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Layered Landscapes: Critical Climate Cartography as a Pedagogical Framework to bring together Data, Experience, Science, and History

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Abstract

The climate crisis has been described as a “wicked problem” requiring attention not only to its scientific, but also to its social, historical, emotional, and geopolitical dimensions. This chapter introduces Critical Climate Cartography (CCC) as a pedagogical framework for exploring the climate crisis's multi-layered nature at the K-12 level. CCC combines geospatial mapping technologies, critical perspectives on social inequality, and students’ everyday experiences to reveal relationships between built, natural, and social environments. It highlights and helps make the complexity of climate investigations manageable by organizing how different social and scientific phenomena are linked together at specific geographic points, and differently layered across broader regions and scales. We provide vignettes focused on student, teacher, and professional learning community experiences respectively that demonstrate CCC's analytical power and challenges. The value of CCC lies in the transdisciplinary practices and tensions it fosters, which require further investigation through empirical research in classrooms and other educational contexts.

Layered Landscapes: Critical Climate Cartography as a Pedagogical Framework to bring together Data, Experience, Science, and History

The climate crisis is described as a “wicked problem” (Incropera, 2015), so multidimensional and nonlinear as to require the integration of multiple disciplinary approaches. This includes addressing its traditionally scientific dimensions, its social situatedness (making the problem “wicked social”; Grundmann, 2016), and the manifold legislative and institutional dimensions that further complicate its resolution (making it “super wicked”; Lazarus, 2009).

The multiple environmental catastrophes that comprise the climate crisis can also be understood as *layered*: overlapping, but manifesting differently across particular social, geographic, and geopolitical contexts and scales, with disproportionate impacts on Indigenous communities and low-income communities of color (Levy & Patz, 2015). As they interact, these catastrophes shape globalized impacts and specific localized effects, particularly for marginalized, frontline, or otherwise vulnerable groups. Faced with the layered social and physical catastrophes of climate change, the idea of climate justice stands as a counterpoint. As with many forms of social justice, working towards climate justice requires a recognition of the ways that colonialism, capitalism, and racism have driven (and still drive) deep inequities of our present and future. In addition, climate justice requires a nuanced and multidisciplinary understanding of humans as a part of the earth system as we collectively work towards a more just future. As Oakland-based youth activist Isha Clark explains, “Climate Justice is about completely reimagining the way that we live on the planet … It is about collective liberation and

dismantling systems of oppression in every way that they exist" (Climate Resilience Project, 2021).

While the ability to critically analyze the ways in which climate change is entangled with historical and ongoing systems of oppression is not the same as taking action for climate justice (Freire, 1970), we suggest that such critical analysis is a prerequisite skill to engaging in just action around our overlapping climate catastrophes. Exploring the layeredness of the climate crisis at the K–12 level requires an organizing pedagogical framework that situates students' personal experiences alongside these heterogeneous impacts and (multi)disciplinary analyses. In this chapter, we propose a *spatial approach* that allows students and teachers to assess and analyze the crisis's multiple layers. As science educators ourselves, we have developed this approach primarily in science education contexts. However, it could work meaningfully in other disciplines as well, and in supporting history, elementary, and other educators we have found this approach to hold.

In this chapter, we address two guiding questions across two sections. The first asks: how can K–12 teachers and students contextualize and connect the overlapping layers that shape the climate crisis? We offer *Critical Climate Cartography* (CCC) as an organizing, transdisciplinary pedagogical framework. CCC leverages mapping technologies, in conjunction with critical perspectives on social inequality, to highlight relationships between built, natural, and social environments that impact ongoing struggles for justice. CCC demands that teachers and students be explicit about what they perceive as important dimensions of the climate crisis as they manifest in specific locations, and to analyze these dimensions and their interactions. Our focus on

“layeredness” is meant to emphasize a central feature of map-based analyses, as well as a defining characteristic of this kind of transdisciplinary analysis.

The second question asks: what opportunities and challenges emerge for teachers and students as they explore a spatialized, layered approach to the climate crisis? We present three vignettes that focus on student experiences, classroom teacher experiences, and a teacher professional learning community, respectively. Our findings across each of these contexts suggest the analytical power of CCC and describe a range of challenges that come with this pedagogical form. The promise of CCC is fundamentally defined by the transdisciplinary practices and tensions it requires teachers and students to enact and confront: practices and tensions that themselves require further empirical research to be fully understood and supported.

Background

A layered approach to climate change education allows us to translate several disciplinary perspectives into cohesive sets of concrete classroom activities. These classroom practices may focus on creating and sharing critical artifacts (maps, stories), as well as building students’ skills as scientists, analysts, or community activists. Normative discussions regarding these practices are contentious. Despite broad international agreement about the necessity of teaching and learning about the climate crisis (IPCC, 2023, p. 74; UNESCO & UNFCCC, 2016), there is, as Reid writes (2019, p. 767), very little widespread agreement about nearly every practical dimension of what form(s) this education should take for K–12 students and for teachers.

