibility, and action orientation, but they do not yet articulate a right to participate in governance or a demand that decision-making processes include affected communities.

Students also differed in whether they understood decision-making as connected to justice. One student explicitly separated decision-making from justice, writing, "Not really it was more just the cost of doing things and who makes the decisions at like city hall and stuff. We talked about how things work not who gets the water." This response is analytically important because it shows that learning about governance does not automatically lead students to interpret governance as a justice issue.

One reason this dimension may have been less visible is methodological. The first reflection prompt, “Is water a human right? Explain,” invited rights-based reasoning about access to water more directly than rights-based reasoning about participation in decision-making. The second prompt, which asked whether ECS made students think about fairness or justice issues related to water, created more space for students to discuss decision-making, city hall, and government responsibility. Even so, students tended to describe who makes decisions or what government should do rather than asserting participation as a right.

4.6.5 Absence of Reasoning about EJ and Race, Environmental Racism

Another of the most important findings in this study was hat race and environmental racism was missing from students’ reflections. In their reflections on whether they thought about fairness or justice in the course of their ECS projects, students discussed socioeconomic inequality, affordability, infrastructure disparities, unequal political attention, neglect, profit, and institutional responsibility. They did not, however, connect environmental injustice to racism or racialized histories. The absence of references to racism connects to my findings on teacher praxis, specifically that participatory inquiry can enable students to recognize environmental unfairness, but it does not necessarily lead them to understanding or analyzing environmental racism.

Several factors may help explain this pattern. Students may have had more language or ease in naming socioeconomic inequality than in naming environmental racism. The reflection prompts may also have invited broad reasoning about fairness and water rights more readily than historical or racial analysis. In addition, teacher praxis varied, meaning students had different levels of exposure to race-explicit EJ content and different opportunities to connect that content to local investigations.

This observation supports EJE scholarship arguing that education must explicitly address racism, classism, colonialism, policy, and power rather than relying on general commitments to fairness or sustainability (Guevara-Herrero et al., 2024; Miles et al., 2025; Tannock, 2021). If students interpret inequality mainly through the lens of poverty or uneven resources, they may miss how race and class inequities are co-produced through housing, infrastructure, land use, political representation, public investment, and the intersectionality of EJ issues.

At the same time, the lack of references to environmental racism should not erase what students did articulate. Their attention to affordability, unequal infrastructure, neglect, profit, and

institutional responsibility reflects important movement toward reasoning about the unjust causes of environmental issues. Thus, the study findings are promising despite their limitations: ECS can open pathways into EJ learning, but race-conscious and historically grounded instruction is necessary if students are to develop robust environmental racism analyses.

4.6.6 Central Contributions

The central conceptual contribution of this study is that EJ learning appeared to deepen when students began to understand environmental systems as governed. Water quality, water access, infrastructure, flooding, heat exposure, and environmental safety were not understood only as ecological or technical matters. Instead, they were framed as conditions shaped by institutions, policies, public investment, infrastructure decisions, corporate practices, unequal responsiveness, and community voice. This governance orientation was visible in both teachers' instructional framing and students' understanding.

This contribution responds to calls in environmental and justice-oriented education to move beyond scientific explanation alone and address the cultural, political, economic, and institutional roots of environmental challenges (Tannock, 2021). EJE scholars have also argued that students should examine who is represented and excluded in environmental decision-making, how policies and institutions shape unequal environmental conditions, and how communities organize to challenge injustice (Guevara-Herrero et al., 2024; Miles et al., 2025). This study adds empirical specificity to those calls by showing how a participatory framework such as ECS can make those questions part of students' learning in standard high school science and social studies classrooms.

Finally, this study adds pedagogical specificity to both EJE and CC theory. ECS points to one pathway through which EJ understanding and environmental CC can develop in classroom contexts: local environmental inquiry makes conditions observable; community engagement connects those conditions to lived experience and collective concern; decision-maker analysis makes governance and accountability visible; and public advocacy gives students a structured opportunity to act on evidence and moral concern. Through this inquiry-to-action process, students can begin to understand environmental systems as governed, justice-laden, and potentially changeable through collective action.

