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Community-Engaged Research Projects in School Settings: Science Teachers' Practices and Reflections

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Abstract: Community-engaged research (CER) is a justice-oriented research paradigm that emphasizes equitable and reciprocal knowledge co-production with community members and organizations, sharing power, benefits, contributions, and responsibilities among all participants. This study explores nine teachers' cases of facilitating CER projects in their respective school settings, aimed to support students' critical consciousness and action for environmental issues and injustices. This study contributes to educational research by adapting an existing framework for CER for environmental justice that can guide K-12 teaching and research on it. By analyzing data from teacher community meetings and individual interviews in the CER framework, this study articulates classroom practices that addressed the Distribution, Procedure, Recognition, and Transformation dimensions of CER, as well as the positive impacts and challenges of these implementations. The findings report teacher practices categorized by the CER dimensions they addressed (the what of the practices) and the instructional strategies they employed (the how of the practices). The findings also compare the frequency of these practices as an indicator of variation in teacher practices and illustrate this variation through three teachers' CER cases. The findings also document the positive outcomes of CER in student empowerment, as well as the challenges related to time, resources, assessment, and stakeholder skepticism, underscoring the need for systemic support to enhance CER in school settings. The discussion focuses on the implications of these findings and ways to address the identified challenges through future research and institutional efforts.

Keywords: community-engaged research; science education; community of teachers; environmental justice

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1. Introduction

Environmental issues—such as extreme weather patterns due to global warming and air, water, and soil pollution exacerbated by human-caused toxins and waste—inevitably result in injustices disproportionately borne by marginalized communities (Sanson and Burke 2020; Thew et al. 2020). Communities with lower socioeconomic status are at a higher risk of suffering from these environmental issues compared to their affluent and privileged counterparts. Additionally, this disparity is intergenerational, as young people and future generations must contend with the more frequent and long-term legacy of environmental issues caused by older generations (Sovacool 2021). Recognizing the disproportionate suffering from environmental harms and risks, it is critical for youths from all backgrounds to empower themselves, critically analyze the complex reality of environmental injustices, and foster a sense of solidarity and agency in addressing these issues (Dimick 2012; Stapleton 2019). Youths have the right to learn about the critical and consequential issues affecting their lives (Tate 2001), including environmental challenges, the injustices they entail, and the ways to challenge and transform these injustices.

Critically noticing the urgency of youth empowerment in tackling environmental injustices, this study focuses on the potential of students' participation in community-engaged

research (CER) as rightful leaders and community experts. CER is a justice-oriented research paradigm that disrupts the researcher–researched power inequality in determining what knowledge matters to produce and transforming the process of knowledge production in ways to actually advance the lives of community members (Raphael and Matsuoka 2024; Wallerstein et al. 2020; Wilson et al. 2017). CER allows community members and their partner researchers to document and address disproportionate environmental threats to historically harmed communities and prevent additional harms from being placed in these areas (Hanna-Attisha 2019; Minkler et al. 2006).

In educational settings, CER can take various forms, such as community ethnography (e.g., Schenkel and Calabrese Barton 2020), participatory design research (Calabrese Barton et al. 2021), and youth participatory action research (Cammarota and Fine 2010). To account for the diverse interpretations of community engagement demonstrated by the teachers, this study uses CER as a broad pedagogical approach to address environmental and climate injustices with youth. For instance, while some teachers empowered students to take the lead in community investigations, as is representative of youth participatory action research, most teachers focused on introducing CER and preparing their students for gradual authorship, with the expectation of sustained community engagement toward youth authorship of participation. This study explores the diverse CER projects of the respective teachers, documenting the opportunities and challenges they identified during their reflections on their approaches to helping youth begin community engagement. Here, CER projects mean the projects in the context of school science, aimed at engaging students in knowledge and practices that prepare them for active participation in CER of environmental justice issues that are relevant and critical to the communities they care about.

1.1. Framing CER in School Contexts with Environmental Justice

CER features knowledge co-production of community members and their partner researchers through sharing power, benefits, contribution, and responsibility across all members involved. Raphael and Matsuoka (2024) articulate CER by contrasting it with the traditional expert-centered research approach. In expert-centered research, research is an endeavor conducted *on or for* the community, forming an extractive partnership that assumes community lives are deficient and can be cured by researchers' assets and expertise. In contrast, CER is a project *with and by* community members and organizations. It recognizes community lives, histories, cultures, and knowledge as assets and momentum toward transformative changes, which inform, inspire, and collaborate with researchers and research institutions. An important aspect of CER is empowering community members and organizations "to build their capacities to conduct research with and without academic and other professional researchers and strengthen their influence over the research agenda" (Raphael and Matsuoka 2024, p. 32). Building community members' knowledge of environmental science, issues, and injustices is crucial to developing grassroots leadership in CER.

CER's focus on empowering community members and organizations aligns with the justice-oriented approach in science education aimed to foster students' critical construction and application of scientific knowledge and practices to address issues that are meaningful to their lives and the communities they care about (e.g., Birmingham et al. 2017). In this approach, education serves as a pathway toward justice through learning and civic participation, with students positioned as co-creators of meaningful learning rather than mere recipients of knowledge (Morales-Doyle 2017; Calabrese Barton and Tan 2020). Students bear witness to the "lived socio-scientific challenges their communities face" and actively engage as "contributors and participants in the pursuit of possible and desperately needed solutions (Bang and Marin 2015, p. 302)". The role of students as knowledge constructors and community leaders parallels the positionality of community members in CER, highlighting the potential of CER in educational settings where students engage with real-world concerns that have significant impacts on their lives and their communities.

Environmental justice issues have been one of the most crucial real-world concerns addressed by this line of work, as tackling these issues involves understanding related environmental science knowledge, applying it to make decisions, proposing solutions, and taking actions (Wilson et al. 2017). Particularly, informal learning programs have led initiatives for CER that address local environmental concerns. Birmingham and Calabrese Barton (2014) conducted a youth action project with Black girls at a local community center, where the girls investigated family electricity consumption, calculated the benefits of energy-efficient alternatives, and presented practical recommendations at a community conference. In Tofel-Grehl (2023), Indigenous Hawaiian youths in a summer outreach program challenged the exploitive land use of tourists and external scientists, leading to the creation of a mobile app to educate community adults and tourists on the histories of sacred sites and respectful tourism behaviors. Littrell et al. (2022) describe how secondary students in an informal science program investigated climate change impacts on their communities, filmed significant locations, and engaged audiences to raise awareness and inspire action.

There also exist exemplary cases reported from the formal learning settings of school science classrooms. Morales-Doyle (2017) demonstrated how school science courses like AP chemistry can provide students with authentic environmental research project opportunities to raise their community members' awareness of soil pollution and the disproportionate suffering of soil pollution across races. The projects supported not only the academic success of the students but, more importantly, their self-affirmation as community researchers who exercised sophisticated reasoning about scientific and social justice matters, strengthening their ties to their cultural roots and communities. Dimick (2012) describes how a teacher took his students from a disadvantaged area on a canoe trip to observe pollution in the Green River, collecting samples and learning about local ecology. Inspired by the students' enthusiasm, the teacher facilitated students' restorative action projects, emphasizing science for social justice and community education.

Despite these exemplary cases, implementing justice-oriented CER projects in school science contexts can encounter significant challenges that hinder successful adoption. Unlike CER in informal science learning settings, CER in school science contexts can be structurally constrained by national and state standards, curricular schedules, and associated assessment plans. These structural challenges are compounded by a lack of understanding, resources, and experiences. Teachers may perceive themselves as having limited understanding, knowledge, and experience in undertaking CER (McGregor and Christie 2021). Even if teachers aim to integrate CER experiences, they may face insufficient support from school community members or the lack of resources, time, and funding (Kim 2024). As a compromise, teachers may resort to briefly mentioning how scientific knowledge relates to environmental issues or stay at the decontextualized, community-detached, and purpose-lacking delivery of environmental concerns. Alternatively, feeling overwhelmed by the structural, institutional, and material challenges of conducting CER, teachers may ultimately exclude environmental justice aspects from their regular science instruction.

Nevertheless, there are indeed teachers who recognize the challenges yet remain committed to implementing CER with their students, as demonstrated by the teachers in this study who formed their own community of practice. While the teachers shared a commitment to CER, their implementation could vary considerably, reflecting diverse interpretations of CER and methods tailored to their specific school contexts and local communities (Trott et al. 2023). This study, therefore, seeks to articulate the varying representations of CER across different schooling contexts.

1.2. Dimensions of Community-Engaged Research Aimed at Addressing Environmental Justice

This study employs the existing framework of CER for environmental justice (Raphael and Matsuoka 2024) developed by academic researchers and community-based organizations and adapts and contextualizes it to be useful in the K-12 educational settings. This contextualization of the CER framework was intended to include obligations to justice for

students as well as to community members, positioning students as rightful and responsible community members and experts.

While the concept of environmental justice is dynamic and evolving, it is broadly understood as based on "the principle that all people have the right to be protected from environmental threats and to benefit from living in a clean and healthy environment" (Davies and Mah 2020, p. 4). Environmental justice calls for the empowerment of and advocacy for historically marginalized groups—including Indigenous peoples, communities of color, low-income populations, future generations, and even nature and wildlife—to protect their environments, lives, and homes from ongoing exploitation and harm (Raphael and Matsuoka 2024).

This study's conception of environmental justice draws on the four dimensions developed through the work of Schlosberg (2007) and Raphael (2019). The Distributive dimension addresses 'who gets what,' focusing on the fair allocation of environmental benefits and burdens. The Procedural dimension explores 'who gets to decide,' examining participation and influence in environmental decision-making processes. The Recognition dimension considers 'who gets respected and valued,' emphasizing the dignity, knowledge, experiences, and values of those disproportionately affected by environmental harms. The Transformational dimension asks 'what needs to change,' calling for the restoration and reparation of environmental damages caused by colonial, racialized, and economically exploitative systems. This dimension advocates for systemic transitions towards just power relations, including those between humans and nature.

Raphael and Matsuoka (2024) extend the four dimensions of environmental justice to frame CER work. CER toward environmental justice can be described in terms of disparities each dimension addresses. The following unpacks the dimensions by revisiting the literature mentioned above Birmingham and Calabrese Barton (2014) Tofel-Grehl (2023), Morales-Doyle (2017), and Dimick (2012) to illustrate how the four dimensions can be addressed by learning programs in informal and formal educational settings.

The **Distribution** dimension of CER is concerned with disparities not only in access to resources and benefits but also in burdens related to conducting CER aimed at working toward environmental justice. To address the disparities, CER distributes the community capacity for self-determined research while balancing workloads involved in research among all CER participants, including community members and researchers (Raphael and Matsuoka 2024). Balancing means a fair distribution of both tangible (e.g., research funding, data, and amenities) and intangible resources and benefits (e.g., relationships and networks) and burdens (e.g., the workload involved in research).

