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Designing for Critical Science Agency in a Community-Based Science Curriculum

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Abstract: Much of the literature that examines critical science agency (CSA) focuses on how students enact their CSA to support knowledge construction and agentic action. Few studies, however, address how science curricula can be specifically designed to support students in exercising their CSA. In this study, I examine features of a community-based science (CBS) curricular design that engages students in justice-oriented science learning to advance their CSA. More specifically, I analyze the design and structure of an environmental science elective course to investigate features of CBS curricular design that support students in exercising their CSA, including: (1) leveraging learning goals to create community change, (2) developing students' toolkits, (3) cultivating spaces for advocacy and critical hope, and (4) critical and ongoing reflection. The findings suggest that science curriculum can be purposefully designed to assist students in exercising their CSA through generative learning experiences that empower them as community change agents. As we move toward more equity and justice-centered science learning, I recommend that future science curricula take community-based science approaches to design, structuring learning around students' CSA by attending to how formal science learning can be used as an avenue to support community change.

Keywords: critical science agency; community-based science; curriculum design

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1. Introduction

Though science education has the potential to improve communities through justice-oriented community action, curriculum and instruction are often structured in ways that do not relate to, or inform, community improvement [1], and lack congruence with students' everyday lives and experiences [2]. Too often, science teachers hear "I don't plan on being a scientist or a science teacher, so why do I need to learn about this?" This illustrates the common frustration students feel about their science education experiences. The habitually abstract, high-level, and impersonal nature of science curriculum plays a significant role in disengaging students, particularly students of color, from seeing the relevance of science learning in their everyday lives and practices [3,4].

To combat this, science education researchers have investigated mechanisms to reimagine more critical science learning spaces. Findings from current research around critical science learning note the importance of integrating students' funds of knowledge (FOK) in science practice (e.g., [3,5]). Few, however, have investigated the design of curriculum that breaks traditional boundaries in science learning to account for this knowledge and create bridges between school science and community learning and improvement. Such work is significant; Tran [6] argues that although positioning connections between classroom science learning and students' out-of-school experiences is significant, students' abilities to make these connections are "heavily influenced by the learning activities structured in the classroom" (p. 1628). The question becomes, then, how can we structure science curriculum that supports these connections, specifically, in ways that promote justice-oriented learning experiences and position students to use science to engage in community action and change? I argue that one such way is designing curricular structures that develop students' critical science agency (CSA).

Responding to Davis and Schaeffer's [4] call for more research that investigates the process of creating curricula that develop students' justice-focused science agency and meaning-making in local, place-based ways, this study seeks to explore the design features of a community-based science (CBS) curriculum developed by a teacher and researcher. Specifically, supported by Schenkel and Barton's [7] argument that promoting CSA is a powerful way to promote justice in science classrooms, this study seeks to address how the CBS curriculum can be explicitly designed to develop and exercise students' CSA. Supporting efforts in the science education community to reimagine science learning from a more critical lens, and "make visible different forms of expertise and the ways those forms of expertise merge to produce critical science agency" [8] (p. 329), this work analyzes features of curricular design that develop and exercise students' CSA by examining how formal science learning can support learner agency and serve as an avenue for community change. The following research questions guide this study:

(1) What features of community-based science curricular artifacts does a teacher describe as supporting the engagement of students' funds of knowledge in learning?
(2) How does a teacher describe these features as supporting students in developing and exercising their CSA in formal science learning?

In what follows, I provide an overview of CSA, how CSA can be developed through CBS learning, our design process, findings from the study, and its implications for the science education community.

1.1. Examining the Connections between CSA and CBS

1.1.1. What Is Critical Science Agency?

The concept of critical science agency (CSA) was first introduced by Basu et al. [9] as they sought to demonstrate how students identify themselves within science in a manner that also advances their community participation. This conceptualization has since been advanced to define CSA as combining scientific knowledge and practices with other forms of expertise to address injustices in youth lives and communities [7]. Vossoughi and Shea [8] note that CSA is accomplished through three mechanisms: (1) developing students' expertise in science and their community contexts, (2) supporting students to use that expertise to identify and take action against community problems, and (3) engaging students in actions that are justice-oriented. These mechanisms, they argue, emphasize how science education can lead to transformation beyond the classroom setting and into students' everyday lives, by challenging normative power structures through centering youth's experiences to support forms of critical knowledge production and agency that are not often privileged. The enactment of CSA differs from other forms of agency in that it explicitly attunes to students imagining participation in a world beyond what it is now, to consider a more just future for their communities [10].

CSA has been investigated in a number of ways in the literature. For example, Basu and colleagues [9] investigated how two high school students developed and expressed agency in a physics class by leveraging and developing their academic and social identities to position themselves as experts in a chosen practice, strategically utilizing resources toward a set goal, and engaging in a process of consistently modifying and expanding their knowledge and identity. As such, the students "advanced their participation in community" (p. 345) to view their lives and the world through a critical lens and envision ways in which to imagine a more socially just and equitable world through science. Schenkel and colleagues [7] positioned CSA as a more equity-oriented approach to science education through their investigation of two girls' enactment of CSA by evolving and leveraging their community and scientific knowledge to make sense of, and address, intersecting scales of injustice, develop their political conscious of said injustices, and reposition authority through expansive expertise in a green energy engineering unit. Schenkel and Barton [10] investigated how middle school students restructured power hierarchies in science learning, and how that restructuring provided opportunities for them to enact their CSA. Specifically, their study found three distinct characteristics of CSA: collective

CSA evolves through interactions and tools, students' multiple forms of expertise must be used and valued in learning, and power "impacts and impedes CSA enactment" (p. 525). Further, McNeill and Vaughn [11] investigated how the enactment of a climate change curriculum supported students in developing their CSA by looking at differences in students' conceptual understandings, beliefs, and environmental actions pre and post-curricular intervention. Their study concluded that a curriculum designed to support students' CSA not only impacts their understanding of a science concept (in their case climate change), but also how their actions can have significant impacts.

Common among these studies is the focus on how students enact and develop CSA in classroom learning and through curricular enactment. While this is important to understand, few studies, specifically, focus on the ways curriculum can be designed (i.e., curricular design structures) to specifically support the development of both scientific knowledge and CSA. A greater understanding of these designed structures is significant as McNeill and Vaughn [11] state,

> "we need curriculum. . .[that goes] beyond presenting students with detailed information about the problem or solely focusing on content knowledge. Rather, science curriculum needs to include lessons specifically focused on environmental actions and their impacts on the natural world" (p. 378).

This study seeks to provide evidence of curricular structures that empower students to develop and exercise their agency in learning. As Manyukhina and Wyse [12] argue, there is a difference between a having sense of agency and exercising agency, as being aware of oneself as an agentic individual does not equate to students exercising that agency [13]. This has implications for understanding how curricular content can be purposefully structured to support students in exercising their agency. One such way, I explore, is through CBS.