4.6.7 ***Limitations***

Several limitations about this study should be noted. This study was exploratory and conducted in a specific regional context, with water as the central environmental focus. Findings may not generalize across regions, environmental issues, or school contexts. The study also relied on classroom observations and student reflections, which provided insight into students' sensemaking but may not capture the full depth of students' EJ understanding or CC. In addition, because teacher praxis varied across classrooms, it is not possible to isolate which ECS elements were most influential for particular student outcomes. Finally, the reflection prompts may have elicited rights-based and fairness-oriented responses more readily than race-conscious or historical analysis.

4.6.8 ***Implications for Practice and Future Research***

This study has several implications for research and practice. For practice, the findings uphold the assertion that teachers and curriculum designers should treat EJE as both content and process. Students need explicit instruction about environmental racism, water justice, policy, and historical disinvestment, but they also need participatory opportunities to investigate, deliberate, collaborate, and act. Teacher preparation should support educators in facilitating inquiry that connects environmental science to governance, power, and structural inequality. Community partnerships should be designed as reciprocal relationships that honor community expertise rather than as one-time enrichment activities. Public action should be treated as a legitimate component of rigorous environmental learning, not as an optional culminating activity.

For research, future studies could further examine the specific mechanisms through which ECS practices support EJ understanding and CC development. The present study points to several likely mechanisms: local monitoring, community knowledge-gathering, decision-maker engagement, rights-based reflection, and public advocacy. Future work could examine in depth how each contributes to critical reflection, motivation, structural analysis, and action.

Future research could also investigate how teacher praxis mediates justice-oriented learning through other flexible frameworks like ECS. Because teachers shape whether students connect local inquiry to race, class, policy, history, and power, studies could attend closely to teacher framing, classroom discourse, curricular materials, and professional learning. Longitudinal research is also needed to understand how students' EJ understanding develops over time. Short-term participation may generate moral concern and initial sociopolitical reasoning, but deeper structural analysis of the root causes of environmental justice issues likely

requires repeated engagement with multiple cases, concepts, community partnerships, and opportunities for action.

4.7 Conclusion

This study examined how ECS can create conditions for students to understand environmental issues as justice issues in high school science and social studies classes. The findings suggest that students' justice understanding can develop not only through EJ content, but also through participation in practices that mirror EJ organizing: documenting local conditions, centering community concerns, identifying responsible institutions, and making public demands for change. These participatory experiences helped students begin to see environmental problems as governed, contested, and potentially changeable rather than as merely technical or individual concerns. At the same time, participatory inquiry alone is insufficient. Students need explicit scaffolding around environmental racism, water justice, historical disinvestment, and structural inequality. This study's central contribution is the claim that EJ learning and emerging CC deepen when students come to see environmental systems as governed and shaped by infrastructure, institutions, policy, power, community voice, and decision-making.

Overall, ECS can contribute to justice-oriented EE and EJE by offering a framework for connecting environmental inquiry, civic participation, community knowledge, and structural analysis of root causes of EJ issues. ECS's promise lies in operationalizing key EJE commitments in classrooms where environmental justice may not be the explicit curricular focus.

4.8 **References**

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Chapter 5 Conclusion

5.1 Summary of Major Findings and Contributions

This dissertation addressed a central challenge for education in an era of socio-environmental crisis: how to prepare young people to draw on environmental science and civic knowledge and practice to respond collectively to environmental problems and environmental injustice. There is growing recognition that school-based learning can better meet this challenge by connecting scientific learning to civic engagement and collective public action while attending to power, policy, and systemic change (Ardoin et al., 2023; Lee et al., 2021; Miles et al., 2025). Scholars therefore call for research on action-oriented environmental learning that uses participatory, community-based approaches to engage young people in civic action (Gyles, 2024; Miles et al., 2025; Sezen-Barrie et al., 2025; Tannock, 2021).

In response to this need, this dissertation examined Environmental Civic Science (ECS) as a theoretical and pedagogical framework that integrates place-based environmental inquiry, community partnership, engagement with decision-makers, and collective public advocacy. Across three interrelated studies, I investigated how high school teachers enacted ECS, how students in science and social studies classes experienced ECS, and how ECS participation related to critical environmental science agency (CESA), collective action, environmental justice (EJ) understanding, and emerging critical consciousness (CC).

The dissertation makes three primary contributions. First, it documents how ECS can be enacted in different formal school contexts and how teacher praxis can shape students' learning opportunities. Second, it introduces and advances CESA as a means for understanding the agency young people need to address socio-environmental issues in community and policy contexts. Third, it contributes to environmental justice education (EJE) by showing how students can begin developing EJ understandings and aspects of CC through participatory inquiry-to-action processes, even in courses not explicitly designed as EJE.