In science learning contexts, addressing the Distribution dimension may involve providing students with ample opportunities to practice CER, supported by appropriate scaffolding for necessary knowledge, skills, and experiences. Morales-Doyle (2017) equipped AP chemistry students with disciplinary knowledge of soil chemical compounds and experimental skills for assaying, enabling them to independently design and conduct experiments analyzing local soil chemicals. In Birmingham and Calabrese Barton (2014), distribution was a key value addressed by youths who educated community elders about the benefits of changing small habits, such as switching to energy-efficient bulbs. The youths were motivated to host an educational and welcoming community conference, ensuring that community members could easily access knowledge and opportunities for habit changes. They also distributed LED bulbs to conference attendees, encouraging the adoption of energy-saving practices to reduce electricity bills.

The **Procedural** dimension of CER is concerned with disparities in decision-making power and participation. It highlights inequities in who has the authority and opportunity to shape CER design, procedures, and purposes. To address the disparities in the procedure, CER seeks to ensure transparency in community involvement and agency throughout the entire research design and implementation (Raphael and Matsuoka 2024). In terms of the Procedural dimension, students will be able to exercise the agency and authorship expected from their involvement in youth participatory action research (Morales-Doyle and

Frausto 2021). In science learning contexts, this would involve students participating in a democratic and transparent process of decision-making. Teachers may share the agenda and expected goals of CER projects with students and engage students continuously in making procedural decisions, determining criteria for final outcomes, providing peer reviews, and having students participate in actual community decision-making processes.

In Morales-Doyle (2017) and Birmingham and Calabrese Barton (2014), students were involved in decision-making for community conferences, determining presentation content, resources, timeframes, and venues. Dimick (2012) describes how a teacher facilitated youth discussions to select their community action project advocating for Green River restoration. In Tofel-Grehl (2023)'s summer outreach program, the Procedural dimension was addressed as Indigenous Hawaiian youth participants reshaped the program's focus. By prioritizing their shared concerns about tourists' exploitative land use, the youths collaborated with educators to redesign the program's content and expected outcomes.

The **Recognition** dimension of CER addresses disparities in the validation and respect given to different knowledge systems. It challenges the inequitable treatment of community-based, traditional, and Indigenous knowledge compared to dominant scientific paradigms in environmental research and decision-making. To address these disparities, CER aims to promote epistemic and cognitive justice by representing community-based knowledge and its sources fairly and accurately on their own terms while respecting the value of diverse ways of knowing and understanding environmental issues (Raphael and Matsuoka 2024). Moreover, the Recognition dimension involves the acknowledgement of the negative emotions that can emerge from tackling environmental issues and the harm done to humans and nature (Lovren and Jablanovic 2023). Increasingly, studies report environmental anxiety or eco-anxiety as emotions that people display due to their concerns about climate change and environmental risks (Pihkala 2020). Recognition is necessary not only for community knowledge and wisdom but also for the harm done to communities and ecosystems, the risks posed by environmental challenges, and the associated emotional impacts on individuals and groups.

Tofel-Grehl (2023)'s educators in a summer outreach program shifted their roles to become co-learners by recognizing Indigenous Hawaiian youths' knowledge of their sacred land and addressing concerns about land exploitation. Youths repurposed electronic devices that educators initially intended to use for STEM tool experiences so as to develop mobile apps aimed at sharing the community's knowledge, wisdom, and concerns around disrespectful and exploitive land use. In another case, Dimick (2012) describes how a teacher's field trip to the Green River offered students a chance to recognize both the challenges and potential of their local waterway. Students investigated the river's history near racially segregated areas that had suffered from soil runoff and garbage accumulation. They also observed the ecosystem's resilience in restoring its natural health and the ongoing restoration project led by local community members.

The **Transformation** dimension is concerned with disparities in the capacity for systemic change. It focuses on inequities in the ability of different communities to envision, initiate, and benefit from transformative environmental justice efforts, addressing historical imbalances in power and representation. To address the disparities in transformation, CER attends to previously neglected research needs of frontline and fenceline communities as well as community members' hoped-for present and future, viewing the hoped-for imaginaries as the inspiration for transformative changes (Raphael and Matsuoka 2024). It consequently involves practicing more just relations with environmental justice communities and with nature.

In science learning contexts, addressing the Transformation dimension of CER involves empowering students to envision transformative changes expected from the result and process of CER. This dimension also focuses on reshaping relationships between educational stakeholders, moving from hierarchical to reciprocal interactions. Educators in Birmingham and Calabrese Barton (2014) and Tofel-Grehl (2023) facilitated youth discussions to brainstorm desired environmental changes in their communities. The youths'

transformative aspirations stemmed from their affection for these environments, suggesting that addressing CER's transformation dimension begins with sharing affection, empathy, and community knowledge of the place. In comparison, Dimick (2012) and Morales-Doyle (2017) addressed the Transformation dimension by having students visit local sites that were environmentally harmed or neglected. Through observation and investigation, students identified the need for transformation, indicating another approach to this dimension: engaging students in witnessing environmental issues and injustices firsthand and then critically addressing them.

The four CER dimensions provide a comprehensive framework for promoting students' learning and practice of CER towards environmental justice. It can contribute to designing CER in ways that promote environmental justice as its ultimate goal while also working toward epistemic justice in the process. Additionally, by using the framework to analyze teacher practices of facilitating CER, we can better understand how teachers equip students with knowledge and tools to recognize, systematically investigate, and transform the disproportionate injustices of environmental issues.

While the potential utility of the conceptual framework for CER is promising for informing instructional designs and analysis of educational projects, there is a notable gap in reporting how CER projects in school settings address the respective dimensions. This study aims to bridge the gap between theory and practice by documenting nine teachers' CER projects, drawing on implementation details and reflections shared during teacher community reflection meetings and individual interviews. Doing so, it also seeks to identify the projects' positive impacts as well as challenges that emerged from the CER implementation.

Drawing on the CER framework, this study analyzes how teachers address the different dimensions of CER and develops the practice-informed operationalization of how each dimension manifests. For example, as the finding elaborates, the manifestation of CER's distributive justice dimension extends to include the distribution of disciplinary and CER-related knowledge with students, in addition to the original framework that primarily highlights the distribution of roles, benefits, resources, and responsibilities.

1.3. Research Questions

To explore the teachers' CER cases, this study employs and adapts the conceptual framework of CER that entails four dimensions of justice—i.e., Distribution, Procedure, Recognition, and Transformation (Raphael and Matsuoka 2024). As discussed thus far, the CER framework articulates the forms of disparities that should be addressed by CER in work on environmental justice. Informed by the CER framework, this study seeks to answer the two questions:

1. How did teachers facilitate students' engagement in CER projects?
2. Subsequently, what opportunities and challenges did teachers identify from conducting their CER projects?

To answer the research questions, a reflexive thematic analysis was conducted on statements extracted from audio recordings from teacher community meetings and individual interviews with the teachers. The findings of this study can provide empirical insights for those conducting CER in formal and informal education contexts, by articulating the sophistication of CER work toward environmental justice as well as reporting challenges and opportunities yielded from the teachers' actual implementation of CER projects.

2. Methods

To address the two research questions, reflexive thematic analysis was utilized (Braun and Clarke 2022), which enabled qualitative data analysis guided by a theory-based coding framework along the concurrent contextualization of the framework during the data analysis process.

2.1. Context and Participants: Community of Nine Teachers Employing CER Projects in Their Respective School Sites

This study took place in a community of nine public school teachers in Korea (two elementary, three middle, and four high school teachers). The teachers already knew each other through a local network of public school teachers seeking to integrate environmental topics into their instructions. They formed a community in December 2022 to create a space for learning and sharing among teachers running or developing CER projects aimed at fostering student engagement in both science and civic participation, particularly around critical environmental issues and their community impacts.

Table 1 shows the descriptive information of teachers and their CER projects. Teachers brought different experiences teaching and engaging in CER. Their projects varied significantly in scale, involving different numbers of students across various grade levels. The projects also differed in duration, curricular integration, formal assessment requirements, and community member involvement. This study specifically focuses on the community teachers' reflection meetings that took place between September 2023 and March 2024.

Table 1. Participant teachers and their CER projects.

Teachers	Teaching Years	Grade Range	CER Project Title or Summary	CER Project Curricular Integration	Number of Students	Engaged Community	A Total Number of Sessions
ES1	7	Elementary 4th	Plastic toy 3R: Recycle, Reuse, Reduce	regular science class	23	students' families, local kids' toy shop	15
ES2	20	Elementary 5–6th	Transforming a school as an eco-friendly community education center	extracurricular program	17	local environmental activists, community leaders, professional artists	12
MS1	5	Middle School 7th	Connecting science with environmental issues	regular science class	32	students' peers at school	15
MS2	7	Middle School 7th	Do you feel global warming and how do you tackle it?	regular science class	27	students' peers at school	15
MS3	8	Middle School 7–8th	Veggie-honoring lunch project	extracurricular program	11	students, teachers, and staff at school, school dining team, and nutrition expert	20
HS1	8	High School 10th	Environmental issues affecting our community	elective course	17	student peers at school and SNS platform	16
HS2	13	High School 10/11th	Book to the Act: environmental issues urgent in Korea	extracurricular program	15	student peers at school and SNS platform	34
HS3	16	High School 11th	Chemistry for Environmental Justice: Bridging Science and Community Action	regular chemistry class	24	student peers at school and SNS platform	35
HS4	17	High School 10th	Community wisdom for environmental issues	elective course	27	student peers at school and SNS platform; teachers and families	35

2.2. Positionality

In this study, I position myself as the teachers' partner who listens to, affirms, discusses, and documents their work. I joined the teacher community in May 2023 at the invitation of the community leader, whom I had known as a colleague science teacher

before transitioning to become a teacher educator and researcher. Given my experience as a secondary science teacher who ran youth action projects, she expected me to contribute insights from both my teaching and current research. During our early meetings, the teachers encouraged me to conduct a study with them, and all nine teachers consented to this study. The teachers were not merely data sources; they eagerly participated in data generation as well as data analysis as critical reviewers, with two teachers volunteering for further data analysis, leading to the production of the final coding scheme and results.

Teachers, despite their unwavering commitment, often expressed frustrations about whether their efforts could make a difference, especially given the increasing perception that little can be done about climate change. However, this despair also became their strongest motivation for agreeing that education should address not just science knowledge and related environmental issues but also the injustices at the core of these issues in classroom discourse. They hoped that the experiences in CER might plant prosperous seeds in at least some of their students' minds, empowering them to readily engage in CER for what matters. I present this manuscript with admiration for these teachers' commitment to CER with students and their willingness to share both the successes and challenges they experienced with colleague teachers and partner researchers. Hereafter, I use the pronoun 'we' when applicable to indicate our partnership that enabled the documentation of this study.