1.1.2. What Is Community-Based Science?

Curriculum and instruction contextualized in the local environment bridge students' use of their everyday experiences as tools to inquire and learn about curricular concepts [14], while linking school science learning to their local community [2]. When learning is contextualized around addressing community-relevant issues, students participate as active citizens by incorporating "the knowledge and representations available in and to the community" [15] (p. 272) into the learning space, and using the knowledge and representations, combined with their scientific knowledge, to create change. When students are involved in community problem-solving in school science, learning transcends preparing students solely for future science classes, to engaging students in everyday, relevant science activities. Further, when community-based learning is situated in a social justice-oriented perspective, we "problematize privileged forms of science and situate learning in the context of larger justice movements" [4] (p. 369) by leveraging students' funds of knowledge and welcoming multiple epistemological ways of thinking in the classroom, to create space for diverse and critical interpretations of phenomena. In this study, my teacher partner and I have defined this curricular practice as community-based science (CBS).

CBS is defined as "science instruction anchored in locally and socially relevant phenomena, where community extends beyond the geographical boundaries of a local area to include the cultural epistemologies, historical ontologies, and social structures of a space and the individuals within that space" [16] (p. 4). In this framework, science is positioned as a collection of social experiences that account for the scientific, historical, social, and political dimensions of scientific enterprise that impact students' interpretations of phenomena [17]. This distinction is important as Vossoughi and Shea [8] claim learning scientific disciplinary knowledge, without community knowledge, is a less expansive approach to science education.

Recent students have taken a CBS-like lens to their work in order to reimagine a broader purpose for science learning. For example, Fazio and Campbell [18] assert that community-based and place-based perspectives in science curricula that address socio-scientific issues make for a "just educational approach and for attending to issues of the Anthropocene" (p. 5). Smith and colleagues [19] investigated how culturally relevant/responsive and sustaining pedagogies (CR-SP) focused community-based STEAM programs can support the development of youth's sense of agency. They found that CR-SP community-based "design dimensions" include topics that are relevant to students' lives, foster students' sense of belonging, encourage students' critical awareness of environmental and political dimensions issues, and prompt students to be innovative in imagining ways to address community-based issues. Additionally, Bird and colleagues [20] found that community and citizen science (CCS) projects support youth in enacting their agency and identity by using science to make change in their lives. Although their work mainly focused on how youth use their experiences and expertise in CCS to inform their environmental decisions, they draw implications for design related to science learning and social action. In their study, they suggest that CCS projects should: be structured to solve issues on a local level, have project goals that reflect student values, and engage youth in critical inquiry problem-posing spaces where youth have experiences in data collection, decision-making and evaluation to support seeing themselves as scientists in their community who have the agency and ability to make an impact.

Distinguishing the CBS curriculum and instruction from other scientific practices, such as citizen science (CS), is essential to establishing its significance. Although definitions of CS are very broad [21], it is generally agreed upon that CS serves to bring the public and science closer together by democratizing science through involving the public in discussion, research, and decision-making around scientific issues [22]. Most commonly, CS is positioned as a research methodology that aims for scientific output by engaging the public in contributing to scientific research through partnerships with scientists to collect, submit, and/or analyze data. Generally, but especially within k-12 schooling, the utilization of CS also promotes science education by strengthening individuals' science and scientific inquiry skills through research participation [23] in "issues of societal importance" [24] (p. 593).

I point out these important facets of CS in order to provide a distinction between CS and CBS. First, CBS is not just focused on scientific output when engaging in scientific investigations. Instead, it attunes to scientific phenomenon holistically, integrating investigations of the scientific, social, political, and historical aspects of the phenomenon in order to understand the issue from multiple lenses and develop solutions that address those multiple lenses. Second, CBS is based on investigations of the local phenomenon that students themselves see as significant, not an issue that a scientist has presented, or one that is necessary of "societal importance". By name, the implications of "community" are significant to CBS as all investigations are centered around issues students see present in their community, supporting Vossoughi and Shea's [8] idea of expansive science education. Finally, CBS does not put students in partnership with scientists, but, instead, in partnership with each other and their communities, where they are the scientists engaged in scientific practice from identifying the problem to developing a solution. This supports students' scientific identity and understanding that expertise in science is not only found in those formally identified as scientists [16].

Our CBS framework was developed through exogenous design [25] across iterative cycles of curriculum development in a multi-year research-practice partnership (RPP) [26], further described in the methods sections. This partnership accrued into the co-design of a yearlong community-based, social, and environmental justice-focused class. Through our curriculum design, we strived to meet three goals, as follows: (1) support students in learning disciplinary concepts, (2) position science learning as and for community participation, and (3) position science learning as and for social justice. The development of this framework was based on our belief that similar frameworks failed to theorize aspects of knowledge, practice, and people, collectively. While in other works we study how, as an instructional framework, CBS supports the reimagining of power and expertise in science learning for urban students of color [16], this paper focuses on features of curricular design in a CBS framework that support students' CSA.

1.1.3. Developing CSA through a CBS Framework

Within our CBS framework, my teacher partner and I developed three principles. In another paper [16] I describe the process of CBS principle development, while here I provide a brief overview of these three principles and how they connect to supporting CSA.

> Principle 1—CBS goes beyond solely cognitive gains in learning by providing students with opportunities to engage in authentic, meaningful science by contextualizing learning around community-relevant issues. Building upon students' prior knowledge and experiences, CBS investigates scientific phenomena within the contexts of students' everyday experiences in classroom learning [27]. This connects to CSA by supporting its purpose of developing student expertise in science and their community contexts.
>
> Principle 2—CBS develops students' justice-oriented science agency to leverage science and scientific ideas to understand, reflect, make decisions, and take action in their communities [4,27]. Specifically, this principle reflects students using formal science concepts and content to conceptualize their everyday experiences, supporting CSA's purpose of students using their expertise to identify and take action in their communities.
>
> Principle 3—CBS empowers students as social and political beings, as well as academic intellectuals, by providing space for student voice and engagement in critical reflection [28,29] This supports CSA's purpose of students taking justice-oriented actions to address scientific issues.

Understanding these principles is significant toward contextualizing how CBS, which guided design, went beyond simply supporting students' sense of agency to actually engage them in exercising their CSA. As noted earlier, Manyukhina and Wyse [12] claim instilling students with agency does not mean that they will take ownership of their learning. Instead, they must be provided with real opportunities to exercise that agency in relation to learning.

1.2. Study Purpose

In this paper, I examine features of a justice-oriented [4,30] CBS curricular design and describe how those design features support students in developing and exercising their CSA. Specifically, I engage in a detailed analysis of features of curricular design that my teacher partner, Ms. V, and I developed to engage our students' community, culture, and funds of knowledge (FOK) to support science content learning and develop their agentic dispositions. Through these design features, we sought to attribute value to different forms of expertise that students have as a result of their everyday experiences that support and produce CSA [8].