Across the three studies, students experienced environmental learning as meaningful when it was locally grounded, community-connected, and directed toward authentic public audiences. Consistent with place-based, civic science, and action-oriented environmental

education scholarship (Gruenewald, 2003; Jensen & Schnack, 1997; Derrien et al., 2020), students developed the skills and confidence for environmental civic action and began to understand environmental issues as governed by systems and institutions shaped by policy, infrastructure, investment, community voice, and collaborative decision-making. Taken together, the three studies show how ECS combines environmental science, civic participation, and justice-oriented action to help young people use evidence, community knowledge, and collective voice in democratic environmental decision-making.

5.2 Summaries by Chapter

5.2.1 ECS Praxis and Students' Opportunities for Consequential Learning

Chapter 2 introduced ECS as a theoretical and pedagogical framework, documented how its core elements were practiced across three high school teachers' classrooms, and examined how variations in teacher praxis shaped students' learning opportunities and outcomes. The study drew on qualitative evidence from classroom observations, teacher logs, student reflections, and focus groups, to show that ECS supported a range of student outcomes under the umbrella of environmental civic learning. These outcomes included understanding of environmental issues from disciplinary perspectives, such as history, biology, and earth science; application of science and civic knowledge and processes; civic and science efficacy; civic literacy about decision-making systems; collaboration and problem-solving skills; and motivation for collective action.

The four core elements of ECS served as mechanisms for achieving these outcomes. Aligning with research on place-based education and critical place-based learning, place-based inquiry made environmental problems consequential by grounding learning in places students knew, (Gruenewald, 2003; Tuck et al., 2014). Peer collaboration made agency a shared practice rather than an individual one, consistent with civic development research that conceptualizes youth agency as relational and collective (Flanagan, 2013; Kirshner, 2015). Intergenerational partnerships expanded what counted as legitimate knowledge and who counted as an expert, echoing justice-oriented science education's emphasis on community knowledge and youth expertise (Bang et al., 2012; Calabrese Barton & Tan, 2018). Public advocacy helped students learn how evidence can be communicated in ways that influence decision-making processes, a

central feature of civic science and action-oriented environmental learning (Derrien et al., 2020; English et al., 2018).

Decision-maker engagement was especially important for students' sense of agency in governance contexts. When students addressed advocacy campaigns to audiences with authority to respond, allocate resources, or change policy or practice, they were more likely to view their work as impactful. This aligns with research on sociopolitical control and youth civic development, which emphasizes young people's perceived ability to understand and influence social and political systems (Zimmerman, 1995; Watts et al., 2011). For example, students who advocated for drinking water infrastructure changes to school and district leaders saw their evidence connected to a concrete infrastructure response. When audiences were less directly connected to decision-making power, students still reported growth in confidence, teamwork, socio-cultural community understanding, and voice, but did not reference belief in their institutional impact.

Chapter 2 also showed that teachers' ECS praxis shaped student outcomes. Differences in teachers' emphasis on scientific investigation, governance, community engagement, and advocacy shaped whether students encountered environmental issues primarily as ecological, civic, or policy-related. Thus, teachers' choices in how they enacted ECS' core elements mattered for students' learning outcomes. For example, when students toured their school campus and neighborhoods to photograph evidence of water issues, they were able to gain insight into how land use affects stormwater and infrastructure impacts neighborhood. Whereas students who focused on water quality testing at local streams learned about human-nature interdependence pollution prevention and mitigation. Both are examples of modes of inquiry and forms of data gathering, but each center a different process for investigating community water issues.

5.2.2 Students' Development of Critical Environmental Science Agency

Chapter 3 advanced CESA as a construct and measured it as an outcome related to ECS participation . Building from environmental science agency and critical science agency, CESA refers to students' capacity and drive to work with others to apply environmental science and civic knowledge and practice to socio-environmental and EJ issues in their community. CESA foregrounds agency as collective, decision-making-centered, and justice-oriented (Ballard et al., 2017; Basu et al., 2009; Schenkel & Calabrese Barton, 2020). Quantitative results showed that

ECS students had statistically significantly greater increases than comparison students in their environmental actions, competence to address community water issues, sociopolitical control, and capacity to take action for environmental change. These findings suggest that ECS was associated with students' perceived capacity to participate in environmental problem-solving and take action with others.