California, where we live and work, adopted the Next Generation Science Standards which address important natural science aspects of the climate crisis, but

offer little guidance from a justice-focused perspective on the changing climate's human causes and impacts. But education for climate justice must also inform students' affective (Davis & Schaeffer, 2019) and critical (Mutegi, 2011) stances on their climate-related work. Geopolitical and socioscientific issues become more complex when we ask students to understand our planetary present and imagine a different future. A layered approach mirrors these layered realities, helping students approach, interrogate, and address transdisciplinary problems with nuance across knowledge domains.

Defining Critical Climate Cartography

Critical Climate Cartography uses maps and mapmaking to support students' thinking about the climate crisis across different disciplinary perspectives. We describe these domains as "layers," and CCC as a "layered" approach, because of the ways in which layers can be overlapped across geographic regions at different scales and with different boundaries. For example, global projections of temperature shifts may be overlaid with local maps of impermeable surfaces or hyperlocal personal stories related to (in)access to air conditioning. Bringing these layers together—lived experiences of climate impacts, for example, alongside social science data describing the distribution of impacts across a population—allows for reasoning about these domains' relationships to one another and to climate science.

CCC builds on three strands of existing research that hold unique affordances when enacted in combination. *Justice-centered science pedagogy* (Morales-Doyle, 2017; Mutegi, 2011) is a framework that "addresses inequity in science education as one component of oppression by challenging larger structures such as white

supremacy, neoliberal capitalism, and heteropatriarchy" (Morales-Doyle, 2017, p. 1035). This approach seeks to position students as transformative intellectuals and actors, and emphasizes the primariness of power and resistance in social and scientific phenomena. *Spatial justice pedagogies* highlight "how spatial environments are shaped by social forces and shape sociality and how those spatial environments inscribe and are inscribed by social inequalities" (Rubel et al., 2017, p. 644). This focus can help us better understand and analyze the embeddedness of power in the social and physical construction of particular geographic places.

The spatial lens further enables analyses that link *action-oriented investigations of climate phenomena* (see Monroe et al., 2019) with interrogations of the exploitative forces that shape them. Such pedagogies of climate action seek to create conditions for students to take action on any number of dimensions of the climate crisis, including its drivers or its impacts. While understanding alone is not sufficient for engaging in action, we argue that critical examination of the interacting social and scientific dimensions of climate change, and of its entailments in particular places, is a necessary prerequisite for considered action. Without such analysis, efforts toward addressing the problems of climate change may become generic or narrow (Fitzmaurice & Wilkerson, 2024). The complementary emphases of these three strands of existing research can support the multiple modes of meaning-making (e.g., Bang et al., 2017; Sengupta-Irving et al., 2021) that student-centered, transdisciplinary, climate-focused science education requires.

Our conceptualization of Critical Climate Cartography emerged over several years and projects, as we worked to humanize the crisis in ways that made it less

abstract and more integrative of social and scientific elements. We leveraged personal stories (Reigh et al., 2022; Sayavedra et al., 2025), offered tools to bridge global climate change with its local causes and manifestations (Lanouette et al., 2024), and rooted deeply in local events (Fitzmaurice & Barton, 2024). Maps sat at the center of these strategies as a tool to locate the human, and to organize thinking and instruction.

Centering Justice

In the informing literatures we cite above, “justice” is defined and operationalized in different ways—for instance, as an object of study, or as an outcome of student learning. This heterogeneity can be advantageous in classroom contexts. In writing about those contexts, however, we face a tension between the sense-making possibilities of a highly open-ended concept of justice, and the valuable specificity of a more narrowly defined version. We opt for the latter, partly because we feel it will help situate our work more precisely alongside the literature cited above and the other chapters in this handbook.

When we describe justice or justice-centered practices in this chapter, we’ll follow Fraser’s (1998) framing of justice as a triadic structure connecting practices of *participation*, *redistribution*, and *recognition*, which links more traditionally materialistic representations of justice with more recent “developments in justice theory” (Schlosberg, 2007, p. 4) that focus on people’s rights to the expression of their personal and collective capabilities (Sen, 2005). Fraser’s emphasis on *participation* is especially aligned with work that seeks to support climate action through a range of social practices. *Redistribution* represents a material focus for most existing mainstream environmental science and climate learning contexts, in terms of natural and social

support resources. *Recognition* highlights how the hierarchical "status order of society" (Fraser, 1998, p. 5) must be remade in the achievement of justice for individuals and communities. This triad guides our understanding of the kinds of justice CCC may support.

Our attention to interdisciplinarity and student experience in teaching and learning about climate change also speaks to *epistemic justice.* The layers of critical climate cartographies seek to make space for different ways of knowing, including different school subjects as well as students' own emotions and experiences (in contrast to privileging e.g., a scientific emphasis (Miller et al., 2018)). These ways of knowing may not align even if grounded in the same geography (Lopez et al., 2021). Rather than wholly rejecting or uncritically accepting any given way of knowing, this approach is meant to highlight how each way of knowing illuminates deeper power relations, addresses certain questions, and lends complementary insights into climate justice.