We designed to redefine the curriculum as a praxis that has "embodied values, thinking abilities and intended actions" [31] (p. 4) to scientize students' lives. Scientizing students' lives means developing their ability to (1) recognize how science is relevant to practical areas in their lives and (2) how, in their everyday situations, they are engaging in the pursuit of science [32]. We take this idea a step further by constructing our curriculum to develop students' CSA in order to help them not only see how science can be used to create change in their lives and communities but also exercise their agency to create that change. This additional step in design is significant as research shows that an individual's sense of their agentic capabilities is based on their past experiences and fluctuates over time in response to changes [12]. Historically, curriculum has not been designed with a focus on supporting the exercising of agency, but, instead, focused on students' memorization of content facts and figures. This has significant implications as the extent to which designed curricula provide context that supports learner agency has "far-reaching consequences for students' actual and perceived capacity to exercise agency" [12] (p. 228). As Vossoughi and Shea [8] note, understanding curricular design within a setting allows us to analyze the dimensions of agency and resistance that students exercise as they learn in and through joint activity. While the analysis of how students exercise their agency through the curricular design is beyond the scope of this paper, I do explore features of curricular design, and address how those structures support students in exercising their agency. Overall, I seek to contribute to work around justice-centered curriculum design that views students as transformative intellectuals [30] who are capable of exercising their CSA to create change in their lives and communities.

1.3. Theoretical Framework

Traditionally, students are expected to learn science in "ready-to-use" formats [33] to be considered as performing well in science classes. A social constructivism theoretical perspective disputes this model of learning by reconceptualizing the way knowledge and knowledge acquisition are understood [34–36]. Based on Vygotsky's [37] perspective that cognition develops first on the social level and then on the individual level, social constructivism views learning as a social process where concept meaning is developed along with others in sociocultural contexts [34,35]. In essence, this suggests that learners construct knowledge and new forms of understanding based on their prior knowledge and social interactions with individuals in different contexts, meaning that knowledge is not constructed through these "ready-to-use" formats.

By definition, a constructivist theory of learning has implications for considering how educational experiences are designed and developed to support student learning, as it constitutes that knowledge construction is based on and around students' life experiences in cultural contexts. Culture, defined as the historical practices developed by communities with specific tools, social norms, and practices to which individuals enculturate [37–40], has significant implications on how students contextualize disciplinary concepts and practices, as concept understanding is situated within the cultures to which students are a part of. If we consider that schools enculturate students into the culture of science learning, I argue that this theory of learning also has implications for the construction of curricular design; specifically, how that design can or cannot support student agency in learning. As curriculum can serve as a cultural broker to help students border-cross between the competing worlds and cultures of home and science [41,42], and support them in seeing how science can be used to exercise their agency to inform community change [1], the social constructivist perspective prompts us to consider the role of curricular design in the culture of science education. More specifically, how it can be used to redefine that culture.

Lemke [43] asserts that "in the sociocultural view, what matters to learning and doing science is primarily the socially learned cultural traditions of what kinds of discourses and representation are useful and how to use them" (p. 298). As such, designing for CSA in science must be positioned as a cultural tradition that is useful to students, and the curriculum must be designed to support students in exercising that agency as part of engaging in scientific practice. If, as contemporary science education researchers have argued, one of the goals of science learning from a social justice perspective is for students to be able to learn how to use science to change their lives and communities, designing for CSA, then, must be positioned as a cultural practice of science education. When science is constructed around sociocultural, community-based learning, we position engagement in science as lifelong participation in learning, by associating normative science learning with participation in students' social worlds [44].

2. Materials and Methods

2.1. Research Contexts and Participants

Analyzing student agency, in any form, necessitates an understanding of the contexts in which claims about agency are being made. This is because contextualizing the settings of how agency emerges among students, and how teachers and curriculum either constrain or support the development of said agency, is significant [8]. Therefore, in this section, I contextualize the setting and participants of this research study.

This study took place at a Southern California middle and high school, "The Community School" (TCS) during the 2020–2021 school year in a middle school environmental justice elective course. TCS has been in partnership with a large Southern California research university for almost a decade to revamp the school as a central hub of rigorous and engaged learning opportunities for its 52% African American and 48% Latinx student population. I was in partnership with a teacher, Ms. V, from 2018–2022 to co-design a community-based science curriculum. Ms. V is an Indian-American woman and social justice educator. She sees the purpose of science learning as creating a space for students to critically think, analyze their current world, and imagine and work toward a more just future. I, Symone, am a Black woman and former middle school science teacher and marine scientist. My belief is that science education should be situated to support students in seeing how science can be used to create better futures for themselves and their communities. Our partnership bloomed out of a mutual belief that science education should be situated in contexts that allow students to see themselves in their learning and address scientific phenomena at the intersections of environmental justice and social justice.

Together, Ms. V and I engaged in a multi-year research-practice partnership (RPP) [26], or partnership that strives to engage researchers and stakeholders, in this case, a teacher, in a joint learning experience through collaborations across multiple projects [45]. By focusing on a problem of practice, RPP participants design interventions and test solutions that seek to improve teaching and learning. Stromholt and Bell [46] note that design-based research studies have the potential to directly impact educational practice as they serve to produce knowledge. Therefore, we used participatory design research (PDR) [47] as an umbrella approach to dismantle traditional roles and relationships as researcher and teacher in collaborative design and, instead, engage in a more collaborative working relationship. Specifically, we used co-design methods to draw upon both of our expertise and ensure the utility and feasibility of the curriculum, and equal voice and stake in the design process [48]. The use of co-design methods allowed us to develop a "shared understanding of how our developed curricula could support transformative educational outcomes" [16] (p. 126), in this case, support students in developing and exercising their CSA.

Although it is beyond the scope of this paper to discuss in detail, it is important to note the non-hierarchical, deconstructed nature of our RPP, making it distinct from other RPPs that do similar work. In our partnership, Ms. V and I both served as designers, researchers, and teachers, working side-by-side in both curriculum development, as co-designers, and classroom implementation, as co-teachers. This model served to increase the sustainability of our work for Ms. V, by strengthening her bandwidth to fully engage in all parts of the design, implementation, and re-design process, and fostered richer data collection and analysis for myself, as I was engrossed in the research process from design to implementation to iterative refinement. This structure supported a more robust learning experience for our students as well, as it sustained more opportunities for small group and one-on-one interactions and academic guidance.

Throughout the years of our partnership (Table 1), we developed iterative units around socio-scientific issues relevant to the local community. Ms. V and I strived to create a generative learning environment that positioned our students as capable of investigating complex socio-scientific issues that were relevant to their lives [3,4]. Overall, our curriculum was designed to

> "give [students] the tools to be able to look at society around them and [recognize] that's a problem, [and] move themselves, help their communities, recognize oppression, recognize untruth, and be able to do something about it to navigate a system that was not built for them" (Ms. V).

Table 1. Overview of partnership work.