Qualitative findings explained what this growth looked like in practice. Students enacted CESA by collecting and interpreting local environmental data, identifying pathways for civic decision-making, developing proposals, mobilizing peers and community members, and advocating for institutional change. Students expressed CESA through their confidence in and ability to apply science and civic knowledge, work together for community change, build collective voice, identify decision-makers, and influence institutions with the power to change policy and practice. These findings suggest how ECS appeared to support students' development of CESA as collective and power-aware.

The introduction of CESA and students' growth in it in relation to ECS is one main contribution of this dissertation. Because CESA is a theoretical construct for understanding students' capacity to use environmental science and civic knowledge collectively for community environmental decision-making, it is also a practical student outcome. It can help identify *what* educators should design for in their classrooms if they want to support students' ability to participate in community decision-making about socioenvironmental issues: competence, confidence, motivation, and perceived power. It is important within the context of ECS because it helps bound *how* educational experiences should be designed, i.e. explicitly teaching how environmental decisions are made, and creating opportunities for participating in associated decision-making processes.

Chapter 3 also shows that CESA as agency for socio-environmental problem-solving develops through participation in relationships, practices, and public-facing action. Students were more likely to see themselves as capable environmental actors when they had opportunities to investigate a local, relevant issue, learn who had authority over it, work with others, and communicate recommendations to authentic audiences. This finding is central to the dissertation's argument: agency was not simply a belief students held internally, but something practiced through evidence-building, collaboration, civic navigation, and public action,

consistent with justice-oriented theories of learning and agency (Calabrese Barton & Tan, 2010).

5.2.3 EJ Learning and Emerging CC

Chapter 4 explored how students expressed EJ understandings and emerging CC within the context of ECS. It examined how ECS's inquiry-to-action process afforded opportunities for students to connect environmental issues to rights, access, decision-making, power, and collective action. Findings showed that students developed multiple??? EJ understandings, including distributive justice concerns about unequal access to clean, safe, and affordable water; recognitional justice through valuing community knowledge and lived experience; procedural justice questions about who participates in decision-making; accountability claims about institutional responsibility; rights-based claims about water as a human right; and ecological justice as responsibility toward waterways, ecosystems, and other-than-human life. These dimensions align with key EJ foci on on distribution, recognition, participation, rights, and ecological relations (Schlosberg, 2007; Wilder et al., 2023).

Students' strongest EJ claims concerned rights and distributive justice, especially water as a human right and unequal access to clean, safe, and affordable water. Some students also moved toward procedural justice and sociopolitical governance reasoning by questioning who makes decisions, whose interests decision-makers serve, and what responsibilities institutions have to communities.

The central conceptual contribution of Chapter 4 is that EJ learning can deepen when students recognize environmental systems as governed and shaped by institutions, policies, investment, profit, decision-making, and power. Students' EJ understandings appeared to develop when issues like water quality, flooding, infrastructure, and access were framed not as natural or merely technical conditions, but as outcomes of social and political choices. Justice-oriented environmental learning, then, can develop when students learn to ask not only what environmental problem exists, but who is affected, who decides, whose concerns count, who is responsible, and what forms of collective action might change the situation; questions highlighted by EJE and justice-oriented science education scholars (Morales-Doyle, 2017; Tannock, 2021; Miles et al., 2025).

In addition, students expressed CC through critical reflection, motivation, and action, though unevenly and at an emerging level, reflecting aspects??? commonly identified in critical

consciousness scholarship (Watts et al., 2011; Diemer et al., 2016). Many students named unfairness, rights, affordability, and institutional responsibility. In contrast, none articulated deeper understanding of environmental racism, historical disinvestment, colonialism, or racialized governance. This finding reveals a limitation of ECS as an inquiry-based justice pedagogy when it is not paired with explicit structural content or when students are not explicitly guided to recognize environmental issues as EJ issues, as was the case across classes in this study because ECS was not framed as EJE.

Overall, Chapter 4 shows that ECS's participatory inquiry-to-action process can give students meaningful experiences as community scientists and civic actors, but participation alone is insufficient for more developed EJ understanding or CC. When explicit EJ content is added, students may be more likely to recognize environmental racism, disinvestment, privatization, regulatory failure, and procedural exclusion, consistent with EJE scholarship arguing that race, history, policy, and power must be named rather than implied (Tannock, 2021; Guevara-Herrero et al., 2024; Miles et al., 2025). ECS's inquiry can create openings for justice-oriented learning, but teacher scaffolding of content shapes what students learn to recognize.