A Framework for Scaffolding Critical Climate Cartography

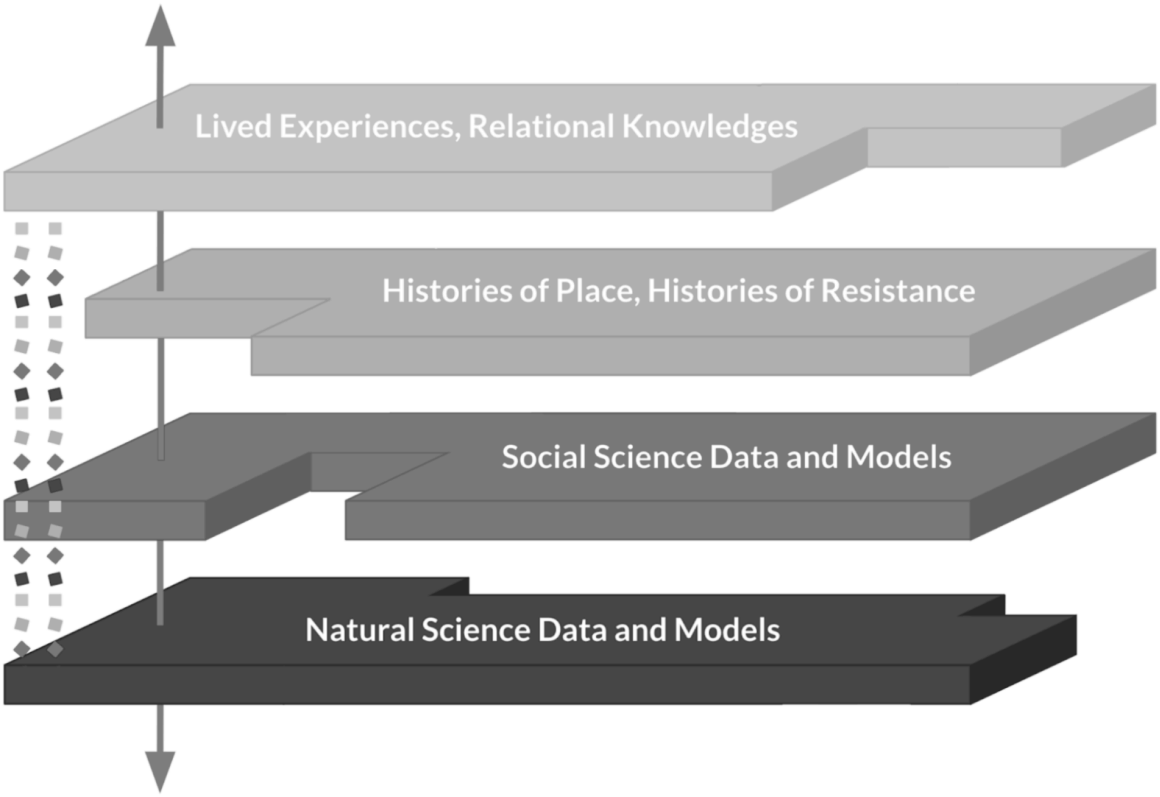
Figure 1 illustrates the layered approach at the core of CCC. The horizontal panels describe analytic and experiential layers that, in our experience as K–12 teachers and designers, can be combined to explore the climate crisis's complexities. These four layers are non-exclusive, and other domains are likely to emerge in other contexts. Their differently-overlapping shapes indicate how they manifest differently across lived realities. The vertical areas represent how these layers can be combined spatially. In a given analysis, we can geo-locate several forms of data and disciplinary perspectives to the same point or area. The blended shades at left illustrate how layers

combine in practice. Even though we distinguish between them in this representation, they may appear as integrated within a single set of classroom practices.

For us, the particular content of these layers is less important than the ways in which they can be brought together. The practice of layering asks students and teachers to engage transdisciplinary perspectives on the climate crisis. It further asks them to make analytic decisions about whether the nature and contributions of certain layers make sense in a given context, or for a given audience, and why. These considerations are reflected in the case study example we describe here, and the empirical vignettes that follow. Our goal in presenting a range of cases is to illustrate how, in a variety of contexts, layers are combined to yield particular qualities or characteristics of teaching and learning conducive to engaging the complexity of climate change.

Figure 1

A Layered Approach to Critical Climate Cartography



Case Study: Air Quality in West Oakland, California

In the historically marginalized area of West Oakland, California, life expectancy for residents at birth is up to seven years shorter than in the surrounding county (BAAQMD & WOEIP, 2019, p. 2–9). West Oakland is generally understood as the area surrounded by the loop of freeways highlighted in Figure 3. Here, maps help make visible key drivers and impacts of climate change and pollution; mapping also helps us hold several meaningful layers of data together, which allow for reasoning about the climate crisis across these domains as well as within them. In the context of a multi-lesson unit focused on air quality, particularly at the high school level, we envision several different disciplinary perspectives coming together as follows.