Time	Partnership Work	Outcome
Fall 2018	Final project co-design	Environmental pollution storyboard project
Spring 2019	Unit co-design	Waste and plastic pollution unit
Summer/Fall 2019	Redesign of Spring 2019 unit	Waste and plastic pollution unit iteration 2
Spring 2020	Co-teaching	Waste and plastic pollution unit iteration 2 implementation
Summer 2020	Co-design of elective CBS course	CBS elective class yearlong curriculum
2020–2021 SY	Co-design and co-teach	Implementation of CBS elective class
2021–2022 SY	Class redesign	CBS elective course iteration 2

As further discussed in the next session, this led to the co-design of a yearlong environmental and social justice-focused elective class in the 2020–2021 school year. The design of the class serves as the basis of the findings for this paper.

2.2. Curriculum Overview

Ms. V and I decided early in curricular design that we would utilize a project-based learning (PBL) approach to instruction to engage students in collaborative explorations of real-world problem-solving around issues relevant to their lives. Rivet and colleagues [49] argue that PBL curricular structures encourage students to "experience a wide range of scientific phenomenon. . .[which] provide various ways for students to interpret and make sense of science ideas" (p. 7). As our designed curricula strived to engage students more deeply in socio-scientific learning through justice-oriented science, a PBL approach supported the integration of student FOK, along with disciplinary knowledge, to address community needs. Further, as our class was rendered online as a result of the COVID-19 pandemic, Ms. V and I speculated PBL would be a supportive structure for our students for three reasons: (1) it allowed students to engage in science practice even if they were not able to synchronously participate in class, (2) it supported social connection in the online environment as students engaged in collaborative work during different dimensions of PBL instruction, and (3) it supported resonance with learning as students investigated issues relevant to themselves and their community. Thus, this structure became the basis of our design.

Ms. V and I designed four project-based units that explored a variety of complex, socio-scientific topics that were relevant to the students' immediate lives and community, bringing together their FOK and disciplinary learning to explore the environmental and social causes and effects of these issues (Table 2). Topics were chosen based on data collected during our prior two years of co-designing, where we identified issues that were significant to our students and the immediate community. We used a progressivist approach to curricular design [50] that was grounded in a skills-oriented and learner-centered model, focusing on "skills/values/attitudes and appreciation of students' individuality, accommodated within a flexible learning process" [12] (p. 330). Skills-oriented models utilize learning disciplinary knowledge as a foundational practice but extend to support students' subject-specific and general skills and proficiencies, such as writing, understanding patterns, etc. Learner-centered models, on the other hand, move beyond knowledge acquisition to focus on developing students' broader educational goals and life-long learning abilities, such as developing students' moral and ethical values and social skills, to be able to engage as future citizens. Within our curricular design, we set out to meet both of these goals as we worked toward designing for CSA.

Table 2. Overview of 2020–2021 SY CBS curriculum.

Project Number	1	2	3	4
Unit Topic	Health and Nutrition	Living in the Time of COVID-19	Guided Inquiry Project	Student Choice Project
Unit Content Focus	Nutritional value, food justice, and food access	Health disparities and inequities	Air pollution Waste and plastic pollution Gentrification	Light pollution Greenspace equity Gentrification
Unit Guiding Question	How can I make my favorite recipe healthier?	How can I make my home work better during the COVID-19 global pandemic?	Student-generated	Student-generated
Unit Final Project	Recreation of a cultural recipe	Infomercial	Advocacy letter	Student choice

In projects 1 and 2, Ms. V and I provided the topics, content focus, and guiding questions. For project 3, we provided students with eight content-focused topic options around community socio-scientific issues students had expressed concern about throughout our work together. Students were able to decide their content focus and guiding question. Project 4 was a student choice project, where students were able to investigate any topic of their choosing as long as it was an issue affecting the local community. In this project, students led project development from choosing the topic to deciding how they would communicate their findings. In the next section, I provide an overview of the data collection methods and sources, and data analysis methods.

2.3. Data Collection Methods and Sources

Data sources for this study were informed by (1) researcher–practitioner co-design meeting artifacts, including lesson plans, PowerPoints, designed activities, meeting notes, and transcripts, and (2) teacher interviews (Table 3). These data sources supported me in documenting the design features that worked toward the inclusion of students' FOK in learning and were structured to encourage students to exercise their CSA.

Table 3. Overview of data sources and analysis.

Data Source	Description	Method of Analysis
Researcher–Practitioner Co-design Meeting Artifacts	Meeting notes and transcripts; lesson/lecture PowerPoints; Designed unit activity templates (e.g., worksheets, unit reflection activities, community circles note catchers); Weekly lesson plans; Digital Interactive Notebook (DIN) template	Round 1: Deductive coding Round 2: Open coding Round 3: Inductive Coding Used constant-comparative analysis to look for common features across artifacts
Semi-structure Teacher Interviews	2 interviews (pre- and post-2020–2021 SY)	Round 1: Deductive coding Round 2: Open coding Round 3: Inductive Coding Used constant-comparative analysis to look for commonalities across interviews

Researcher–practitioner co-design meeting artifacts included over 43 audio-recorded meetings (ranging from 20 min to 3 h), as well as deliverables from those meetings. These meetings were set up in two sections. First, we spent time reflecting on the past week of teaching, discussing student learning and engagement of their agentic systems, and areas of success and improvement. Second, we developed our weekly lesson plan and designed any lecture slides, worksheets, reflections, or other such activities. We also iteratively refined our digital interactive notebook (DIN), which served as a space for students to document and keep track of their research, findings and developed solutions at each point during the PBL project.

Audio-recorded, semi-structured one-on-one teacher interviews were conducted twice, pre and post-curriculum implementation focusing on Ms. V's teaching philosophy, teaching practices, beliefs around CBS as an approach to science learning, implications of engaging in co-design, and discussion of observations in curricular design and implementation. Although data from participant observations and field notes were not used for this article, it should be noted that I collected them five times per week during the nine-month school year. During class times, I served as a participant observer and a co-teacher, both memoing, leading lessons, and supporting learning as another classroom teacher.

2.4. Data Analysis

A social constructivism theoretical perspective guided data analysis for this study. As the theoretical literature around constructivism in science states that learning and doing science is grounded in socially learned cultural traditions that determine who and what is useful in science and how they should be used [43], I utilized this framework to understand how Ms. V and I worked to design for CSA as a cultural tradition in our CBS class to support students in developing and exercising their agency. Specifically, this framework supported me in determining patterns across the data sources that became cultural traditions, or practices and features in our design that sought to redefine how students could use science to imagine change in their lives and communities.

Data analysis was an iterative process. I first engaged in an overall reading of the data to generate a high-level understanding of the different approaches used in the design features to support students' CSA. Next, I engaged in deductive coding, guided by different codes in the literature that were relevant to CSA. From the constructivist perspective, I specifically was guided by codes from the literature that supported border crossing between students' life experiences, cultural contexts, community contexts, science learning, and science practice [41,42]. Such codes included "power and positionality" [10] "expertise" [7] "identity development", "leveraging resources", "science practice" [9], and "relevance and applicability [51], to name a few.