5.3 Cross-Chapter Synthesis: What Students Learned and How

The dissertation examines four primary student outcomes associated with ECS participation. First, environmental civic learning captures students' developing understanding of environmental issues as community and civic problems. Second, CESA captures students' capacity and drive to use environmental science and civic knowledge collectively in community environmental decision-making. Third, EJ understanding captures students' reasoning about rights, access, distribution, recognition, participation, accountability, and ecological responsibility. Fourth, emerging CC captures students' critical reflection, sociopolitical analysis, motivation, and action in relation to environmental injustice. Across chapters, I also identify environmental decision-making literacy as a cross-cutting synthesis concept that helps explain how these outcomes are connected.

Across the three studies, students' experiences and learning followed the instructional arc of the ECS process: they investigated local environmental issues, connected those issues to community knowledge, identified decision-makers and governance structures, developed public-facing calls to action, and advocated to authentic audiences. This arc mattered because it

connected environmental knowledge to civic possibility. Students developed agency and justice reasoning when they experienced environmental issues as locally situated, socially consequential, institutionally governed, and influenced by collective action. The strongest student outcomes emerged when these dimensions were explicitly connected rather than isolated. For example, students' sociopolitical efficacy grew when they used results from water quality monitoring and community surveys as evidence that their advocacy demand was a legitimate need, then advocated for that need to someone in a position to implement the requested policy or practice change.

A central cross-chapter finding is that students' learning deepened when environmental issues became visible as institutionally governed. When students learned to identify socio-ecological systems and the people and institutions responsible for them, they began to develop what I suggest could be termed "environmental decision-making literacy"[1]. I use environmental decision-making literacy as a synthesis concept rather than as a separately measured outcome. Across chapters, students' learning deepened when they began to understand environmental conditions as shaped by institutions, policies, infrastructure, funding, regulation, and public engagement. This form of literacy helps connect the dissertation's primary outcomes: it supports environmental civic learning, is necessary for CESA, and deepens EJ understanding and CC.

I interpret environmental decision-making literacy as closely related to sociopolitical understanding and CC, but specific to environmental decision-making contexts (Watts et al., 2011; Diemer et al., 2016). I use the term here to conceptualize young people's developing capacity to understand how environmental conditions are shaped by decisions, who has authority or responsibility for those decisions, what forms of evidence and public participation matter in those processes, and how communities can intervene to advocate for change. This concept also builds from environmental governance scholarship by focusing on how ecological conditions are shaped through institutions, policies, infrastructure, regulation, community participation, and power (Shapiro & Brown, 2018; Ostrom, 2010).

Environmental decision-making literacy differs from CC broadly by focusing specifically on how socio-environmental conditions are governed: how water, air, land,

[1] I intentionally use "decision-making" rather than "governance" to avoid limiting the concept to government and to include decision-making roles outside formal public institutions.

infrastructure, risk, and environmental protection are shaped through institutions, policies, funding, regulation, community voice, and power. It is therefore a bridge concept between CESA and CC. Students need environmental decision-making literacy to enact agency because they cannot effectively advocate for change if they do not understand how environmental conditions are governed. They also need it for justice reasoning because environmental injustice is produced and maintained through decisions about whose environments are protected, neglected, invested in, or sacrificed.

Environmental decision-making literacy also helps clarify what ECS adds to existing educational approaches. ECS did not only help students learn environmental content or practice civic participation. Across the studies, ECS helped students connect environmental evidence to decision-making pathways. Students learned not only about water quality or flooding, but also about who manages water systems, who funds infrastructure, who responds to complaints, who has authority in schools or municipalities, and how evidence can be used in public claims. This is why decision-maker engagement was so important across chapters: it made environmental governance visible, concrete, and potentially navigable.

The studies also show that civic-scientific agency and justice understaning are not guaranteed outcomes of environmental inquiry. They depend on the learning context. ECS requires time, partnerships, authentic audiences, explicit teaching about governance, and intentional scaffolding around justice, power, history, race, and accountability. Without these conditions, environmental learning may remain at the level of awareness or individual behavior change rather than collective action. With them, students can begin to understand environmental problems as shared public issues that require evidence, collective action, and institutional response.