Figure 2

Tile A, Mapping Lived Experiences



Note. Shades of grey show the percentage of K–12 students living in each census block with asthma. Asthma data is overlaid by a “Three Stop Tour” of personal experiences, described in the text. (Data Sources: *Black Liberation Walking Tour*, n.d.; Radke, 2012)

Layer 1: Lived Experiences

Tile A (Figure 2), demonstrates the ways in which past and present experiences intersect, by overlaying contemporary student asthma rates by census tract in which students live[1] (school district data) with a three stop “tour” derived from lived experiences, local walking tours, and newspaper articles. Stop 1: Before the 980

[1] Oakland Unified School District is a choice district in which families have some opportunities to select schools other than neighborhood schools. However, the dataset illustrated in Figure 3 indicates asthma rates by students’ residence.

freeway “fenced in” West Oakland, kids from that neighborhood could ride their bikes straight to downtown (*Black Liberation Walking Tour*, n.d.). Stop 2: Part of the 880 Freeway collapsed in 1989 during the Loma Prieta earthquake. Rather than being rebuilt, significant community organizing and resistance helped turn the site into the Mandela Parkway, connecting parts of the neighborhood that had been previously severed (*Black Liberation Walking Tour*, n.d.). Stop 3: Community members including several teachers we work with have been working to oppose a proposed coal terminal. Asthma is experienced in all West Oakland classrooms. All three stops highlight civil and industrial projects that burden local communities with poor air quality and contribute to the mapped student asthma rates, and to our global community with climate altering greenhouse gas (GHG) emissions. Stop 1, in particular, illustrates the connection between students’ lived experiences with asthma and Freeway construction as student asthma rates diminish substantially directly on the other side of the Freeway.

Figure 3

Tile B, Histories of Place



Note. Home Owners' Loan Corporation Redlining Areas, with Interstate Freeways in . (Data Sources: Esri, 2022; Nelson & LaDale, 2023)

Layer 2: Histories of Place

Tile B (Figure 3) represents a perspective grounded in local histories of redlining (1930's) and freeway construction (1980's). Redlining was a practice through which the Home Owners Loan Corporation, a branch of the U. S. federal government, used a racially and ethnically based A–D grading systems to label the "risk level" (A = lowest risk, generally used to describe well off areas populated by whites who were not recent immigrants; D = highest risk, generally used to describe areas populated primarily by Black residents, but might be used to describe areas populated by other racial or ethnic

groups) associated with home loans in specific neighborhoods. In combination with racially-restrictive housing covenants, redlining was used to deny whole neighborhoods access to home loans and racially segregate America's cities (Rothstein, 2017).

These histories describe decades of racist, xenophobic selective-lending practices coupled with the outright destruction of predominantly Black homes, businesses, and cultural centers to build Interstate 980, which separates West Oakland from Downtown, along with Interstate 880 (see City of Oakland, n.d.). Alongside the Port of Oakland, which borders West Oakland to the south and west, this area of Oakland faces a disproportionate burden of particulate pollution from greenhouse gas-emitting mobile and stationary sources. The health effects of this pollution, further exacerbated by changes in climate and decades of disinvestment, are also disproportionately borne by marginalized residents of this area of the city, as demonstrated by the asthma rates in Tile A. Historically situating these lived realities helps contextualize West Oakland communities' ongoing struggles for justice, as well as how the health and climate burdens they face emerged over time.

Figure 4

Tile C, Social Science



Note. Circle shade represents estimated % of census tract residents identifying as Non-Hispanic African American or Black. Circle size represents % population living below 2x federal poverty level (Data Source: August et al., 2021).

Layer 3: Social Science

Tile C (Figure 4) offers two sets of social science data. The first, shown in the shading of the circles, indicates a 2019 estimate of the percentage of census tract residents identifying as non-Hispanic African American or Black. The size of the circles corresponds to the percentage of residents living below twice the federal poverty level.

Students might draw connections between these data and the layer above, as they examine how patterns of anti-Blackness, as represented by redlining policies, have shaped West Oakland's socio-economic demographics. They might also explore relationships between this layer and the natural science data that follows, elaborating how anti-blackness manifests in the concentration of major pollution and GHG sources in this area of the city. Centering lived experiences, they might explore how socioeconomic status and geography—as well as Blackness (Adebayo et al., 2022)—may limit community members' access to high-quality healthcare.

Figure 5

Tile D, Natural Science Data & Models



Note. Circles represent stationary sources of CO_2. Circle diameter corresponds to estimated CO_2 emitted per year in metric tons. (Data Source: Mangat et al., 2010)

Layer 4: Natural Science Data & Models

Tile D (Figure 5) applies an atmospheric science approach to this case, showing emissions from stationary "point" sources of CO_2 (Mangat et al., 2010). An atmospheric scientist (e.g., Turner et al., 2020) might seek to model total CO_2 emissions over the area by (a) adding source layers that use economic data to estimate vehicle and home

heating emissions, (b) using satellite observations to estimate CO_2 uptake by the biosphere, and (c) creating models of CO_2 concentration by using weather forecast models to blow around pollutants. A fuller exploration of the area from this perspective might pinpoint local sources of pollutants co-emitted with CO_2 (especially particulate matter implicated in health disparities), as well as mean daily and seasonal patterns of wind and other pertinent meteorology. With such data, students might explore how the co-emission of particulate matter, greenhouse gasses, and respiratory irritants produce interrelated health and climate effects.