2.3. Data Generation

The primary data consist of transcripts from audio recordings of teacher reflection meeting sessions and individual interviews with teachers. These recordings were automatically transcribed in Korean using an online transcription service. Secondary data include instructional materials and student artifacts that teachers shared during the meetings. These materials and artifacts, related to their respective CER projects, were uploaded by the teachers into a shared electronic folder.

2.3.1. Teacher Community Reflection Meeting

The primary (audio recordings) and secondary (materials/artifacts from CER projects) data for this study were generated from 12 online meeting sessions of the teacher community reflection held biweekly over a six-month period between September 2023 and March 2024. Each meeting lasted about 2.5 h and focused on the teachers' ongoing or recently completed CER projects. Each session involved three teachers' presentations of their CER projects, followed by an all-teacher discussion. In preparation for their presentations, I provided teachers with guiding questions to help them reflect on key aspects of their projects that could help me answer both RQ 1 and RQ 2. The questions asked about procedures, purposes, outcomes, tips, resources, and any challenges or questions they encountered. Each teacher had four presentations across the 12 sessions. After the presentations, all teachers engaged in collaborative discussions, offering feedback, insights, and further reflection on their CER projects.

I also delivered presentations during the sessions to share conceptual and procedural frameworks for reference, including the CER framework, as well as findings from studies that conducted similar projects to theirs. Also, I prepared and presented materials based on teachers' requests, such as community interview and survey templates, and instructional content and activities. At the invitation of teachers, I participated in their CER project sessions either in person or online, serving as a discussion panelist, student proposal reviewer, or teacher assistant.

2.3.2. Individual Interviews

Two months after the final teacher reflection meetings, I conducted individual online interviews with each of the nine teachers. These interviews were audio-recorded and lasted approximately 1.5 h each. For Research Question 1, I asked teachers to reflect further on their CER projects while reviewing my initial open-coding data analysis (See below for the details of the open-coding phase). Teachers read through how I grouped and coded

their statements made during their presentations as practices for facilitating CER projects. Teachers provided additional explanations or suggested revisions to the initial coding. For RQ 2, I prompted teachers to reflect on the positive impacts of their CER projects, both for their students and themselves, as well as the challenges they encountered. Our discussions then evolved into a generative exploration of how CER approaches in school settings could be advanced and what systemic support would be necessary to facilitate future success. Additionally, at the end of the interviews, I asked if they were interested in further participating in the next data analysis (the second and third data analysis phases), and two teachers volunteered to be co-analyzers.

2.4. Data Analysis

To answer the two research questions, I conducted a reflexive thematic analysis (Braun and Clarke 2022) in three phases of analyzing primary data of transcripts generated from teacher reflection meetings and from individual interviews (Figure 1). The secondary data, including teacher presentation materials, instructional materials, and copies of students' artifacts examples, were used to triangulate the primary data analysis.

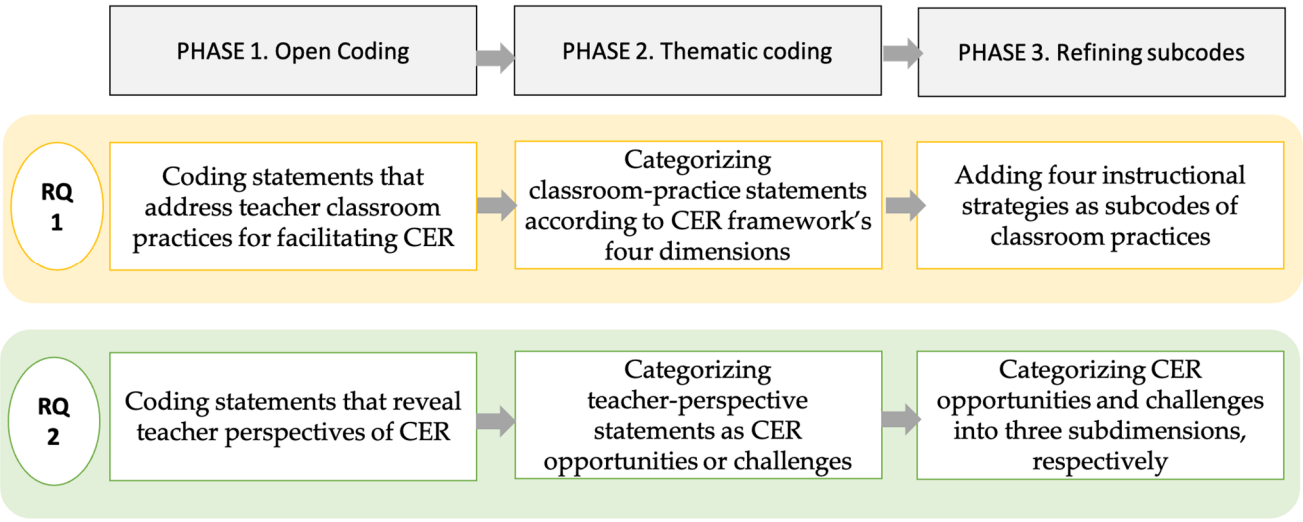


Figure 1. Data analysis phase.

In the first phase, I open-coded teachers' statements that addressed the classroom practices for facilitating students' engagement in CER (RQ 1) and teacher perspectives of CER from their project implementation (RQ 2). Classroom practices refer to the coherent set of actions and interactions of teachers and students, carefully designed and intended to engage in CER projects focused on environmental and climate issues. For open coding, I first pre-processed the data. Transcripts from reflection meetings and individual interviews were chronologically arranged in a single document. I then created an electronic spreadsheet to extract statements from the original document and assign codes to these statements.

The extracted statements served as a unit of analysis, containing single to multiple sentences that represented a particular classroom practice (RQ 1) or a particular idea of opportunities or challenges that emerged from CER (RQ 2). For example, HS3 delivered 45 sentences over approximately 4 min during her second presentation at the teacher community reflection meeting. I coded this entire segment as 'Explain criteria for evaluating the reliability of online information on environmental and climate issues.' These sentences collectively provided a coherent elaboration of how and why she gave explicit instruction on the importance of critically reading online information about environmental and climate issues. Similarly, the open coding focused on identifying coherent and explicit ideas from elaborate statements generated from the teacher community reflection meetings and individual interviews.

As a result, 647 statements were coded as 39 classroom practices, and 61 statements were coded as 19 ideas on teacher perspectives of CER from their implementations. As mentioned above, I brought the preliminary result of open coding to individual interviews with teachers, from which the coding results were confirmed and further refined.

In the second phase, I sorted the open-coded statements according to the coding scheme developed based on this study's conceptual framework. The initial coding scheme comprises two categories that entail dimensions, respectively: (1) CER dimensions and (2) teacher perspectives on CER. The first category, CER dimensions, is related to the RQ 1 and entails four dimensions of CER and descriptions of each dimension developed referring to Raphael and Matsuoka (2024) and related literature on CER (e.g., Raphael and Matsuoka 2023; Wallerstein et al. 2020). The second category is related to RQ 2 and entails two dimensions: opportunities (positive impacts) and challenges teachers mentioned about conducting CER in school science education contexts. In the data analysis spreadsheet, I added a column of 'dimension' to assign the open-coded statements to the respective dimensions of CER (the first category) or teacher perspectives on CER (the second category). Next to the dimension column, I added a column to leave memos about why particular statements were assigned to those codes. For example, I codify the statements that describe a teacher's introduction to science knowledge and inquiry practices. For the first instance of this type of codification, I left a memo: 'This practice is observed by most teachers is considered a regular part of their CER projects'. This was coded to 'distribution' because teachers raise students' capacity to conduct CER based on sound knowledge and inquiry bases.'

At this phase, two teachers joined as independent coders. Once the coding scheme and analytic spreadsheet were refined, I held a training session with the two volunteer teachers to introduce the coding scheme and ways to record their coding in the spreadsheet. To calculate interrater reliability (Gwet 2014), we coded 10% of statements together so as to develop a common understanding of the coding scheme. We then coded a randomly selected 30% sample of the statements independently. On the ratings from the three of us, intercoder reliability between the respective teachers and I was calculated as Kappa values 0.89 and 0.91, indicating substantial agreement. The remaining 60% of statements were divided equally (i.e., 20% per coder) and coded independently. We conducted a cross-coding process, reviewing and discussing any discrepancies until reaching a consensus. As a result, the 39 open codes assigned to 647 statements were grouped into the four respective dimensions: the 9 practice codes assigned to the Distribution, 9 practices to Procedure, 10 to Recognition, and 11 to Transformation dimension. Also, the 19 teacher perspective codes were grouped into two: 11 for the Opportunities dimension and 8 for the Challenges dimension.

The last phase further sophisticated analysis by adding subdimensions that help to refine and better reflect the variation in statements. Regarding the four CER dimensions (and thus regarding the RQ 1), four subdimensions were added drawing on data analysis discussion among the two teacher coders and I. They are Approach, Introduce, Practice, and Apply, which were added to better reflect the difference in the extent to which the classroom practices addressed each dimension of CER. For example, two sets of statements coded under the same dimension of 'Distribution' would be further assigned to the different subdimensions: one to 'Introduce' if they involve structured instructions from teachers, and the other to 'Apply' if they involve students' actual implementation of CER at community settings. The number of classroom practice codes and examples are displayed according to the four CER dimensions and the four instructional strategies. Regarding the teacher perspectives of CER (and thus addressing RQ 2), we added three subdimensions under opportunities and three under challenges.

Three months after the audio-recorded teacher community reflection meetings, we brought the community our initial data analysis results for the teachers to review, critique, and confirm. Their feedback led to further refinement of the analysis. Additionally, with the codified list of classroom practices, positive impacts, and challenges in hand, the teachers

engaged in discussions about potential future practices and the systemic support needed to sustain and advance CER projects in school settings.

2.5. Limitations

Several limitations of this study should be noted. As an exploratory, interpretive, and small-scale study of a cohort of Korean K-12 science teachers over six months, this study does not aim to provide a representative picture of all teachers' practices but seeks to identify a variety of instructional strategies that teachers use to engage students in CER projects and the educational opportunities and challenges that arise from this teaching. While these reflections provide empirical evidence of CER in school settings, the study does not include direct analysis or references to students' or community partners' perspectives. Given that the study was also conducted within the specific cultural and educational context of Korea, the findings may limit its applicability to other national or cultural settings where community engagement in schools might differ. Despite these limitations, this study focuses on its primary goal of identifying empirical evidence and practical examples of how teachers can facilitate CER experiences as well as areas for necessary systemic support and future directions in this scholarship.

3. Findings

Drawing on the analysis of teachers' statements and materials from their presentations at the teacher community reflection meetings, this section elaborates on the findings in relation to the two research questions.