5.4 Contributions to Research and Theory

This dissertation contributes to scholarship in four ways. First, it extends environmental education research by offering empirical evidence of how scientific inquiry can be connected to civic engagement, community concerns, and collective action in public high school classrooms, responding to calls for more research on action-oriented and participatory environmental learning (Ardoin et al., 2023; Levy & Zint, 2013; Sezen-Barrie et al., 2025). This dissertation shows that students' learning was strongest when environmental inquiry was not an endpoint, but part of a sequence that moved from local investigation through community partnership,

decision-maker engagement, and public advocacy. As such this dissertation addresses a longstanding goal in environmental education: to translate environmental knowledge into collective civic action.

Second, it contributes to civic education by grounding democratic participation in environmental science and community knowledge. The dissertation's studies show that environmental issues can serve as meaningful contexts for developing civic efficacy, civic systems knowledge, public communication, and students' understanding of environmental decision-making. This is different from traditional civic education focused solely on knowledge of government or political institutions. In ECS, civic learning emerged through students' attempts to understand and influence real environmental problems in their schools and communities.

Third, the dissertation introduces CESA as a student outcome and theoretical construct for understanding the forms of agency students need to address socio-environmental problems in an era of climate crisis, extending prior work on environmental science agency and critical science agency (Ballard et al., 2017; Basu et al., 2008; Schenkel & Calabrese Barton, 2020). CESA clarifies that agency in this domain includes not only confidence and motivation, but also the capacity to work with others, use evidence, understand governance, identify decision-makers, and act toward community environmental change. Moreover, the dissertation adds empirical specificity by showing what CESA looked like in student practice: collecting water data, interviewing community members, identifying school and municipal authorities, developing proposals, mobilizing peers, and presenting evidence-based calls to action.

Fourth, the dissertation contributes to EJE by showing how a participatory inquiry-to-action process can support EJ understandings and emerging CC, responding to calls for EJE that combines local inquiry, structural analysis, community knowledge, and action (Delia & Krasny, 2018; Tannock, 2021; Miles et al., 2025). This contribution is important because students in the study developed EJ understandings despite not being enrolled in EJE focused courses. Participation via the ECS inquiry-to-action process mattered. At the same time, the limited emergence of race-explicit analysis highlights that ECS experiences alone are not enough. Students need additional explicit support to connect local environmental observations to racism, classism, historical disinvestment, colonialism, governance, and power.

Taken together, these contributions show that the distinctive contribution of ECS lies in organizing environmental learning around community environmental decision-making. ECS links scientific evidence, community knowledge, public voice, and institutional accountability in ways that can support CESA, environmental decision-making literacy, and justice-oriented learning.

5.5 Implications for Educational Practice

The findings point to several implications for educators, schools, districts, community partners, and curriculum designers who want to engage their students in local environmental action and prepare them to participate in community environmental decision-making. First, because students experienced ECS as more meaningful when learning was grounded in places they knew, environmental learning could begin with real community issues that students can observe, investigate, and connect to their lived experience. In Chapter 2, students described firsthand investigation, ecostrolls, water testing, and neighborhood observation as central to why ECS felt different from typical instruction. In Chapter 3, place-based inquiry was one way students enacted CESA- generating evidence about local environmental conditions. Thus, local relevance is not only a motivational strategy; it supports students in seeing environmental problems as connected to community well-being and as issues they can investigate.

Second, because students' agency and EJ understanding deepened when they learned who had authority over environmental issues, environmental inquiry should connect explicitly to civic decision-making. To enact their EJ based right to participate in community environmental decision-making, students need to learn who has authority, what policies or institutions shape the issue, what evidence matters in public contexts, and where community members can intervene. Chapter 2 showed that students who advocated to audiences with decision-making authority were more likely to view their work as influential. Chapter 3 showed that students' CESA included identifying decision-makers and civic pathways. Chapter 4 showed that procedural and governance-oriented reasoning helped students understand environmental issues as justice issues. For these reasons, environmental investigations should not end with a lab report or classroom presentation when the issues students study are shaped by civic decisions. Instead, students should have opportunities to use their findings in the kinds of public and institutional contexts where environmental decisions are made. This may include presenting evidence to school facilities staff, city officials, school boards, community

organizations, watershed councils, or other audiences with responsibility for the issue. Connecting investigation to these pathways for civic engagement helps students see environmental knowledge as something that can inform public action, accountability, and change, rather than as information produced only for classroom assessment.