Teaching and Researching CCC in Practice

We envision CCC as a pedagogical tool for *designing* climate pedagogy as locally-grounded and transdisciplinary, as well as for *guiding facilitators' attention* to how students and educators reason about the spatial dynamics of climate change across multiple scales and disciplines. In terms of design, CCC offers a concrete way to make explorations of the climate crisis tractable and human-scale. It can also serve as a planning and reflection tool for designers and educators to identify and hold themselves accountable to the multiple scientific, social, experiential, and other perspectives of the crisis with which they intend students to engage. In terms of attention, we see CCC as a way for facilitators and educators to make sense of and respond to multidimensional engagements. Here, we leverage CCC in this second way, as a pedagogical lens to explore two cases, derived from our own work, in which students and teachers respectively engaged in multidisciplinary reasoning about climate change and the environment. We also describe how we have begun to support teachers in CCC in the context of professional development.

Student and Teacher Learning

Fiona: "We can see it's all connected through this picture"

Our first vignette focuses on Fiona, a student in an after-school "Data Storytelling" workshop we offered to students in grades 7–9. Though the workshop was designed prior to our conceptualization of CCC, it emphasized interdisciplinary examinations of health and the environment as spatialized phenomena. The workshop was designed and offered for free in collaboration with a partner organization to recruit low-income youth enrolled in local public school systems. Final enrollment in the workshops was racially and socioeconomically diverse, but reflected more students from upper-middle income households who identified as white, South Asian, or Middle Eastern students than anticipated (see Reigh et al., 2022).

The workshop first introduced students to a brief history of West Oakland, similar to the one we describe above, including a presentation by a local activist who engaged in storytelling and data-based advocacy for reducing emissions in the West Oakland region. Students were then encouraged to find an issue related to environmental justice in their own communities. They interviewed family members, reviewed current local news stories, and discussed their own observations and concerns. We provided students with a Bay Area specific version of CalEnviroScreen 3.0 data (which includes dozens of environmental and health indicators; Faust et al., 2017) and census data at the ZIP code level[2]. We led mini-lessons and discussions about distinguishing causation from correlation, describing relationships, and otherwise exercising care with data.

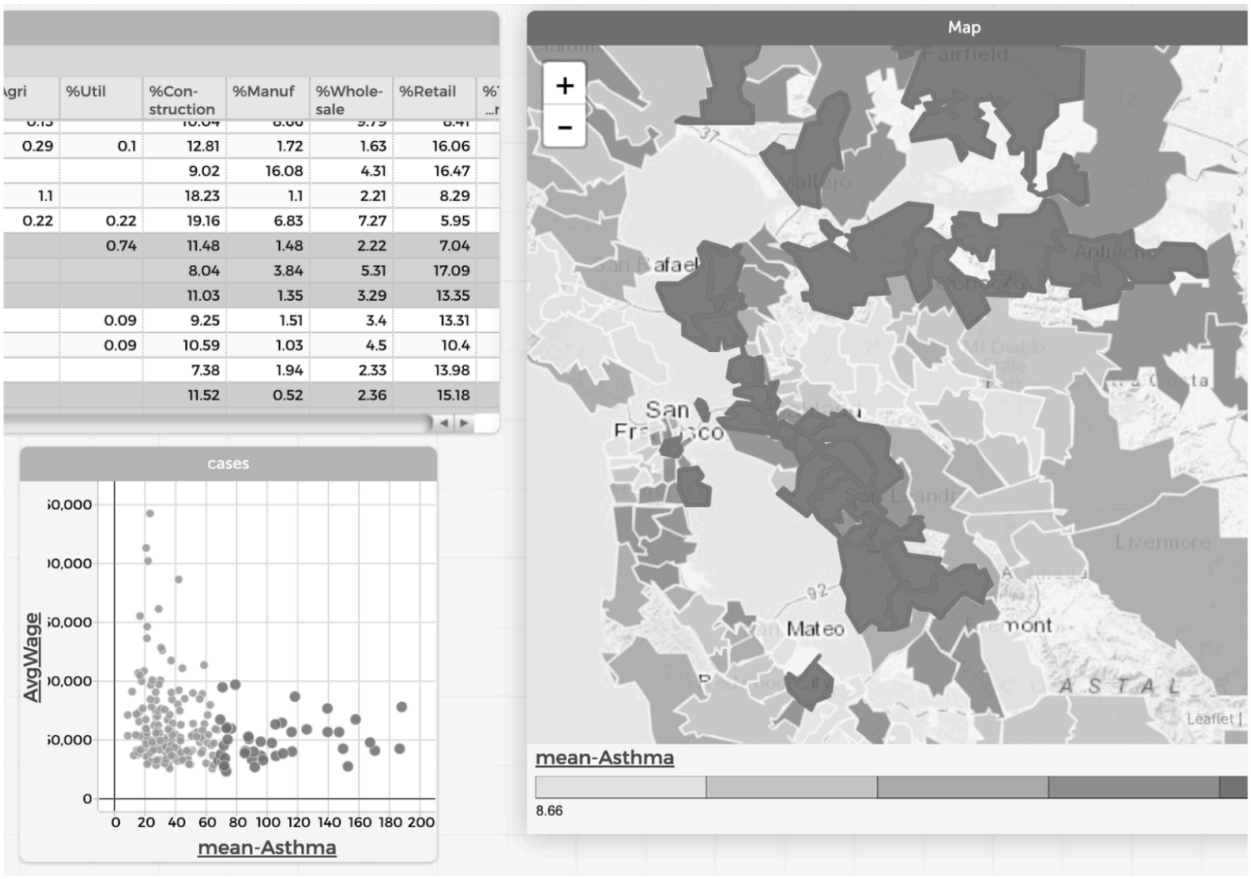
[2] Examples of other datasets we provided to students during these workshops included datasets from the U. S. Environmental Protection Agency, and Pew Research Center data about Civic Engagement.