3.1. RQ 1: How Did Teachers Facilitate Students' Engagement in CER Projects?

RQ 1 prompts the main findings of this study on the classroom practices for facilitating CER projects. As a result of data analysis informed by the main question of this study, 647 teacher statements were coded into 39 practices addressing the Distribution, Procedure, Recognition, and Transformation dimensions. Also, the analyses of nine teachers' cases revealed the practices' dynamic display at teachers' implementations of CER projects.

Practices for addressing the **Distribution** dimension involved those directly addressing the issues of distribution and those ensuring the distribution of knowledge base and capacity in conducting CER. To address the issues of distribution, teacher practices focused on helping students understand and investigate environmental issues related to resource distribution (e.g., distributing material benefits to community members, discussing the criteria to distribute fundings for different CER projects) and distributive injustices through activities where students mapped environmental resources or simulated resource maldistribution. Practices for distributing capacity in CER focused on advancing students' environmental and climate science knowledge, concepts, and practices and developing knowledge of CER methods. This dual focus empowers students to both comprehend and take active roles in addressing distributive justice related to environmental issues as well as distributive justice in CER itself.

Practices for addressing the **Procedure** dimension involve engaging students in classroom voting and discussions on inclusivity, brainstorming research procedures with community stakeholders, and participating in decision-making scenarios where information is unevenly distributed. Teachers explained CER cases that highlight both community involvement and disparities in decision-making and facilitate student activities related to local environmental issues through participatory decision-making. Students were supported to design and circulate surveys to gather community votes, conduct mock research proposal reviews, engage in peer review of CER procedures, and participate in local decision-making processes.

Practices for addressing the **Recognition** dimension involve engaging students in raising awareness and respect for communal and cultural knowledge and expertise crucial for CER. Teachers had students reflect on their understanding of community and family knowledge regarding environmental issues, climate, and sustainability. They ex-

plained the criteria for evaluating the reliability of information and shared historical cases where community knowledge informed scientific research. They also supported students in researching and presenting historical examples of community knowledge influencing environmental policy and investigations, participating in peer-to-peer surveys, and interviewing community elders to document traditional environmental knowledge and insights.

Lastly, practices for addressing the **Transformation** dimension engaged students in identifying sites for change within their community and seeking to transform them through CER. Teachers had students reflect on their connections to nature and brainstorm ideas for an environmentally friendly school and neighborhood. Teachers introduced CER's purpose for transformative changes, shared case studies of communities that addressed environmental injustices, and supported students in investigating these cases. Students designed and circulated surveys probing community hopes for environmental change and developed proposals for transforming neglected areas and disadvantaged communities, both locally and globally.

These practices were further categorized according to four instructional strategies: Approach, Introduce, Practice, and Apply, each of which explains *how* teachers addressed the CER dimensions. The **Approach** strategy focuses on building awareness of each dimension without explicitly framing them as justice issues through activities like lesson-opening questions. The **Introduce** strategy involves direct, structured, and informative instruction from teachers to students to enhance their knowledge and understanding of CER. The **Practice** strategy focuses on facilitating students' classroom engagement in CER processes and knowledge-building activities. Finally, the **Apply** strategy supports students' participation in CER, either through community settings or by collaborating directly with community members. Together, these strategies provide a comprehensive framework for integrating CER into classroom instruction and community engagement. Table 2 displays the full list of identified practices organized by both the four CER dimensions and the instructional strategies.

Table 2. Practices for conducting CER projects in educational settings.

Dimensions	Instructional Strategies	Practices Identified from Data
Distribution	Approach	Elicit students' prior understanding of research that engages communities. Engage students in identifying community environmental resources. * Engage students in mapping environmental resources across different communities provided by teachers. *
	Introduce	Explain scientific concepts related to key environmental issues. Explain the concept or examples of resource distribution. Explain examples of distributive injustices. Explain examples of CER and community organizations. *
	Practice	Facilitate students in designing a hypothetical CER project addressing a specific scenario. Facilitate students' investigation of science knowledge related to broad environmental issues. Facilitate students in activities that simulate resource maldistribution, prompting students to develop solutions.
	Apply	Support students in evaluating resources and assessing their credibility and relevance. Support students in investigating and presenting environmental issues of resource maldistribution. Support students in investigating and presenting environmental resource disparities they have observed or experienced in their own communities. *

Table 2. *Cont.*

Dimensions	Instructional Strategies	Practices Identified from Data
Procedure	Approach	Engage students in classroom votes on relevant issues, followed by discussions on inclusivity in decision-making processes. Engage students in brainstorming an imaginary procedure for collaborative scientific research with community stakeholders on environmental issues. Engage students in decision-making scenarios where students have different information. *
	Introduce	Explain case studies of CER projects, highlighting community involvement in decision-making. Explain case studies of CER projects, highlighting not only community involvement in decision-making but also the disparity. Explain the influence of community organizations on environmental policy decisions. Explain procedures for gaining community stakeholders' consent to and approval of community-engaged research. *
	Practice	Facilitate activities that address local environmental issues through participatory decision-making. Facilitate students in designing surveys to gather community input on local environmental concerns. Facilitate students' mock research proposal review process. *
	Apply	Support students in circulating and analyzing the survey that gathered community input on local environmental concerns. Support students in peer review of their peers' CER project procedure. Support students in participating in actual local decision-making processes related to environmental issues.
Recognition	Approach	Engage students in brainstorming attributes of reliable knowledge and information. Engage students in reflecting on their understanding of community and family knowledge regarding environmental issues, climate, and sustainability. Engage students in brainstorming examples of community knowledge. *
	Introduce	Explain criteria for evaluating the reliability of online information on environmental and climate issues. Explain historical cases where community knowledge of local environmental issues informed scientific research.
	Practice	Facilitate student research and presentation of historical cases of community knowledge influencing environmental investigations and environmental policy discussion. Facilitate peer-to-peer surveys on environmental issues and peers' sustainable living practices based on lived experiences. Facilitate students in designing survey questions to probe community partners' environmental knowledge and experiences. Facilitate students' evaluation of environmental knowledge claims made by different stakeholders Facilitate students in exploring diverse cultural approaches to living with nature. *
	Apply	Support students in circulating and analyzing the survey that probes community partners' environmental knowledge and experiences. Support students in interviewing community elders to document traditional environmental knowledge, sustainable living practices, and insights on local environmental issues. Support student-led community conferences where research findings on local environmental knowledge and sustainable practices are presented and discussed. *

Table 2. *Cont.*

Dimensions	Instructional Strategies	Practices Identified from Data
Transformation	Approach	Engage students in reflecting on their personal connections to nature. Engage students in brainstorming the image of an environmentally friendly school they aspire to attend. Engage students in brainstorming the image of an environmentally friendly neighborhood they aspire to live in.
	Introduce	Introduce the purpose of CER for transformative changes. Introduce cases of communities that have successfully addressed environmental injustices.
	Practice	Facilitate students in discussing the purpose of CER for transformative changes. Facilitate students investigating cases of transformational change in communities. Facilitate students in designing survey questions that probe community members' hopes for environmental change.
	Apply	Support students in circulating and analyzing the survey that probes community members' hope for environmental change. Support students in developing proposals for transforming a neglected area of their community. Support students in identifying environmentally disadvantaged local/global communities and propose ways to transform these communities' environments, outlining necessary efforts to bring about change. Support students' planning and organizing a community conference where they present their research projects, highlighting transformative changes in the local environment. *

Asterisked practices represent additional practices suggested by teachers during discussions of the data analysis. These are practices that teachers believed could be useful but had not yet implemented in their teaching.

In addition to Table 1, which displays the full list of practice codes, Figure 2 summarizes the frequency with which teachers addressed each CER dimension in their practices. We used the number of statements coded as the practices addressing the respective dimensions as an interpretive measure of the weights teachers gave to support their students' CER (not necessarily how much time they spent on the practice during instruction). The "Distribution" dimension was the most frequently addressed, as indicated by a total of 260 statements coded to this dimension (approximately 40%), while the numbers of statements coded to the other three dimensions had relatively similar frequencies (Procedure: 131, Recognition: 130, and Transformation: 128 instances). Although these descriptive statistics from nine teachers are not generalizable, they offer insight into the teachers' shared perspectives on CER projects. The teachers agreed that their projects should build students' competence and confidence in conducting CER. To achieve this, they prioritized providing structured instruction, that is, the distribution of knowledge and skills necessary for conducting CER effectively.

This shared perspective among teachers may also explain the instructional strategy frequency that shows Practice strategies were highest (233 statements), followed by Introduce strategies as second highest (187 statements). All teachers exercised Introduce strategies to offer structured learning experiences of core concepts and skills they considered crucial for CER, and then they paid substantive attention to students' practical engagement in CER in ways available in classroom settings. The frequency data displayed in Figure 2 suggest that teachers prioritize students' practice-oriented learning of CER, with a strong emphasis on distributing essential knowledge and skills, which aligned with teachers' shared goal of building students' confidence and competence in CER, preparing them for real-world applications of and participation in CER beyond the classroom setting.

Figure 3 illustrates individual teachers' percentile frequency of statements coded to each of the four dimensions, organized in the order of teaching grade levels (ES: elementary school, MS: middle school, and HS: high school), revealing variations in emphasis among teachers. While three teachers (MS1, MS2, and HS1) addressed three out of four dimensions,

the other six teachers incorporated all four dimensions into their practices. This suggests that teachers, without an explicit introduction to the four dimensions, still managed to create meaningful CER engagement for their students while leaving room for refining their practices if given explicit guidance on the four dimensions. It is also noteworthy that students, in some teachers' cases (e.g., HS3's case illustrated below), took the initiative in addressing particular CER dimensions beyond what teachers had planned. Teachers were impressed by this as a meaningful learning outcome, demonstrating students' sense of authorship in their learning facilitated by CER experiences.