Once deductive coding was completed, I engaged in open coding during which the deductive codes were compiled into larger themes. This open coding was completed to surface: (a) overall structures in the design of the curriculum that aligned with CSA, (b) Ms. V's thoughts on how/why these features supported CSA, and (c) how we iteratively designed to improve these structures throughout the class. Some of these open codes included, "humanizing science" "science as a larger purpose" and "agentic systems". Finally, I engaged in inductive coding to determine the emergent subcodes of my identified open codes as related to the specific features of design that were positioned as cultural traditions that support students in developing and/or exercising their agency as a part of engaging in authentic science practice. These inductive codes are presented in the findings of this study. Across all rounds of data analysis, I used Bazeley's [52] describe–compare–relate formula for qualitative analysis. Results from the data analysis were member-checked by Ms. V.

In the next section, I provide empirical evidence of one approach to designing for CSA in science to support students in developing their content knowledge, while addressing injustices in their lives through meaningful, engaging, and relevant community-based learning.

3. Results

In this section, I provide a detailed exploration of specific features of the curriculum that Ms. V and I designed to support our students in developing and exercising their critical science agency (CSA) and give examples of how those features were enacted in practice. By redefining curriculum, specifically the CBS curriculum, as a praxis with embodied values and specific actions [31] to engage their CSA, Ms. V and I strived to scientize students' lives [32] to engage them in science education that promotes human dignity [53]. Although an analysis of the ways students enacted their CSA is beyond the scope of this paper, I do explore the design features that support this agentic system and demonstrate that "all contexts can potentially...be leveraged by educators as a resource in other settings to support learning" [46] (p. 1021) and create community change. These design features strived to position science as beneficial to students' lives and communities in the present, proximal future, and distant future, through informed decision-making and action by reframing students' "personal challenges as systemic issues" [4] (p. 385). Below I examine these four design features and how they were engaged in action.

3.1. Design Feature 1: Leveraging Learning Goals to Create Community Change

If supporting students CSA is to be central to design, before we can begin to develop curricular activities, it is important to consider how the units themselves as positioned to support this effort. Hodson [54] notes that science education has four learning goals: (1) learning science, or developing theoretical and conceptual knowledge, (2) learning about science, or understanding science inquiry and generated knowledge, (3) doing science, or engaging in science inquiry, and (4) addressing socio-scientific issues, or developing critical skills to address the intersecting effects of scientific phenomenon. Often, curriculum development in science education is only situated within the first two goals, where students are prompted to ingest as much content knowledge as possible and understand how scientific knowledge is generated (i.e., the scientific process). Few science classrooms, however, actually engage students in the act of doing science, and when it is done, it is often structured in abstract and irrelevant contexts of inquiry. Even fewer, however, push toward addressing socio-scientific issues that are significant to students' lives. In order to design for CSA in our curriculum, Ms. V and I structured our learning goals around "doing science" to "address socio-scientific issues".

Early in the curriculum development process, Ms. V and I discussed the need to position community and science in conversation with each other in our learning goals to show students that science can be used to generate community change. Our purpose was twofold: (a) support students in learning more about their community by engaging in community-oriented scientific inquiry by "doing science", and (b) create community change through science practice by "addressing socio-scientific issues", both actions of which are components of exercising CSA. We were guided in our planning by the foundational question Ms. V proposed in our second co-design meeting, "What does it mean for students to do a science project within their community?" This question positioned us to think about how to design our curriculum in ways that students engage in meaningful work that positions them to use science to imagine change in their community.

As the literature shows that students do not always see themselves as capable of engaging in agency [27], we felt it was important to scale up our learning goals, moving from lower-order learning goals to higher-order ones. For example, in project 1, learning goals were written as follows: (1) understand macronutrients and the building blocks of nutrition ("learning about science"), (2) investigate food desserts and food swamps and their effects on communities of color ("doing science"), (3) develop a new version of a cultural recipe that is more nutritious ("doing science"). These lower-order learning goals were focused on initially supporting students in understanding the science content, how this content connects to their community and cultural contexts (FOK), and how science can help them to better understand community injustices, a component of CSA.

We progressed toward higher-order learning goals in our later projects, such as in project 3, where learning goals were written as follows: (a) investigate a problem in your community ("doing science"), (b) create a change idea for how to address that problem ("addressing socio-scientific issue"), and (c) write a letter presenting your research and change idea to someone who can act on it now ("addressing socio-scientific issue"). In these learning goals, students were asked to use their community FOK and experiences as tools to contextualize and understand an environmental injustice and how it affected their community, and then address that injustice by developing a solution. As such, these project goals met all three components of CSA. In a project 3 co-design meeting, Ms. V described the significance of leveraging the project goals to create community change in design as supporting students to "genuinely learn more about a problem in their community that they care about, and. . .start thinking about how to solve it". Her position of "thinking about how to solve it" demonstrates that curriculum design should be centered around students' not meeting the lower-order design goals typical of science classroom learning, but using that content knowledge, along with their everyday FOK and experiences, to exercise their agency and employ their agentic systems to think about ways to improve their communities. In the post-interview, Ms. V reflected on our learning goal structure stating,

> "I wanted them to feel like science was something they could do, something that was enjoyable, meaningful and important for them to be a part of. . .something that is useful to them in their lives. . .we wanted students to feel validated. We wanted them to feel increasingly confident."

In this reflection, Ms. V notes that our learning goals were structured for students to see how science is not only has to be about content learning, but, also, situated to create space for them to explore how science can be used to support greater change. In developing students' confidence and skills, as discussed in the next design feature, to work toward that change, we support students in developing and exercising their agency to advance their communities and lives.

3.2. Design Feature 2: Developing Students' Toolkits

In the pre-interview, Ms. V described one of the central features of designing for CSA as "build[ing] citizens" by "giv[ing] them the tools to be able to look at society around them and [recognize] that's a problem and someone should fix it". Developing students' toolkits and skillsets was a recurring theme in our co-design meetings to support building students' agentic systems to question, criticize, and develop solutions. In a co-design meeting, Ms. V described these toolkits and skillsets as supporting students to "recognize oppression and recognize untruth. . .and be able to do something about it. . .and navigate systems that are not built for them". This aligned with our belief that school science learning should not only support students in concept learning, but also engage them in curriculum that develops their capacity to think critically, participate as active and informed citizens, and be prepared to traverse the world.

For each of our four units, Ms. V and I grounded our design in the development of "lifelong" skills through engagement in "science and engineering practices". As this was an elective course, our curricular design was not explicitly aligned with the U.S. Next Generation Science Standards (NGSS). We did, however, structure our design to support students in developing NGSS-aligned skills and practices that would develop their expertise in science, as well as their community contexts. Our goal in developing students' toolkits was to aid them in building skills that not only supported them in critically engaging in science for concept understanding but, also, building and sustaining their agency to feel capable and competent to use science skills to create community change. These NGSS-aligned skills and practices included: developing their critical thinking, inquiry, analytic, and reflection skills, asking questions and defining problems, obtaining, evaluating, and communicating information, carrying out investigations, collecting, analyzing, and interpreting scientific data, designing solutions and constructing explanation, and communicating findings.