Students used the Common Online Data Analysis Platform (Finzer & Damelin, 2015), a tool for novice data analysts that allows for simple creation of graphs and data maps.

Fiona described herself as a white public school student who had not experienced environmental racism, though she reported observing frequent racial inequities in land use and pollution exposure. To kick off her investigation, she interviewed her father, who had grown up in Europe, about environmental racism. He described having seen Roma people living near more industrial parts of town. He also shared that his own family moved to the countryside to avoid the health impacts from a nearby refinery. Fiona decided to further explore the relationship between refineries and asthma. She created a map examining the spatial distribution of asthma hospitalizations in the Bay Area (Figure 6). She also consulted Google Maps and news stories to learn more about local refineries, and generated maps of demographic and economic indicators across the region. These would eventually become distinct layers of analysis in Fiona's final project.

Figure 6

A subsection of Fiona's Day 4 CODAP document



Note: Left top: a section of the CalEnviroScreen data table. Left bottom: plot of asthma hospitalizations vs mean wage per ZIP code, with higher asthma hospitalization instances highlighted in darker grey. Right: map of mean asthma rates. ZIP codes highlighted in dark grey correspond to highlighted data in the table and scatterplot.

In her final presentation, Fiona began by referencing the City of Richmond, discussed on the first day of the workshop. Richmond hosts a large oil refinery visible from the Interstate freeway, and has been the site of explosions, fires, and periodic "flares" that pose significant respiratory risks to nearby residents:

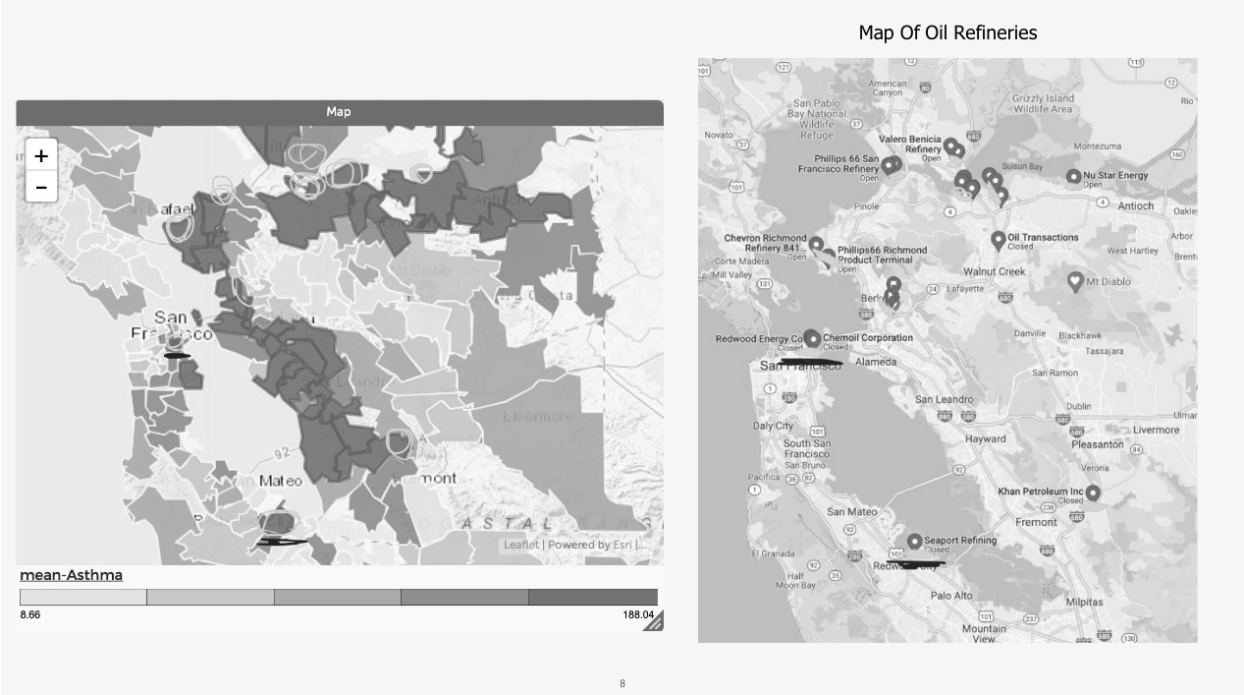
> “I can't remember who mentioned this, but one of you said that you had seen, like, an oil refinery here in Richmond. And yeah, like, I've seen that too, just like driving over the bay bridge and yeah and my parents have occasionally brought up the subject of oil refinery spill. Or leaking some chemicals into the air, but I never thought about the harm and consequences that refineries have until I started researching.”