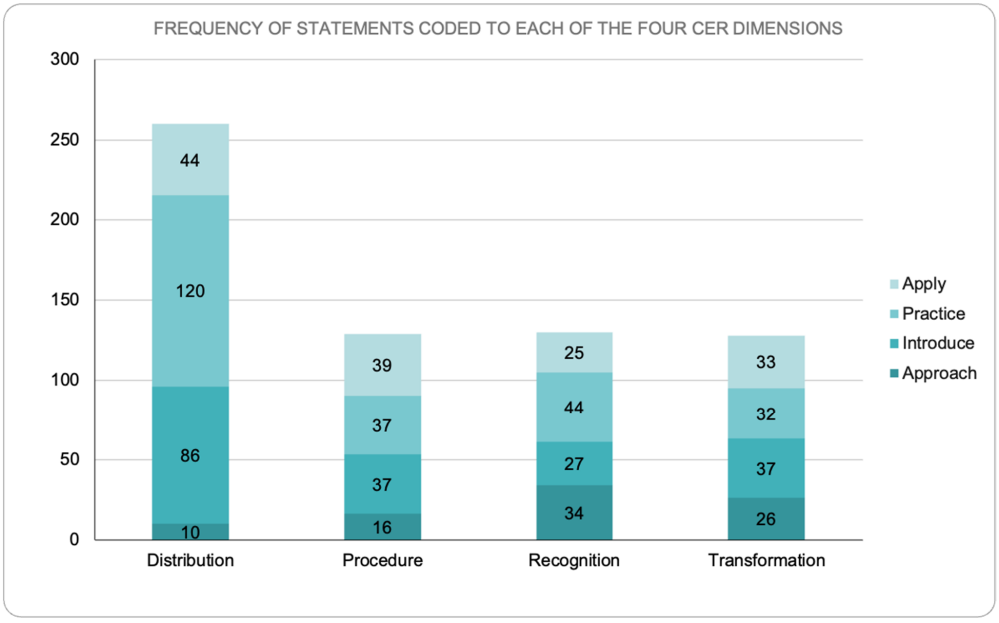


Figure 2. Frequency of statements coded to each of the four CER dimensions.

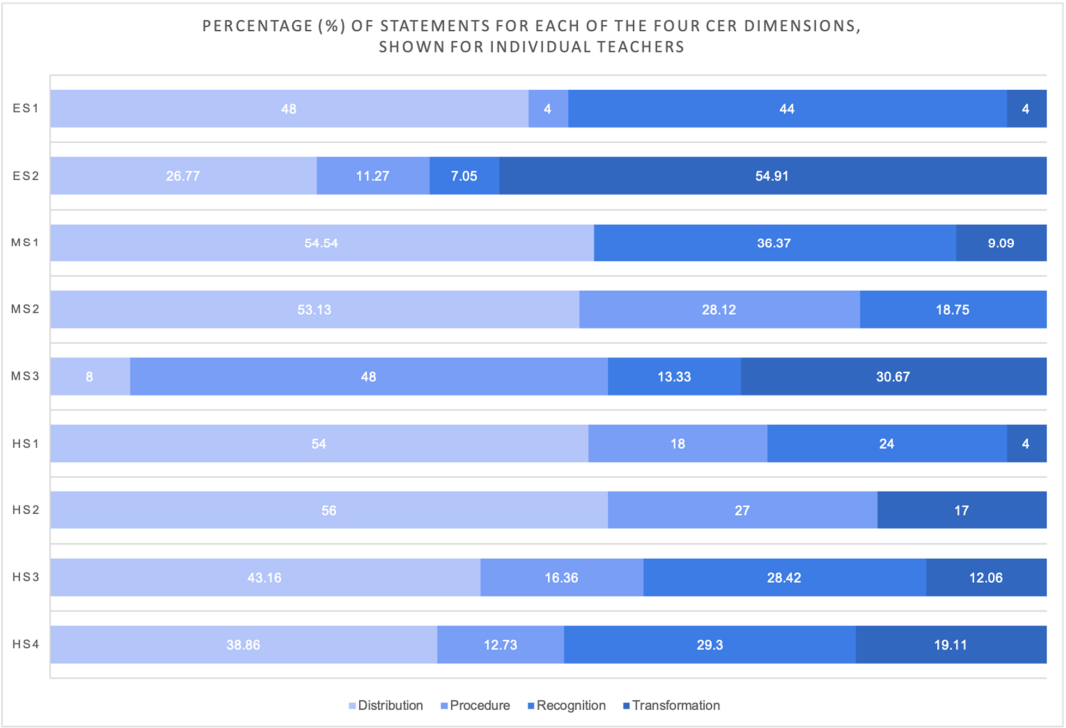


Figure 3. Percentage of statements for each of the four CER dimensions, shown for individual teachers.

In the following sections, I illustrate the nuances of teacher facilitation of CER projects using three teacher cases: ES2, MS3, and HS3. I selected these cases for their rich variety of teacher practices. These cases demonstrate how teachers can address the four CER dimensions using various instructional strategies while also emphasizing specific dimensions to create unique learning experiences. The variation in grade levels and class contexts (extracurricular settings for ES2 and MS3 and a chemistry course for HS3) further highlights the diversity of CER project implementation. Below, I present classroom practices according to the CER dimensions and instructional strategies they were coded to. CER dimensions are **in boldface**, while [instructional strategies] are indicated within square brackets.

3.1.1. ES2's Case: Transforming Our School into an Eco-Friendly Community Hub

ES2's CER project, "Transforming Our School into an Eco-Friendly Community Hub", involved 17 fifth and sixth graders in a 48 h afterschool program over four months. With 20 years of experience in community learning programs, ES2 viewed his school in an economically challenged but environmentally rich agricultural area as the ideal setting for CER. Inspired by the community's cultural heritage, elders with expertise in farming, and local environmental activists, he initiated a program for students to design a community center within the school. ES2 aimed to empower students to shape the hub's purpose and offerings, envisioning it as a site for environmental justice education serving both local and urban communities.

The program's early phase addressed Distribution and Recognition dimensions. For **Distribution**, ES2 focused on distributing or broadening students' understanding of science and CER methods. He began by asking students' perceptions of research and community [Approach], aiming to create a shared understanding. ES2 then provided direct instruction on environmental science concepts [Introduce], facilitated hands-on activities [Practice], and had students brainstorm educational programs for the community hub [Apply]. Simultaneously addressing **Recognition**, ES2 had students interview community elders about their environmental knowledge and advice [Apply].

Moving to the main phase of the community hub program/space design revealed ES2's practices focused on **Procedure** and then mainly Transformation dimensions. ES2 recruited five adults in the neighborhood (two farmer grandparents, two artists, and a leader of a nearby environmental organization) to join the community hub project. Forming the project members from different walks of life, ES2 sought to inform both students and community adults in the respectful decision-making processes, addressing CER's Procedure dimension. He showed them example processes of civic decision-making [Introduce] and had them role-play several decision-making situations [Practice].

ES2's practices then transitioned to primarily address the **Transformation** dimension over the remaining sessions, culminating in the grand opening of the community hub at the school. ES2 facilitated an initiative brainstorming session where groups of students and community adults proposed ideas for community hub learning programs and physical space designs [Practice]. He also instructed students on designing Likert-scale surveys for local community members both within and outside the school [Instruct]. The students then distributed, collected, and analyzed survey responses to confirm and revise program content and design components [Apply]. The students presented their proposals along with the survey results at a meeting involving school administrators, teachers, and district staff held to officialize the community hub as an educational center.

Finally, the community hub opening event was held, inviting residents from the neighborhood and nearby cities. ES2 proudly reflected on this final event:

> The way they articulated complex environmental concepts and engaged with visitors was remarkable. This project has really succeeded in transforming our school into a vibrant center for eco-friendly civic engagement. Seeing the students take ownership of the change and connect so meaningfully with community members... it's exactly what we hoped for when we started this project.

During the event, he witnessed his students' growth as confident environmental educators and community leaders. The event featured three booths introducing community programs, each run by students:

- Eco-friendly Lifestyle (providing education on gardening, composting, plastic-free consumption, and other participant-requested topics);
- Documentary Production (reporting on local and global environmental issues and injustices);
- Sustainable STEM (creating projects that produce useful items for the local community, such as portable solar lanterns).

Visitors were asked to complete and spread an enrollment survey indicating their preferred programs and availability. Based on the results, ES2's school was actively running all three programs at the time of the final data analysis. Additionally, the district education office provided funding for community members offering instructional services, showcasing how local governing bodies can support grassroots movements that promote environmental awareness.

3.1.2. MS3's Case—A Plate of Change: Veggie-Honoring Lunch Day Initiative

MS3's afterschool program, entitled A Plate of Change: Vegan Lunch Day Initiative' involved 11 7th and 8th graders over a span of four months, totaling 50 h across 20 sessions. Through this project, she sought to facilitate students' actual participation in science-related social matters. At the beginning of the program, MS3 had in mind the direction of the program and brought the initial idea that the program would center on climate change. However, she did not prescribe what students should do as actions for change because she considered "if the action is what I considered important, still students may not see it matter and thus actual participation might become a fake".

In the project's early phase, MS3's practices primarily addressed the Distribution and Transformation dimensions. For **Distribution**, MS3 first had students probe their own understanding of CER [Approach], then provided structured instruction on climate change fundamentals, covering topics like greenhouse gasses, carbon emissions, and climate change consequences [Introduction]. This led to group-based investigations exploring local and global climate problems and causes [Practice]. Notably, two out of three groups focused on the environmental impact of carnivorous diets, examining disparities in environmental burden caused by the meat industry's land use practices.

MS3 then addressed the **Transformation** dimension by guiding students to reflect on their connection to nature and potential environmental changes [Approach]. She asked questions like "When do you feel connected to nature?" and "What changes can you make to slow down climate change?" Students' responses ranged from ambitious policy ideas to skepticism about their ability to impact global warming. MS3 embraced both perspectives, reminding students of CER's purpose for transformative changes [Introduction]. She encouraged students to explore practical actions [Practice], bridging the gap between abstract hope and skepticism. Through online research, students discovered youth climate action groups and their specific multi-stakeholder campaigns. One popular idea that emerged was a "veggie-honoring lunch project", promoting plant-based meals and raising awareness about the dietary industry's impact on global warming.

MS3 then shifted focus to the **Recognition** dimension, encouraging students to view their own, friends', and family members' knowledge and experiences as sources of change [Approach]. She introduced CER examples related to climate change, demonstrating how it integrates community insights [Introduce]. Students designed surveys and interview protocols to gather community thoughts on potential dietary changes [Practice]. They surveyed school peers and interviewed parents and teachers, revealing the need to raise awareness about dietary habits' impact on climate and seek responsible adults' participation in determining feasible transformative changes [Apply]. MS3 noted how this process bridged generational wisdom with modern environmental challenges.

The remaining sessions focused on the **Procedure** dimension of CER. MS3 guided students in decision-making for the campaign and lunch event. She introduced a role-play activity where students took on different stakeholder roles, each presenting various arguments [Approach]. Then, MS3 explained the general decision-making process, norms for respectful communication, and the importance of selecting community partners [Introduce]. Student discussions followed to ensure inclusivity in the decision-making [Practice]. For example, one of her students raised concerns about students with dietary restrictions, sparking a broader discussion on equity and accessibility in environmental initiatives. Next, students took action [Apply]. They drafted letters to invite the school principal, the school culinary team, and parent representatives to a discussion meeting.