Third, because community partnerships expanded what counted as knowledge and who counted as an expert, schools could build sustained partnerships with community organizations that bring local expertise, historical memory, and organizing knowledge. Chapter 2 showed that intergenerational partnerships helped students see environmental work as carried out by real people in their communities. Chapter 4 showed that centering community expertise supported recognition as a dimension of EJ learning. Community partners can help students understand environmental issues from the perspective of those most affected and can model how communities work to challenge harm.

Fourth, because public advocacy helped students experience their evidence and ideas as potentially consequential, educators provide opportunities for students to engage with authentic public audiences, especially audiences with a capacity to respond. Presenting to school boards, city councils, facilities directors, or public health officials can help students understand that environmental knowledge can be used in public policy decisions. Because students' sense of agency was strongest when inquiry culminated in advocacy to people with authority over students' issues, these audiences should be selected with deliberate intent.

Fifth, because students' CESA developed through teamwork, role-sharing, and coordinated action, collective action could be taught as a skill. Students need support to deliberate, organize, build coalitions, divide roles, communicate strategically, write proposals, create petitions, speak publicly, and sustain campaigns. Chapter 3 showed that students named these procedural civic skills as things they believed they apply/deploy??? after ECS. Collective action is therefore should??? not an optional add-on to environmental learning; it is a learnable civic practice central to democratic environmental problem-solving.

Sixth, because students' EJ reasoning was uneven and race-explicit analysis was absent, teachers are encouraged to explicitly scaffold analysis of power, history, injustice, policy, and accountability. Students should be supported to ask: Who benefits? Who is harmed? Who decides? Whose knowledge counts? What histories produced these conditions? What policies maintain them? And to ask: How do race, class, geography, and political power shape

environmental risk? Without such scaffolding, students may recognize unfairness but not able to make the necessary connections such as understanding structural roots.

5.6 Future Research Agenda

The findings in this dissertation point to a future research agenda organized around ECS implementation, CESA development, environmental decision-making literacy, and EJ learning/CC.

5.6.1 Implementation, Teacher Praxis, and Learning Conditions

Future research could further examine how ECS is enacted across additional teachers, subjects, school contexts, and communities, and how those enactments connect to student learning. This dissertation showed that ECS functioned as a flexible framework rather than a scripted curriculum, and that this flexibility enabled adaptation across classes. At the same time, findings showed that variation in teacher praxis shaped the students' differentiated learning outcomes. For example, students' learning differed depending on whether teachers foregrounded scientific investigation, governance and decision-making, community expertise, public advocacy, or explicit justice-oriented analysis. ECS is positioned to meet the educational need of preparing young people to address socio-environmental decision-making by supporting their entry through various pathways. This necessitates specific goals and learning objectives. However, for teachers to be confident that they are using the ECS process in ways that meet their respective objectives, more research is needed on how educators adapt ECS's core elements and how those adaptations mediate student learning.

Future studies could also investigate how teachers connect environmental inquiry to governance and justice because findings across chapters showed that these connections were crucial for students' agency and environmental justice learning. Students developed stronger civic efficacy and environmental decision-making literacy when they learned who had authority over the issues they were investigating and when they communicated evidence to audiences with some capacity to respond. Similarly, Chapter 4 showed that students could identify unfairness and institutional responsibility, but were less likely to develop robust structural analyses of environmental racism, disinvestment, or racialized governance without explicit teacher scaffolding. This necessitates specific goals and learning objectives. However, for teachers to be confident that they are using the ECS process in ways that meet their respective

objectives, more research is needed on how educators adapt ECS's core elements and how those adaptations mediate student learning.

Research could also examine the practical conditions that enable or constrain ECS implementation. The findings showed that impactful ECS depended on time for field-based inquiry, access to community partners, opportunities to engage decision-makers, and space for students to engage in public-facing advocacy. These conditions may not be available in school contexts. These conditions are not always available in everyday school contexts. Studies could therefore investigate how teachers and schools navigate barriers such as schedules, testing pressures, transportation, administrative approval, district policy, and uneven access to community networks. In-depth ethnographic studies of individual classrooms and comparative studies across disciplines could clarify how these implementation conditions shape what forms of evidence, argumentation, civic participation, and student learning become possible. This knowledge could help schools and districts provide the necessary support and enable teachers to adopt ECS praxis as part of curricular mandated instruction and everyday school learning.