In one of the initial summer co-design meetings, Ms. V and I engaged in a discussion about the development of students' toolkits as "embedded in our class norms". This meant that curricular design was rooted and fixed around the specific skills that we wanted our students to develop. For example, unit 1 was focused on developing skills including collecting, analyzing, and interpreting scientific data, and constructing explanations. In this project, students were tasked with taking their favorite cultural recipe and creating a healthier version of it. In their work, students collected and analyzed community data including interviews with community members about their healthy eating choices, as well as conducting surveys of food choices in the local community including fast food, grocery stores, and farmers markets, and comparing it to other areas across the city. Students were then tasked with taking a critical lens to their data analysis to determine trends in food access and implications for community members. Their reflection skills were developed through storytelling activities, such as the "My Food Story" activity, where students wrote a short story describing a connection, memory, or significance of food in their culture and community. Reflection prompts, which were embedded as formative and summative assessments throughout, conveyed to students the importance of taking a critical perspective on learning, how it can be used, and how it will support your community. An example reflection prompt was "How can you use what you have learned about food/nutrition to help your family and your community?" This reflection prompted students to think deeply about how they could use what they learned throughout the project to support community change, an aspect of CSA.

In Unit 3, skill development was focused on asking questions, defining problems, and communicating findings. As this was their first student-led project, Ms. V and I wanted to support students in learning to construct their own research questions and define research problems. We accomplished this by giving students a variety of general topics around community environmental issues. Students were tasked with defining that socio-scientific problem within the context of their community and generating an original research question about the topic. In using their FOK from their everyday experiences living and engaging in their communities, the curriculum became a space where students were able to use their expertise to identify community problems and determine what questions they could ask in order to address them. Students took justice-oriented action to solve that problem, another aspect of CSA, through their final projects. Further described in feature 3, students' final projects were designed to be shared with their families and community organizations to communicate their suggestions to address their identified issues. This practice aligns with exercising students' CSA, as they not only completed the research on their community issue but developed a solution to address this issue and disseminated their findings to the community to try and put their solution into practice.

Skill development was further situated in students' engagement with their DIN. Ms. V and I developed the DIN as a scaffolding tool where students could take notes, engage in science practice, and build upon their knowledge during each step of the research process. Each page of the DIN was structured to support students' critical thinking and develop evidence-based solutions to community-oriented issues [55]. Describing this in an interview as "hon[ing] in on those skills rather than telling students the most important thing to memorize is the concept," Ms. V positioned the DIN as supporting students in developing their science expertise while engaging in community-action-oriented investigations. For example, DIN features included scaffolds on how to develop a research question, how to conduct background research, how to collect community data through surveys, interviews, and observations, and how to develop a solution. As many students had not previously engaged in science classes that allowed them to move past concept memorization to actual engagement in authentic science practice by investigating issues in their own communities, the DIN served to provide a framework to assist students at each part of the process and position engagement of their agentic systems as not a far-off possibility. The enculturation of students into the culture of school often positions them as not seeing themselves as capable of creating change [27]. The DIN serves as a mediating tool to break down this process into small, actionable steps, supporting students in exercising their CSA.

Overall, developing students' toolkits was structured to assist students in concept learning and developing their capacity to critically think and be active community members who use science to imagine change. In reflecting on this design feature in one of our final co-design meetings, Ms. V stated that we strived to prepare students to think,

> "How can I use science to talk about this issue? What are some methods I could use to figure out more about the problem? What's the best way to act on this issue and share information?. . . That's [the] goal."

Here, we see that by developing students' toolkits we sought to give them the skills to feel as though they have the expertise and agency to use the tools and skills they have developed in the class to address issues in which they see in their everyday lives.

3.3. Design Feature 3: Cultivating Spaces for Advocacy and Critical Hope

In school science, environmental injustices are often taught from universal perspectives that not only address issues in worldly contexts but also do not consider the social and political aspects of these injustices or their effects on communities of color [56]. Therefore, Ms. V and I sought to design a curriculum that positioned science classrooms, and science practice, as a means to investigate the political, social, *and* environmental implications of community injustices. Specifically, this would be accomplished by cultivating spaces where students could engage in advocacy to understand, reflect, make decisions, and act in their everyday lives to transform community spaces in agentic ways [27]. Creating spaces for advocacy supports moving from engaging in scientific practice for content learning purposes, to engaging in scientific practice for community change. In the pre-interview, Ms. V described this process as, "community-based science brings in an element of empathy to the scientific process because we are always asking, no matter what the research question is, how is this going to come back and help people?" By designing a curriculum to iteratively prompt students to ask themselves how their work could be used to aid the collective well-being of their community, we position students as agentic individuals capable of imagining such possibilities.

Cultivating spaces for advocacy was most saliently seen in the development of students' final projects. Final projects were designed to have students develop a change idea for an issue, and present that idea to someone in the community that could potentially support its implementation. We specifically did not present these projects as students targeting the mayor or larger government bodies to present their findings, but, instead, identifying community members or organizations that address this issue in order to show students that community change can be bottom-up.

In unit 3, for example, students wrote advocacy letters that were sent to local community leaders and organizations, identified by students themselves as leading change agents in their community, to communicate their research question, data collection methods, research findings and present a change idea on how to address the issue and why they should consider using it. In unit 4, students had the option of developing social media profiles, creating a presentation, developing an art piece or invention, or creating an action project proposal to support their advocacy. Students decided on the mechanism in which they wanted to exercise their agency, with the premise that it was designed to engage the community in understanding the issue in which they investigated and demonstrated their change idea. We believe that learning and community change can be facilitated through multiple modalities, and wanted to demonstrate to students that change is possible and they could utilize whichever method felt most comfortable for them to support that change.

In their final projects, students engaged as agentic individuals most specifically in developing their "change idea". Change ideas were defined as action-oriented transformations students could engage in to address a community injustice. In a co-design meeting, Ms. V described the purpose of the change idea as "mak[ing] [their project] this process of hope and building for our kids versus it being like 'look at what's happening and everything is terrible'". Students' development of their change idea was scaffolded to support connecting their FOK and experiences of their community and cultural needs, with science practice, to take justice-oriented community action. Change ideas are an important practice when designing for CSA, as Davis and Schaeffer [4], "caution against conceptions of justice-oriented science education that focus exclusively on the identification of the problems" (p. 386). If we are to position students as agentic individuals, the curriculum must move past the sole identification of problems. Further, focusing solely on the problems of environmental injustices without accounting for opportunities for community thriving, can lead to ecophobia [57]. Ms. V noted that CBS can be a difficult format for science learning at times, as students are "focus[ing] so much of their energy on these topics (community injustices), when maybe they're used to school being a break from real life". By focusing curricular design around the development of change ideas, we move past identification to addressing and supporting students' critical hope for the future.

Cultivating critical hope was an ongoing design theme discussed in our co-design meetings. Ms. V stated in the post-interview,

> "I always wanted to put in that element of critical hope and action, and not just be like, well, things suck and we're moving on, right? Because that doesn't help anyone. So, I think rather, we end on this note of okay, what do we do to fix this inequality?"