In the discussion meeting, students proposed the veggie-honoring lunch event by presenting not only scientific research but also results from their community survey and interviews. The discussion concluded with an agreement to pilot the proposed lunch event. While the school nutritionist and culinary team selected the menu (e.g., seasonal vegetables), MS3 and the students focused on raising awareness throughout the school. They created informative posters and gave informal presentations both in and out of class, explaining to their peers in simple terms the environmental impact of food choices and how individuals could contribute to slowing global warming. The teacher reflected on the very first pilot lunch day:

> Students from all grades curiously examined their trays, filled with colorful, plant-based options. I overheard Ji-ho, one of my most skeptical students, admit, "This actually tastes pretty good!" The success of this day was a testament to the power of student-led initiatives and the importance of making environmental action tangible and relatable.

Similar to MS3's observations on the event day, a satisfaction survey revealed that about 72% of students were satisfied, not just because of the lunch menu but also due to their increased awareness of the dietary impact on climate change. This positive response led the school to implement a vegetarian lunch day once a week. MS3 emphasized that this success was a collective effort, with the nutritionist playing a key role by offering vegan meals and snacks that appealed to students' tastes. However, MS3 and her students also noticed complaints about the food options and concerns from parents regarding their children's dislike of the change. MS3 highlighted the complexity of these differing perspectives and discussed how students could continue engaging with those opposed to the changes.

3.1.3. HS3's Case—Chemistry for Environmental Justice: Bridging Science and Action

HS3's 11th grade chemistry class involved 24 students over a span of 4 months, totaling 51 h across 34 sessions. During teacher community reflection meetings, she presented her CER project topic, Chemistry for Environmental Justice: Bridging Science and Community Action. Drawing from her past instructional experience in facilitating CER, HS3 aimed to prepare her students—soon-to-be adults—for real-world CER in various community settings. To achieve this, HS3 provided students with rich learning opportunities to develop knowledge, expertise, and competencies necessary for students in leading CER regarding critical environmental issues.

HS3 began the first session of the class by addressing the **Transformation** dimension of CER. She elicited students' vision for environmentally friendly schools and neighborhoods [Approach], pointing out actual examples of successful CER for positive environmental changes [Introduce]. Introducing the importance of CER as an approach to bringing a transformative change in environmental concerns critical to community members, HS3 proceeded with stressing the importance of promoting students' capacity as competent community researchers for CER.

The **Distribution** dimension was emphasized as it involves broadening community participants' knowledge and capacity necessary for CER. She asked about students' comparative understanding of research and community-engaged research [Approach]. She then offered a series of direct instructions to advance students' chemistry knowledge related

to environmental issues and critical evaluation of information presented with disparate credibility [Introduce]. She introduced the concepts, examples, and behaviors of organic polymers, radioactive molecules, isotopes, and greenhouse gasses while immediately connecting them to environmental justice issues such as global plastic pollution.

HS3 also addressed the **Distribution** dimension by facilitating students' group-based investigations on critical environmental issues relevant to the course [Practice] and resulting actions of sharing their investigation results with communities they care about [Apply]. Over the course of group investigations and actions, students engaged in the **Procedure** dimensions. Students made their own decisions of identifying topics of group investigations and dividing roles among group members [Practice]. They also determined which action projects they would conduct and which community members they would engage in through the projects [Apply]. Given the course's focus on chemistry, most groups examined the environmental impacts of petroleum-based plastics. They investigated the health risks associated with microplastics, greenwashing practices in the plastic product industry, and the complexities surrounding alternative plastics' utility. Students chose to engage various audiences, including school peers, family members, and social media connections.

To facilitate the student-led investigation, HS3 addressed the **Recognition** dimension. Students investigated historical and natural chemical practices that were environmentally friendly [Practice]. For instance, as alternatives to petroleum-based plastics, they researched the history of creating durable containers using bio-based materials. One group collected online resources for consumer guidelines identifying greenwashing in advertisements and corporate practices. In addition, HS3 explicitly emphasized the importance of evaluating the credibility of knowledge claims and information before using them as resources or evidence [Introduce]. She provided a comprehensive checklist for assessing online sources, which included factors such as author relevance, research base, potential conflicts of interest, and recency of information.

It is worth noting that HS3's instruction and materials for information credibility evaluation activities were shared during a teacher reflection meeting, which inspired three other high school teachers in the community to adopt HS3's approach in their own CER projects. This instance provides a snapshot of how teachers learned from each other and refined their instructions for CER projects through the formation of and learning from a teacher community. Furthermore, the ready adoption of HS3's instruction by these three high school teachers, aimed at advancing students' evaluative capacity, suggests a collective awareness among the educators about the disparate credibility of information available both online and offline, particularly concerning environmental issues. This awareness led them to identify the need to promote students' informed evaluation of credibility as an essential capacity for students' participation in CER as community researchers.

The final two sessions of the chemistry class showcased the rich results of students' group-based investigations and actions. Examples of students' action projects include the following:

- 'Reduce more than recycle' short video series addressing common misconceptions about recycling codes, the fact that less than 5% of plastics are recycled globally, and the impact of plastic pollution on low-income communities and environments worldwide.
- 'Don't be fooled by greenwashing' campaign with on- and offline posters showcasing examples of greenwashing and providing tips to identify such practices.
- 'Peel-out label from plastic bottle' campaign showcasing how to properly remove labels from plastic bottles to facilitate recycling.
- 'Plastic Baby' campaign warning about the risks of baby products containing harmful plastics, widely received by local mom online community visitors.
- 'Microplastics in cosmetics' public announcement targeting their fellow students at school who were keenly interested in cosmetics.
- Participating in the 'Ocean Clean Up' global movement and taking part in a cleanup of a nearby ocean.

Over the weeks these campaigns spread out, they gained significant traction within the school community and their social media networks. HS3 viewed that these diverse projects not only raised awareness on various aspects of plastic pollution but also empowered students to identify which specific issues they can and should work on so that the awareness and knowledge from the projects could prepare them for future engagement in CER. HS3 also reflected that the diversity and depth of students' projects far exceeded her expectations. She found herself learning from and inspired by students who demonstrated authentic interest and engagement in their projects, as they were thoroughly supported in producing actionable tasks.

3.2. RQ 2: What Opportunities and Challenges Did Teachers Identify from Conducting Their CER Projects?

Data analysis informed by this research question revealed three themes highlighting opportunities or positive impacts of CER projects and three themes describing challenges teachers encountered. Below, I briefly summarize the positive impacts and provide a detailed discussion of the challenges teachers reported, framing these challenges as key areas to consider for future research on CER in educational settings.

3.2.1. Positive Impact of CER Projects

As illustrated by the three cases, CER projects yielded positive learning outcomes for students and provided meaningful insights for teachers. Teacher reflections identified three key themes of positive impacts from CER: students' enhanced sense of empowerment in civic participation, development of competence in CER, and curricular utility. First, teachers largely perceived the positive impacts of CER in building students' sense of confidence and competence that they know and can do informed civic participation, showing their empathy and civic responsibility. One teacher made a particularly noteworthy point, highlighting that her CER project provided a space for students to transform environmental anxiety into active community engagement and knowledge creation, ultimately preparing them to be informed and engaged citizens capable of addressing complex environmental challenges in the future. Second, they noted that CER projects helped students develop essential skills (e.g., critical thinking, problem-solving, scientific literacy, and research methodologies) to help them readily engage in CER. The skills they considered also could benefit their successful civic and academic participation. The last apparent theme of positive impacts teachers mentioned was the flexible yet structured instructional approach allowed by conducting CER projects, which engaged students with local and communal environmental issues, creating interdisciplinary connections between science and social concerns.

3.2.2. Challenges Teachers Faced

While the cases described above and their positive impacts suggest that teachers' practices were streamlined, successful, and joyful, they were consistently accompanied by challenging instances and thoughts teachers encountered. These challenges arose not only from conducting CER (i.e., concerns around time, resources, and assessment) but also from addressing the skepticism of various stakeholders (i.e., skepticism on the academic benefits to students and actual impacts to the community).

One general concern across teachers was the potential constraints of time and resources. Consider ES2's reflection shared during our individual interview:

> Planning each session is inherently time-consuming. I wanted to give my students a rich experience—from hands-on environmental science to authentic research and community hub design. But, that's a basic thing and there was still a lot to manage behind the scenes, like recruiting volunteers and dealing with legal requirements like background checks and school permissions. I knew that's what I signed up for, driven by personal passion, not material rewards. Still, it's overwhelming when you're racing against the clock.

As ES2 points out, time behind the scenes for instructional planning is inherent, but he also had to devote additional time to facilitate CER projects in educational settings, particularly as he sought to involve community adults in the project aimed at bringing actual physical and social impacts by creating a community hub run and welcomed by students at their school. Even though not all teachers carried out projects like ES2's, CER can demand more time from teachers than traditional instruction because they were investing more than the work expected of them outlined by regular curricular schedules. Relevantly, teachers were concerned about the time excessively invested by students, which could concern their parents.

In the same vein, teachers mentioned the difficulty in securing the necessary resources, experiences, and materials (or funding to acquire them) to support CER initiatives effectively. While ES2 and MS3 were fortunate to secure funding for their afterschool programs, such financial support was not always available to all teachers. Particularly, funding was not readily accessible when CER projects took place in regular science classes, as exemplified by HS3, who conducted her CER in an 11th grade chemistry class, providing students with grants out of her pocket. Similarly, three teachers pointed out the scarcity of professional development opportunities to prepare educators for implementing CER with their students. Although the lack of professional learning opportunities prompted them to create their own community, they were concerned about whether the CER projects could inspire other teachers who might be interested but feel unconfident when they had little access to learning opportunities.

The assessment was another challenge raised mainly by middle and high school teachers who conducted their CER projects in regular in-curricular courses. Particularly, the requirement to adhere to a mandatory grading curve often limited teachers from fully recognizing students' participation and efforts in their CER projects. HS3, during her last presentation, shared her unresolved questions about how to assess her 11th chemistry class students. Pointing to the list of her student action projects (described above), she said the following:

> As you can see from this list, every student did their best. But how do you even grade that? Honestly, I don't think these kinds of projects should be graded in regular classes. 11th graders care about their grades. Even though I developed the performance-based rubric for the projects, I ended up giving everyone full points but relied on multiple-choice questions in chemistry. Students seemed more comfortable with that. My concern is that, because of the assessment system, projects like ours could become something students do superficially, just to get a grade.

The performance-based rubric HS3 applied entailed components such as participation, project impact, and reflection. She even opened the possibility of discussing the rubric components with students, but she felt the sentiment of discomfort and hesitance across students. Since the early session when she introduced the rubric, assessment had been her major concern despite her students' successful completion of action projects. Secondary teachers who attempted CER projects in regular classes faced similar challenges in developing and applying rubrics, often resorting to traditional multiple-choice questions.

Teachers also reported skepticism and concerns they faced from crucial stakeholders, ranging from the skepticism of CER's direct impact on the students' academic success, its potential to compromise the school's academic neutrality norm, and overwhelming emotional reactions from engaging in CER. Teachers said the following:

> HS3 (during the teacher reflection meeting): The principal told me a parent called, saying they get the good purpose but wondered if it actually helps their kid's grades.
>
> MS3 (during the teacher reflection meeting): We got this anonymous survey response from a parent worried our CER project might be politically biasing kids on environmental issues, even though we tried our best to present scientific facts.