5.6.2 Critical Environmental Science Agency

Because this dissertation advances CESA as a multidimensional agency related student outcome related to community environmental decision-making, future research should continue to refine how it is measured. Because this dissertation advances CESA as a multidimensional construct for understanding students' agency as an outcome in relation to community environmental decision-making, future research should continue to refine its measurement. Measure may include scales that capture not only students' subjective confidence and dispositions, but also more objective ways to assess their ability to identify decision-making systems, use evidence in public argument, collaborate with peers, develop advocacy strategies, and participate in civic processes. Performance-based assessments, student interviews, classroom discourse analysis, and observation protocols could deepen understanding of CESA as an outcome and how it develops \.

Future research could also investigate which ECS experiences are most strongly associated with different dimensions of CESA. Engaging with decision-makers may be especially important for sociopolitical control and environmental decision-making literacy. Community partnerships may strengthen collective agency and recognition of local expertise. Public advocacy may strengthen civic competence, voice, and perceived efficacy.

Understanding these relationships would help educators design more targeted learning experiences.

Longitudinal research is also needed to examine the durability of CESA-related outcomes. Future studies could investigate whether students who participate in ECS continue to engage in environmental action, civic participation, community organizing, environmental science learning, or justice-oriented work after the ECS experience ends.

5.6.3 Environmental Decision-Making Literacy

Future research could also develop environmental decision-making literacy as a concept and student outcome in its own right. This dissertation suggests that students' agency and justice reasoning deepened when they understood environmental issues as governed by institutions, policies, infrastructure, investment, and public accountability. However, more research is needed to identify the dimensions of this literacy, how it develops, and how it can be measured.

Future studies might examine students' ability to identify relevant decision-makers, distinguish between different forms of authority, understand how policies and infrastructure shape environmental conditions, evaluate what evidence matters in public decision-making, and explain how community members can influence environmental outcomes. Such work would help clarify the relationship between civic literacy, CC, CESA, and EJ learning. It would also support curriculum designers in building tools that help students understand environmental problems not only as ecological systems, but as systems shaped by governance.

5.6.4 EJ Learning and CC

Future studies could further examine the mechanisms through which ECS practices support EJ understanding and CC development. The present study points to several likely mechanisms, including local monitoring, community knowledge-gathering, decision-maker engagement, rights-based reflection, and public advocacy. Future research could examine how each contributes to critical reflection, motivation, structural analysis, and action. Research could also investigate how teacher praxis mediates these processes through classroom discourse, curricular materials, and explicit attention to race, class, policy, and history.

Particular attention could be given to environmental racism and racialized environmental governance. In this dissertation, students often articulated rights-based, distributive, and

procedural justice reasoning, but race and environmental racism were less prominent in their reflections. Future research could examine how explicit teaching about race, class, history, policy, and environmental racism shapes students' EJ reasoning and how teachers develop the racial literacy and pedagogical skill needed to facilitate these conversations in their classrooms.

Finally, future research could examine institutional responsiveness to student advocacy. If ECS is deployed as both pedagogy and democratic practice, then an important question is not only what students learn, but how adults and institutions respond. Studies could investigate to what extent student advocacy influences school, district, municipal, or community decisions; how decision-makers perceive student evidence; what conditions make youth participation meaningful rather than performative; and how schools can support sustained youth involvement in community environmental decision-making.

5.7 Overall Conclusion

Across the three studies, this dissertation shows that environmental learning becomes more powerful when students investigate real issues in their communities, work with others, learn how those issues are governed, and advocate publicly for change. Under these conditions, students developed environmental science and civic skills, collective agency, justice understanding , and a stronger sense that their expertise and voices can matter.

The central contribution of the dissertation is ECS as a model of environmental learning in which science is not separated from democracy, and civic action is not separated from environmental learning including justice aspects. ECS offers one theoretical and practical approach for preparing young people to participate in the environmental decisions that shape their lives and communities. Ultimately, this dissertation argues that young people should not only learn about socio-environmental problems; they should have meaningful opportunities to investigate them, challenge the decisions that produce and affect them, and participate in transforming them for their communities' well-being.

In a time of accelerating climate crisis and persistent environmental injustice, education cannot stop at helping students understand a damaged and precarious world; it must also help them practice the collective, evidence-based, and justice-oriented action needed to heal it.

5.8 References

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