Her presentation displayed a map indicating asthma hospitalization rates across the Bay that she constructed using CODAP and the CalEnviroScreen dataset. She described the spatial distribution of asthma as “kind of random,” without clear correspondence to geographic features of the Bay. She then juxtaposed that map with a screenshot of a Google Map of the same region, with the location of oil refineries clearly indicated. Fiona annotated both maps with matching black and green markings, to emphasize correspondences between what she perceived as “random” cases of high asthma hospitalization and co-located nearby refineries (Figure 7)[3].

Figure 7

Fiona’s Scientific Map Layers

[3] One of the locations indicated on the map of refineries, located near SF’s Embarcadero district, is in fact a corporate headquarters mislabeled as a refinery. The area also represents a busy port.



Note. Fiona highlights spatial correspondences between asthma hospitalization rates (left) and oil refineries (right).

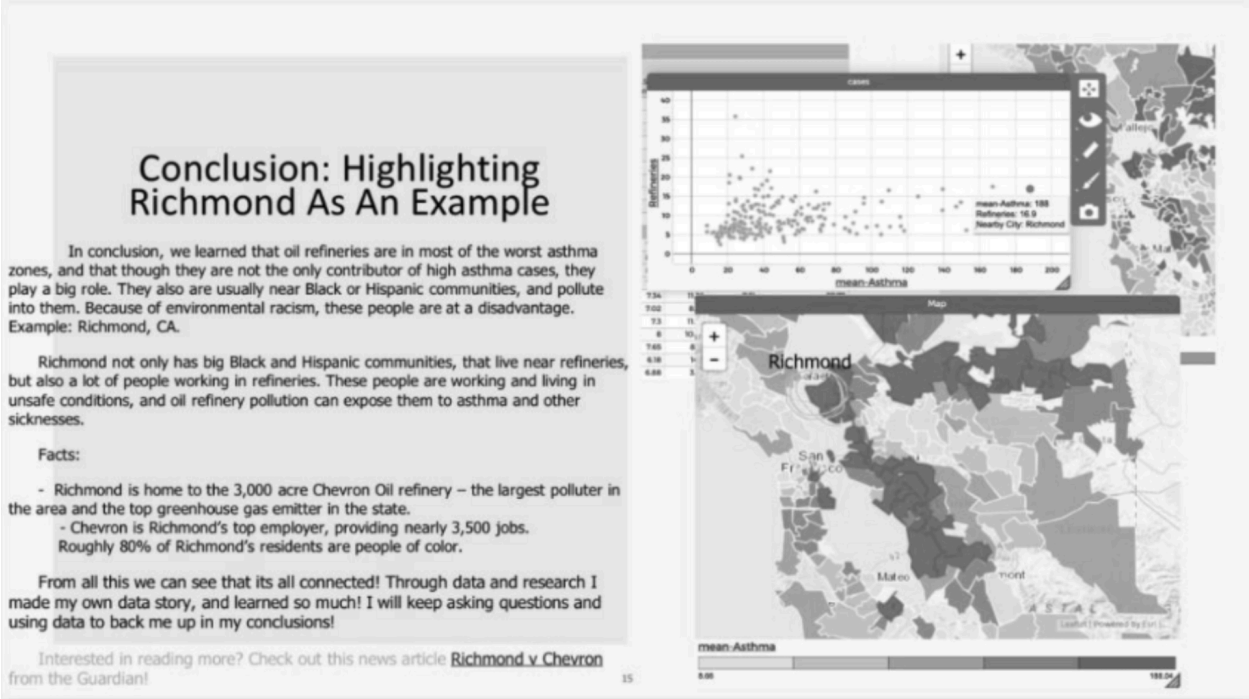
Fiona extended these correspondences to two more layers. She compared asthma hospitalization rates with demographics including the proportion of people in each ZIP code that are identified as Black or Hispanic in one map, and displayed the proportion of people who work in manufacturing (which she understood to include refinery jobs) in a second map. While displaying these maps, she continued:

> “Here I highlighted in green what I think stands out, those same two cities on the left side have people working in manufacturing. Some [in] refineries, or living near the refineries. And the ones on the right [side of the Bay] are mostly aligned with the asthma map, so people in the places with bad asthma are more or mostly black or Hispanic, we can see that everything is connected.”

To conclude, Fiona returned to the example of Richmond. This time, she displayed her full collection of maps featuring demographic, health, and employment information; some overlapping with others (Figure 8). On a new scatterplot, she arranged ZIP codes by mean asthma hospitalization rate on the x-axis and a new measure she constructed, indicating the proportion of the population in *any* employment sectors associated with the energy industry, on the y-axis. Richmond was highlighted in the plot to emphasize its especially high asthma rates. Fiona added key facts about the refinery's presence and impact in the region, including that it was the city's top employer and one of the top polluters in the state.

Figure 8

Fiona's Conclusion Slide



Though here we focused on Fiona's final presentation, throughout the workshop she moved back and forth in this way between general regional correspondences, and

specific points of interest (the cities of Richmond, Benicia, and Martinez). This allowed her to exercise care in how she described causality, while still engaging with the connectedness of the phenomenon across social, economic, and environmental layers.

Eleanor: Supporting Students' Cartographic Skill-Building

Eleanor, a second-year high school science teacher, was a participant in a year-long project on mapping and food justice in partnership with a local science museum. The students in Eleanor's class were all seniors, and demographically representative of the high school at which she taught (88% non-white, 73% qualifying for free or reduced-priced lunch). She held exceptionally deep knowledge of mapping based on undergraduate work with Geographic Information Systems (GIS). While this prior knowledge is not a prerequisite for CCC, it was clear throughout our visits to Eleanor's classroom that her skills with GIS software were an asset to her students.