> MS3 (during the individual interview): How I could better support students' emotional burdens was a challenge. Some got pretty worked up about the gloomy future outlook. They were like, 'Is changing our own habits even enough? Why aren't adults doing more when it's our future at stake?' And some students were embarrassed and hurt when their friends pushed back against the veggie lunch day. It's a lot for them to process.

These teacher comments collectively point to the complex dynamics of implementing CER in school settings. HS3's episode with a principal reflects a broader issue within the education system, where parents often prioritize measurable academic outcomes over experiential learning opportunities that CER provides. MS3 also mentioned another layer of concern around the potential politicization of environmental issues within CER projects. Although MS3 and her students had deliberately framed the project around scientifically grounded facts of human-caused global warming, which is widely accepted in the scientific community, the parent's reaction highlights the perception among some parents that environmental issues are politically charged. Furthermore, the emotional impact of CER on students presents a significant challenge. MS3, as illustrated in her case, aimed to transform the negative emotions students experienced when confronting climate realities by channeling them into action through CER. However, the more students learn, the more upset they could become. This emotional toll was often compounded by negative reactions from community members whom the students cared about and sought affirmation from.

These multilayered pushbacks suggest that conducting CER in school settings requires ongoing negotiation with the concerns and expectations of the broader school community. However, they also add to the burdens teachers already face, such as time and resource constraints and challenges in assessment. To sustain teachers' efforts in facilitating meaningful student engagement through CER projects, teachers need allies who can support their work, provide trust, and assist in overcoming these challenges, maximizing the opportunities they witnessed that CER offers for student learning.

4. Discussion

Our findings identified teacher practices addressing the four dimensions of CER (Distribution, Procedure, Recognition, and Transformation), and opportunities and challenges the teachers perceived from conducting CER projects. The findings demonstrate that the CER framework is effective in identifying four distinct dimensions of CER enacted through teachers' practices, indicating that teachers are capable of addressing all these dimensions. The CER framework, along with the detailed examples of practice (Table 2), is instrumental in guiding teachers' curriculum development and supporting future researchers in studying community-engaged approaches that foster students' engagement in CER.

This section discusses the findings in the order of research questions by focusing on their implications for future approaches to CER in educational settings.

4.1. Teacher Practices for Addressing the Four Dimensions of CER

The findings on teacher practices (regarding RQ 1) highlight three main points: the varying ways teachers addressed the dimensions, specific practices that emphasized these dimensions, and practices grouped as instructional strategies.

First, the findings revealed that even if the teachers were not fully familiar with the four dimensions of CER, they effectively addressed all or some of them. This finding suggests that teachers' CER practices can be enhanced by informing them of this study's findings on specific CER practices in addition to this study's CER framework. The frequency analysis of teacher practices across the four dimensions reveals interesting patterns that reflect the teachers' shared perspectives on CER projects. The Distribution dimension was the most frequently addressed, accounting for approximately 40% of all instances. This emphasis aligns with the teachers' shared goal of building students' competence and confidence in conducting CER. The prioritization of structured instruction in knowledge and skills necessary for

effective CER underscores the importance teachers place on equipping students with a solid foundation for engaging in environmental research and action.

In comparison, the practices of other dimensions differed in frequency according to the purpose, project types, and goals of respective CER projects. For example, in ES2's case for creating a community environmental hub at school, the Transformation was a consequential dimension that determined the ultimate goal of conducting a CER. ES2, once beginning the sessions by addressing the other three mentions, finally focused mainly on the Transformation that involved diverse community members in actualizing and specifying community members' visions and needs for changes. HS3, in contrast, began with addressing the Transformation dimension to set out the ground for why it matters to broaden students' knowledge and epistemic reasoning, as such, giving the utmost emphasis on the Distribution dimension throughout most sessions.

These findings of varying manifestations of teacher practices aligned with prior reports of justice-oriented science learning projects diverse in the process, purpose, and learning outcomes. As students involved community adults and stakeholders in addressing energy concerns (Birmingham et al. 2017), this study's teachers supported students in leading the community environmental education hub at their school (ES2) and the vegetable lunch event (MS3). Similar to Morales-Doyle (2017), in which a teacher covered social justice science issues in an AP chemistry course, HS3 designed the 11th grade chemistry class for students to investigate and present environmental issues, from which students' participation addressed the Recognition and Transformation.

Second, the specific teacher practices addressing the respective dimensions add to the literature by documenting the detailed instructional strategies that facilitate CER in educational contexts. To document the specificity, teacher practices were further grouped according to different instructional strategies coded as Approach, Introduce, Practice, and Apply. Teachers drew students' attention to CER with activities analogous to each of the four dimensions (Approach), offering direct instructions (Introduce), facilitating students' exercise or rehearsal of CER (Practice), and actually supporting students' engagement and leadership in CER projects (Apply). These four categories of instructional practices provide a comprehensive framework for integrating CER into classroom instruction and community engagement.

The frequency of statements that described teachers' Practice strategies was the most common followed by Introduce strategies. This reflects the teachers' focus on providing hands-on learning experiences. This approach allows students to hone their knowledge and skills in classroom settings, preparing them for real-world applications of CER beyond the classroom. The emphasis on practice-oriented learning, coupled with a strong foundation in essential knowledge and skills, aligns well with the goal of preparing students for active participation in addressing environmental issues in their communities.

In addition, teachers also need to consider ways to enhance opportunities for applying the learned and practiced knowledge and skills to actual CER projects where they would collaborate with community partners. This also can be the area of future investigation interested in a research–practice partnership that works with teachers and students so that researchers and community partners can use their networks and mobility to support teachers and students to apply their CER knowledge and skills to actual community contexts.

Lastly, the findings illustrate the varying ways teachers demonstrated in addressing the four dimensions of CER conceptualized in this article. The teachers' CER projects demonstrated rich exercise of all four dimensions while their main focused dimensions differed. Within schooling contexts, the CER projects were conducted in different curricular contexts ranging from regular science classes to elective courses and afterschool programs. While some projects involved students' affinity groups and families as community members, some projects reached out to local communities and took the initiative to create new partnerships with community adults in and out of their schools.

The focal cases of ES2, MS3, and HS3 illustrate how teachers can implement CER projects across different grade levels and educational contexts. These cases demonstrate the flexibility of the CER framework and its adaptability to various environmental issues

and community needs. These cases also highlighted the importance of student initiative and ownership in CER projects. In all three cases, students took active roles in shaping the direction and outcomes of their projects, from designing community surveys to creating awareness campaigns. This level of student engagement not only enhances learning outcomes but also fosters a sense of responsibility and empowerment in addressing environmental issues.

For example, while literature highlighted the distribution of resources, benefits, roles, and responsibilities (e.g., Birmingham and Calabrese Barton 2014), this study reported the distribution of disciplinary and CER-related knowledge and skills with students as the main pattern of addressing the Distribution dimension. In comparison, the Recognition dimension involved practices for validating community knowledge and wisdom as well as exercising critical acceptance of information available on and offline. In particular, as exemplified by HS3, the four high school teachers agreed that they emphasized students' epistemic agency in discerning credibility and carefully using information related to environmental issues that come with disparate degrees of credibility. Teachers facilitated the balanced exercise of epistemic agency (i.e., critically evaluating and generating knowledge and action plans to address environmental injustice issues) and epistemic dependence (i.e., respectfully using disciplinary, communal, and cultural knowledge). These findings add to the literature of CER by showing that teachers addressed the Distribution and Recognition dimensions by seeking to facilitate students' epistemic growth.

The variation in details of instructional strategies for teaching the four dimensions indicates that the successful implementation of CER does not have one-size-fits-all answers. Table 2 in the findings section displays the variety and specificity of classroom practices that can facilitate CER in educational settings. The listed examples can inform researchers and practitioners who may seek to scaffold CER participation for youths and young adults like the cases of this study's teachers. They could adopt and modify the practices to fit their own research contexts.

4.2. Reframing Challenges into Opportunities

The second set of findings report positive impacts and challenges mentioned by teachers. Teachers reported positive impacts of CER projects, including student empowerment in civic participation, skill development, and flexible instruction. These impacts were evident in students' leadership and project outcomes, such as launching environmental hubs (ES2), initiating vegetable lunch days (MS3), and leading community campaigns on environmental issues (HS3). These findings align with studies on justice-oriented science education's contribution to student empowerment (Dimick 2012) and critical consciousness (Upadhyay et al. 2020). In addition, I would like to note that the teacher community formed during this study facilitated these positive outcomes, especially given the scarcity of professional development opportunities.

Despite positive impacts, teachers faced significant challenges: time and resource constraints, assessment difficulties, emotional impacts, and stakeholder skepticism about CER projects' academic benefits and potential biases. These findings contribute to the literature on instructional approaches in support of consequential learning and youth empowerment in addressing real-world issues, expanding on previous findings that reported challenges about integrating real-world concerns with subject instruction (Kim 2024), teacher confidence (McGregor and Christie 2021), and managing students' emotional burdens (Lovren and Jablanovic 2023).

The challenges do not have clear-cut solutions; however, it is worth a discussion to envision future directions for moving forward. First, time and resource constraints suggest a need for more flexible, integrative educational approaches that transcend disciplinary boundaries. This may involve reconsidering traditional time management and fostering interdisciplinary approaches. Teacher collaborations could design integrated curricula with CER projects as unifying themes across subjects, maximizing instructional time while providing rich learning experiences. To facilitate the curricular integration across subjects,

teachers within the same school can form teacher-led communities of practice, similar to the teacher community created by this study's teachers across schools.

Second, the difficulties teachers faced in assessing CER projects within traditional grading systems highlight the need for innovative assessment practices that align with the goals of community-engaged learning. Ultimately, a profound discussion is needed about the definition, necessity, and forms of assessment in the context of CER as a learning project. For example, teachers viewed elective courses or afterschool programs as optimal settings for CER due to the significant challenges of assessing students' engagement in CER in regular assessment-bound courses. They also suggested competency-based assessment models, already applied to elective courses or afterschool programs, including portfolio assessments, peer and community evaluations, and self-reflection (Bingham et al. 2021; Evans et al. 2020).

Another challenge to navigate includes stakeholder skepticism and emotional distress students may experience. To address these challenges, teachers may consider strategies shifting the relationalities of those stakeholders. For example, they can invite school administrators and parents to the CER sessions with students where they would observe students' ongoing exercise of capacity as agentic community researchers. Regarding the emotional engagement of students in CER projects, teachers, as demonstrated by teacher MS3, need to embrace the emotional burdens and share them by introducing CER as one way to process and productively transform the emotional burdens. At the same time, teachers also need learning opportunities to share and process their emotional burdens, such as strategies for transforming negative emotions to gather behavior options (Pihkala 2020) and actionable message framing through storytelling for social changes (Wang et al. 2023).