Based on Freire's [58] pedagogy of hope, where hope is a verb, and not a noun, as it is not a matter of wishing or aspiring, but instead critical and collective transformative action, we sought to design for CSA in a way that prompted students to see that positive change through science is possible. Critical hope, in curricular design, was guided by the foundational question of "how can you use what you learned to help your family and community?" Part of the purpose of developing a change idea was to support students' critical hope that they can engage in transformative action through CBS. By merging their FOK and life experiences with scientific knowledge and practices to create change in their communities around identified injustices, the development of the change idea is positioned as a tool that students to exercise their CSA. As such, students served as transformative intellectuals [30], or change agents capable of imagining and creating mechanisms for social and environmental improvement in their lives and communities. Agency is complicated and contextual, but by designing for the cultivation of advocacy and critical hope through students' development of change ideas, we prompt them to exercise their CSA to enact change and take action in their communities through using science practices [59].

3.4. Design Feature 4: Critical and Ongoing Reflection

Sreyashi Basu and colleagues [9] note that engaging in agency requires ongoing reflection in order to develop awareness. Although they specifically discuss it in terms of individuals examining their own identities, I argue that in order to design for CSA, there also needs to be space for ongoing critical reflection of one's own communities and circumstances in order to be able to identify problems and take action. As such, group and individual reflections were significant design practices that Ms. V and I engaged students in throughout the curriculum. In our first two co-design sessions, Ms. V and I discussed the "must haves" of each designed unit. Group and individual reflection were positioned as one of the essential must-have design elements. Some of these reflections were verbal, happening unplanned in the moment, but the majority of these reflections were specifically designed and structured throughout instruction to prompt students to consider their learning at the intersections of science, community, and justice. Our hope in these reflections was that students would be able to demonstrate engagement in the first two components of CSA: developing expertise in science and community contexts and using that expertise to identify and take action against community problems.

Reflection design was based on our (Ms. V and I) discussions in co-design meetings as to how we had previously attempted, but failed, to actively engage students in justice-oriented reflective work that supported their agency. In the past, we had used a compare-and-contrast model of reflection, focusing on learning demonstration. In thinking back to this reflection strategy, we felt it was too conceptual and impersonal, and did not connect with our students or help them to see the value of reflection as an agentic exercise. In one of our co-design meetings, Ms. V stated, "We've always done equity work. . .[but] I feel like it's just so abstract to them when you're trying to do that kind of comparison and contrast [reflection], unless there is something personal". This prompted us to consider what the "personal" aspect of reflection may consist of. Inevitably, the "personal" became a structure of supporting students in demonstrating their learning, while also positioning reflection as an exercise of action and agency in which they could imagine more just futures for their lives and communities.

As such, reflections were structured in design in two ways: periodic mini-reflections throughout the unit, and end-of-the-unit reflections. For example, in project 1, students completed end-of-the-week reflections using the "3-2-1" reflection model, where they described three things they learned, two connections they made, and one feeling they had. During quarter 1 when students completed an investigation of food deserts in the city in which TCS is located, they engaged in the following reflection questions: "(1) What are THREE things you learned this week about macronutrients and what makes up the food we eat? (2) What are TWO connections you made between what we've learned in class about food access and food deserts and how it is relevant to your community? and (3) Describe ONE feeling you had after learning about the unequal access to healthy food in your community and why you felt that way". In another reflection that followed students' interviews of community members about their knowledge of nutrition and community food access points, students engaged in the following reflection questions: "(1) What are THREE things you learned from the community expert about food and your community? (2) What are TWO connections you made between what we learned about in class and something the expert speaker discussed? And (3) Describe ONE feeling you had after hearing the guest speaker talk and why you felt that way". Students' answers from both of these reflections served as the foundation for whole class discussion around how their community was affected by a lack of healthy food access, how members of their community conceptualized healthy eating, and who was responsible for fixing this injustice. Collectively, these reflective activities supported students in engaging their CSA by developing their expertise around nutrition and how healthy food access affects their community and prompted initial conversations about how action can be taken to address this issue. Critical reflection, as a process of individual and collective action, positions students to think toward the future as to what actions can be taken to address community injustices, supporting another critical aspect of CSA.

3.5. Bringing It Together

Collectively, by positioning the CBS curriculum as a praxis with embodied values and specific actions, in this case, the design features presented in these findings, I demonstrate how curriculum, and its associated activities, can be designed as tools that engage students in developing and exercising their CSA to imagine and create community change. By positioning school science learning as significant to students' lives and communities, and imagining a more justice-oriented future, I believe these design features can provide a foundation for curriculum development that engages students in CBS instruction to foster relevance, excitement, and youth activism through science learning and practice. In the next section, I situate these findings in the current literature and make an argument for how designing for CSA through CBS creates generative learning spaces that position youth as agentic individuals who are capable of imagining and creating change.

4. Discussion

This article examines features of a middle school environmental justice community-based science (CBS) elective curriculum, co-designed to support the development and exercising of students' critical science agency (CSA). My teacher partner, Ms. V, and I worked together over a multi-year research-practice partnership to co-design a community-based, justice-oriented science curriculum that supported our students in developing content knowledge while also becoming and being community change agents. The literature has long documented that student understanding of connections between science and their out-of-school experiences is influenced by the structure of learning activities and the design of the curriculum [6]. There are few examples, however, of studies that document the design and development of science curricula—specifically justice-oriented curricula—that support students' critical science agency in meaningful and relevant ways [4,28]. This work addresses this under-studied area by exploring curricular design features that intend to not only support the advancement of students' scientific knowledge and engagement in practice, but also empower students to develop and exercise their critical science agency in learning [11].

In this paper, I illustrate how four curricular features, leveraging learning goals to create community change, developing students' toolkits, cultivating spaces for advocacy and critical hope, and critical and ongoing reflection, were designed to support students in not only developing their CSA but, also, exercising it. CSA is concerned with three components: (1) developing students' expertise in science and their community contexts, (2) supporting students to use that expertise to identify and take action against community problems, and (3) engaging students in actions that are justice-oriented [8]. Each of the design features presented in this article, and the associated practical examples of how to exercise the feature, demonstrate how to support these components of CSA in practice. By integrating and valuing students' community and culture funds of knowledge, the features of curricular design presented were structured to support content learning and the development of students' agentic dispositions to locate them as capable intellectuals [30] who can imagine and create more just futures for their communities. This work shows that developing and exercising agency can be purposefully designed for in curriculum, especially from a critical perspective. Criticality in science agency differs from other forms of agency in that it explicitly imagines engagement in a future, more just community [10]. These design features presented support students in working toward that criticality by grounding science learning, and engagement in science practice, in understanding and taking action against community injustices. In the sections below, I discuss my findings in conversation with the current state of the literature to consider the impact each of these design features can have on how we design for CSA through the CBS curriculum.