As these discussions indicate, the efforts to tackle these challenges require both the individual- and community-scale shift in practices. And achieving such a transformative shift is another challenging task. By reframing these challenges as opportunities, we can share the vision for engaging and impactful learning environments that prepare students for complex civic participation. This approach can guide educators, administrators, and policymakers in creating educational experiences that address current pedagogical needs and equip students for active civic engagement in an increasingly complex world.

5. Conclusions

This study reported how teachers facilitated CER projects in their respective school contexts and the opportunities and challenges they encountered during implementation. The findings provide specific instructional approaches that teachers can use to address the Distribution, Procedure, Recognition, and Transformation dimensions of CER. The primary contribution of this study, as such, is to develop an empirically informed framework and instructional examples for designing and studying CER for environmental justice in K-12 education. These insights can serve as references for researchers, teachers, and community leaders seeking to conduct CER with youth and students in various educational settings. Furthermore, building on this study's findings on how teachers introduced students to the broad concept and practices of CER and helped them develop familiarity and confidence, future work can extend to more explicitly youth-authoring forms of community engagement, such as youth participatory action research.

Additionally, the challenges identified by the teachers revealed a range of tasks that are practical (e.g., enhancing resources), systemic (e.g., transforming assessment systems), and social-relational (e.g., tackling stakeholder skepticism and emotional burdens), all of which contribute to fostering learning projects that are relevant to students' lives, such as CER. In addition, the opportunities created by the teachers created a community where they learned from each other and shared their insights, questions, and suggestions. The community worked as a space for teacher learning, reflection, and collegial affirmation, and we highlight this bottom–up approach as one approach to support CER projects in educational settings, particularly when professional learning opportunities were not readily available to teachers.

Future research can build on these findings while also addressing the limitations of this study. This study's findings are based on nine teachers' reflections on their own CER cases conducted in one local area of Korea over six months. Future investigations should address these limitations by utilizing this study's findings as a foundation to more proactively exercise instructional practices for addressing each CER dimension and responding to the challenges identified from this study. They could expand the scope of data collection (from teacher perspectives to those of youth, community participants, and principals), the sites of observation (from a community of teachers to one or more actual CER sites in different regional contexts), and the duration of investigation (from six months to long-term follow-ups). New research could also focus on challenges mentioned by the teachers in this study, such as developing innovative and fair assessment systems or creating professional learning opportunities for teachers new to CER.

My hope is that this study serves as empirical evidence showing how CER can be practiced in school settings and inspires educators and researchers pursuing similar projects. The findings of this study can be a useful reference for evolving instructional approaches to better prepare students for the complex environmental challenges they will face in the future while also nurturing their capacity for community-engaged research aimed at environmental justice and driving transformative change.

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References

Bang, Megan, and Ananda Marin. 2015. Nature–culture constructs in science learning: Human/non-human agency and intentionality. *Journal of Research in Science Teaching* 52: 530–44. [CrossRef]

Bingham, Andrea J., Matthew Adams, and Randall Lee. Stewart. 2021. Competency-based education: Examining educators' experiences. *The Qualitative Report* 26: 674–95. [CrossRef]

Birmingham, Daniel, and Angela Calabrese Barton. 2014. Putting on a green carnival: Youth taking educated action on socioscientific issues. *Journal of Research in Science Teaching* 51: 286–314. [CrossRef]

Birmingham, Daniel, Angela Calabrese Barton, Autumn McDaniel, Jalah Jones, Camryn Turner, and Angel Rogers. 2017. "But the science we do here matters": Youth-authored cases of consequential learning. *Science Education* 101: 818–44. [CrossRef]

Braun, Virginia, and Victoria Clarke. 2022. Conceptual and design thinking for thematic analysis. *Qualitative Psychology* 9: 3. [CrossRef]

Calabrese Barton, Angela, and Edna Tan. 2020. Beyond equity as inclusion: A framework of "rightful presence" for guiding justice-oriented studies in teaching and learning. *Educational Researcher* 49: 433–40. [CrossRef]

Calabrese Barton, Angela, Day Greenberg, Won J. Kim, Sinead Brien, ReAnna Roby, Micaela Balzer, Carmen Turner, and Louise Archer. 2021. Disruptive moments as opportunities towards justice-oriented pedagogical practice in Informal Science Learning. *Science Education* 105: 1229–51. [CrossRef]

Cammarota, Julio, and Michelle Fine. 2010. *Revolutionizing Education: Youth Participatory Action Research in Motion*. Abingdon-on-Thames: Routledge.

Davies, Thom, and Alice Mah. 2020. *Toxic Truths: Environmental Justice and Citizen Science in a Post-Truth Age*. Manchester: Manchester University Press.

Dimick, Alexandra Schindel. 2012. Student empowerment in an environmental science classroom: Toward a framework for social justice science education. *Science Education* 96: 990–1012. [CrossRef]

Evans, Carla M., Erika Landl, and Jeri Thompson. 2020. Making sense of K-12 competency-based education: A systematic literature review of implementation and outcomes research from 2000 to 2019. *The Journal of Competency-Based Education* 5: e01228. [CrossRef]
Gwet, Kilem L. 2014. *Handbook of Inter-Rater Reliability: The Definitive Guide to Measuring the Extent of Agreement Among Raters*. Houston: Advanced Analytics, LLC.
Hanna-Attisha, M. 2019. *What the Eyes Don't See: A Story of Crisis, Resistance, and Hope in an American City*. Chino Valley: One World.
Kim, Won Jung. 2024. At first they felt barely relevant': Teacher reflective sensemaking of justice-oriented science teaching. *International Journal of Science Education*, 1–22. [CrossRef]
Littrell, Megan K., Anne U. Gold, Kristin LK Koskey, Toni A. May, Erin Leckey, and Christine Okochi. 2022. Transformative experience in an informal science learning program about climate change. *Journal of Research in Science Teaching* 59: 1010–34. [CrossRef]
Lovren, Violeta Orlovic, and Milica Marusic Jablanovic. 2023. Bridging the Gap: The Affective Dimension of Learning Outcomes in Environmental Primary and Secondary Education. *Sustainability* 15: 6370. [CrossRef]
McGregor, Callum, and Beth Christie. 2021. Towards climate justice education: Views from activists and educators in Scotland. *Environmental Education Research* 27: 652–68. [CrossRef]
Minkler, Meredith, Victoria Breckwich Vásquez, and Peggy Shepard. 2006. Promoting environmental health policy through community based participatory research: A case study from Harlem, New York. *Journal of Urban Health* 83: 101–10. [CrossRef] [PubMed]
Morales-Doyle, Daniel. 2017. Justice-centered science pedagogy: A catalyst for academic achievement and social transformation. *Science Education* 101: 1034–60. [CrossRef]
Morales-Doyle, Daniel, and Alejandra Frausto. 2021. Youth participatory science: A grassroots science curriculum framework. *Educational Action Research* 29: 60–78. [CrossRef]
Pihkala, Panu. 2020. Eco-Anxiety and Environmental Education. *Sustainability* 12: 10149. [CrossRef]
Raphael, Chad. 2019. *Engaged Scholarship for Environmental Justice: A Guide*. Santa Clara: Santa Clara University.
Raphael, Chad, and Martha Matsuoka. 2023. Aligning Community-Engaged Research Methods with Diverse Community Organizing Approaches. *Social Sciences* 12: 343. [CrossRef]
Raphael, Chad, and Martha Matsuoka. 2024. Community-Engaged Research. *Ground Truths*, 31–53.
Sanson, Ann V., and Susie EL Burke. 2020. Climate change and children: An issue of intergenerational justice. In *Children and Peace*. Cham: Springer, pp. 343–62.
Schenkel, Kathleen, and Angela Calabrese Barton. 2020. Critical science agency and power hierarchies: Restructuring power within groups to address injustice beyond them. *Science Education* 104: 500–29. [CrossRef]
Schlosberg, David. 2007. *Defining Environmental Justice: Theories, Movements, and Nature*. Oxford: Oxford University Press.
Sovacool, Benjamin K. 2021. Who are the victims of low-carbon transitions? Towards a political ecology of climate change mitigation. *Energy Research and Social Science* 73: 101916. [CrossRef]
Stapleton, Sarah Riggs. 2019. A case for climate justice education: American youth connecting to intragenerational climate injustice in Bangladesh. *Environmental Education Research* 25: 732–50. [CrossRef]
Tate, William. 2001. Science education as a civil right: Urban schools and opportunity-to-learn considerations. *Journal of Research in Science Teaching* 38: 1015–28. [CrossRef]
Thew, Harriet, Lucie Middlemiss, and Jouni Paavola. 2020. "Youth is not a political position": Exploring justice claims-making in the UN Climate Change Negotiations. *Global Environmental Change* 61: 102036. [CrossRef]
Tofel-Grehl, Colby. 2023. "There is no room for me, for a Hawaiian, in science": Rightful presence in community science. *Journal of Research in Science Teaching* 60: 1879–911. [CrossRef]
Trott, Carlie D., Stephanie Lam, Jessica Roncker, Emmanuel-Sathya Gray, R. Hayden Courtney, and Trevor L. Even. 2023. Justice in climate change education: A systematic review. *Environmental Education Research* 29: 1535–72. [CrossRef]
Upadhyay, Bhaskar, Erin Atwood, and Baliram Tharu. 2020. Actions for sociopolitical consciousness in a high school science class: A case study of ninth grade class with predominantly indigenous students. *Journal of Research in Science Teaching* 57: 1119–47. [CrossRef]
Wallerstein, Nina, John G. Oetzel, Shannon Sanchez-Youngman, Blake Boursaw, Elizabeth Dickson, Sarah Kastelic, Paul Koegel, Julie E. Lucero, Maya Magarati, Kasim Ortiz, and et al. 2020. Engage for equity: A long-term study of community-based participatory research and community-engaged research practices and outcomes. *Health Education and Behavior* 47: 380–90. [CrossRef]
Wang, Hua, Debra L. Safer, Maya Cosentino, Robin Cooper, Lise Van Susteren, Emily Coren, Grace Nosek, Renee Lertzman, and Sarah Sutton. 2023. Coping with eco-anxiety: An interdisciplinary perspective for collective learning and strategic communication. *The Journal of Climate Change and Health* 9: 100211. [CrossRef]
Wilson, Sacoby, Aaron Aber, Lindsey Wright, and Vivek Ravichandran. 2017. A review of community-engaged research approaches used to achieve environmental justice and eliminate disparities. In *The Routledge Handbook of Environmental Justice*. Abingdon-on-Thames: Routledge, pp. 283–96.

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