McNeill and Vaugh [11] argue that curriculum needs to focus learning on environmental actions and their impacts on the world, instead of simply presenting students with content knowledge. By leveraging learning goals to create community change, the designed curriculum was structured to support students in using their science learning to impact their worlds, meeting the three goals of CSA [8]. In our curricular design, Ms. V and I structured the learning goals of each unit to position engagement in the community as a central aspect of the learning process. As such, we sought to support students in utilizing what they learned in the classroom while "doing science" to "address socio-scientific issues", by engaging students in meaningful work that could impact their communities. Mirroring findings from Schenkel and colleagues [7], we believe this design feature impacted students in building their political consciousness by more deeply understanding and defining injustices in their communities and leveraging scientific knowledge and practices in ways that mattered to them, situating them to take ownership of enacting their CSA to create positive and justice-oriented community change.

Designing for the development of students' toolkits and cultivating spaces for advocacy and critical hope worked in conjunction to help students learn how to recognize injustices in their communities and gave them the tools and space to use scientific knowledge and practices to address the issue and determine mechanisms for change. Studies have demonstrated that curricular content must be purposefully structured to support students in exercising their agency as having a sense of agency and actualizing and exercising that agency are not the same [12]. These systemic measures in design positioned students as capable of imagining and creating social change. By developing their toolkits, we provided students with the equipment to develop their expertise in science practice, as well as their community contexts, and imagine and actualize change, critical aspects of CSA. Centering the development of their toolkits in curricular design served as an embodied value to support intended actions [31]. In designing each unit to be grounded in a set of NGSS-aligned skills and practices, we sought to nurture students' capacity and agency to utilize the scientific tools and skills they developed in classroom learning to critically think about mechanisms to address socio-scientific issues present in their everyday lives, advancing how students can participate in their communities [9] and support community improvement [1].

Further, by ending each project with students developing a change idea, we nurtured a space that put their tools into action and prompted students to exercise their CSA by serving as advocates to engage in community change. By facilitating connections between their scientific knowledge and practices and their FOK to develop practical solutions to community issues, we positioned students to engage in more critical science learning through spaces of advocacy and critical hope. Vossoughi and Shea [8] assert that a more critical lens to science learning makes evident different forms of expertise that join to yield CSA. Supporting this idea, students' development of a change idea positioned their expertise, based on their FOK and science learning, as needed and necessary to be advocates while answering the question, "How can [I] use what [I] learned to help [my] family and community?" In doing this, we reframe school science as a space where scientific practice is needed to not only investigate the political, social, and environmental implications of community injustices but, also, a space of critical hope that can support community transformation [27]. Centering critical hope pushes students to dream toward a world beyond what it is now, one that cultivates a more thriving future for their communities and sees the value of their expertise in creating that future. By countering deficit views of student knowledge in science learning and practice [60,61] we center youth experiences as critical to knowledge production and agency [10].

Finally, critical and ongoing reflection was another significant design feature in our curriculum. Basu and colleagues [9] state that in order to engage in CSA, we must consistently reflect on our own identities to develop our awareness. This study expands on this work by situating reflection as not only a process of reflecting on our individual selves but, also, a process of reflecting on our communities and the injustices present in those communities to be able to identify a problem and take action. The critical and ongoing reflective structure Ms. V and I designed prompted students to not only individually reflect on their science and community learning, but also served as a foundation for collective reflection, through discussion, toward thinking around future actions to address community injustices, supporting critical elements of CSA. Reflection is a crucial aspect of the scientific process as it prompts scientists to frame the problem, investigate what is currently being done to address it and determine alternative, in this case, more justice-oriented, actions that could be used. In employing critical reflection as a design feature, we engage students in authentic science practice to develop awareness and envision justice-oriented actions, supporting critical aspects of CSA.

Overall, findings from this study help us to further consider the role of curriculum design in constructing generative learning spaces that position youth as capable, intellectual, and transformative beings who can investigate complex socio-scientific issues and imagine and support community change [30,46]. Curriculum design provides the foundation on which teaching instruction is built, as it necessitates what is considered relevant and significant for student learning and science teaching. Design features that challenge and disrupt hegemonic power structures and hierarchies in science education are needed and necessary to dismantle embedded systems in science education [62]. As the science education community pushes toward more justice-oriented, community-based approaches to science curriculum and instruction, we must make efforts to specifically design for these features as current curricular structures do not create space for this type of engagement. The design features described in this paper position developing and exercising students' CSA as an essential practice to "make visible different forms of expertise and the ways those forms of expertise merge to produce critical science agency" [8] (p. 329), advance student participation in community through science learning [9], and promote justice in science learning experiences [7] to imagine a more just future [10].

5. Limitations

While this work expands on existing literature around structures to support CSA in classroom learning through an exploration of design features structured as supporting students in development and exercising their CSA in a CBS class, this study is limited in a few ways. First, this work does not present an analysis of the impact of these design features on students' perceptions of their abilities to engage and leverage their agency to take action that supports community change. In other words, at the time of writing this paper, I am unable to present conclusions as to the impact of these design features on students' sense of their CSA in CBS. Further, the context as to which this study took place can lead to potential limitations as to the generalizability of these results. More specifically, the elective context of the study offered more flexibility in design, supporting Ms. V in having autonomy over curricular structures for the course. Other teachers may not have such autonomy due to broader power structures, commitments to curricular standards and or mandates, ideas around alignment to the NGSS, or other boundaries that present difficulties in reimagining curriculum in justice-oriented ways [16].

I highlight these constraints to bring light to the notion that developing and exercising agency is complicated and contextual, even within purposeful design. For many educators, the structures and demands of science teaching in formal settings present limited time, space, and autonomy to redesign the curriculum to be more justice-oriented or elicit student support for the development and engagement of CSA. For many students, especially students of color, the current culture of science education does not view them as capable individuals. As noted earlier, students' enculturation into the system of school science education can put them at odds with the goals of this work as they do not see themselves as having choices or being agents of change [27]. Curriculum design is just one mechanism to transform this framing and the culture of school science learning, generally, but it cannot be the only way. It must be coupled with changes in pedagogy and instruction so students can recognize clear patterns in instructional moves that support a reframed purpose of science learning. More explicitly, a purpose that "bring[s] the outside world into the classroom" [4] (p. 370) to position science education as a pathway to social change, and students as having the autonomy and support to be change agents.

6. Conclusions

As we work toward more justice-centered and equity-focused science education, we must promote the development and exercising of students' critical science agency as a necessary part of the learning process. The design features presented in this paper, as part of a community-based science class, sought to engage students' funds of knowledge to improve learning and develop their agentic dispositions. Ideas around agency in science need to be embraced from a more critical lens to promote expansive ideas of how expertise, in multiple forms, can be utilized to create community change. By designing a community-based science curriculum that draws upon students' funds of knowledge and seeks to develop their critical science agency, we challenge and transcend the pitfall of narrowly defining how science can be useful in students' everyday lives, as well as how their everyday life experiences can be useful in science. As such, we take a step toward constructing learning environments that demonstrate to students the possibility of using scientific knowledge and practices for a larger, more meaningful, and just purpose.

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