Eleanor scaffolded her students' work with maps with three projects over the course of the year. These included a two-lesson *conceptual* sequence focused on evaluating the credibility of different forms of spatial data; a series of *analytic* activities where students created several maps to demonstrate different socioscientific issues, and; a multi-week *communicative* project where students developed StoryMaps to examine food items and their agricultural relationship to climate changes in California.

Late in the fall semester, Eleanor crafted a two-lesson sequence where students could evaluate bias in spatial and other forms of data. Lessons included sections on "Identifying & Defining Data," and "Communicating About Data & Looking at Historical Maps". First, student groups developed a four-part rubric for evaluating whether data

was “credible.” Then, they applied this rubric to a historical map of the city, asking: “What do [the rubric parts] tell you about the credibility of your map layer?”

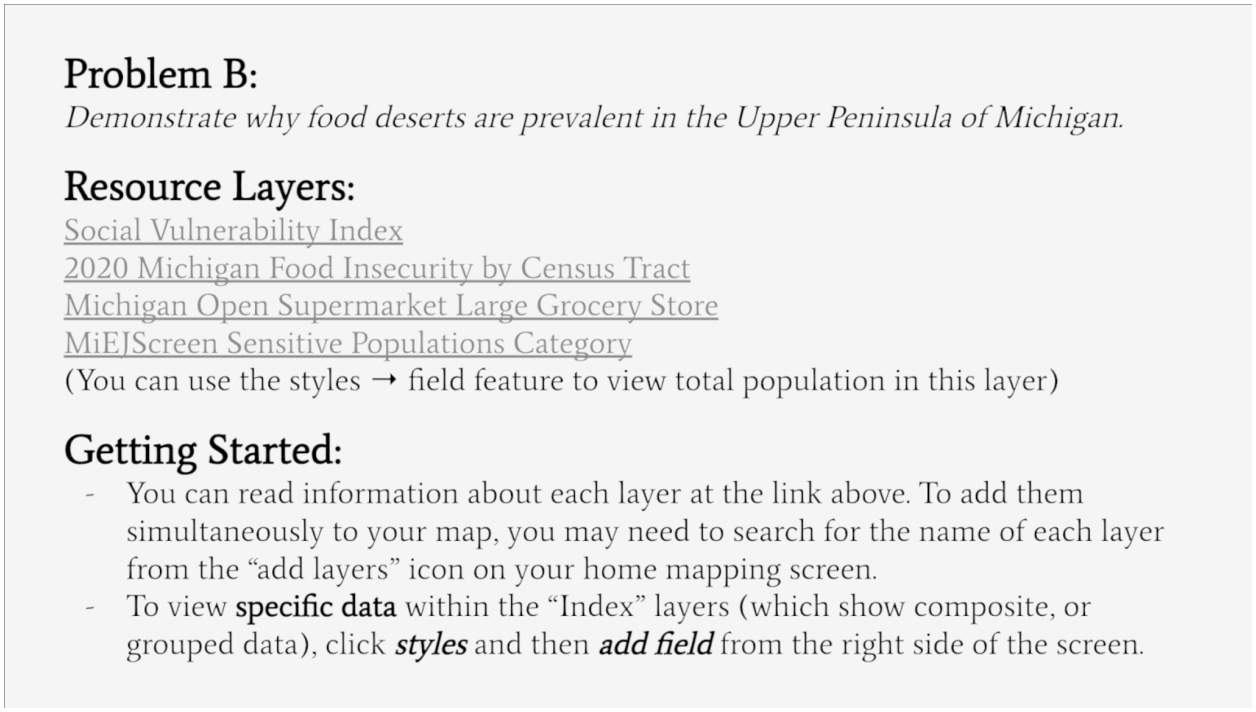
This emphasis on credibility implies that map layers *are themselves data*. It also suggests that a given data layer may tell an incomplete story, and that incorporating other perspectives (including personal critique) might be necessary. These emphases echo work highlighting data’s “truthiness” as one of its impactful social valences (e.g., Fiore-Gartland & Neff, 2015; Van Wart et al., 2020). For Eleanor, engaging students in evaluating the nature of data formed the basis for their work to come.

Next, Eleanor asked students to engage in “Telling a Story *With* Data,” through which they began to make maps that demonstrated different socioscientific phenomena. While not inherently climate-connected, these activities introduced students to the practices and purposes of layering spatial data as a form of analysis, as well as considerations around narrative that Eleanor built on with the StoryMap project in the spring. With the stated goal of “Practic[ing] telling a story with spatial data about social inequality to an audience,” students were given the guidance and resources shown in Figure 10.

Building around these data layers, Eleanor was interested in the language of “demonstrating” phenomena through mapping artifacts, in her curricular materials and her interpersonal engagement with students. Facilitating a discussion of students’ maps, for example, she asked one group: “Do you feel like this map really accurately demonstrates why [this phenomena is occurring]?”

Figure 10

In-Class Guidance and Resources from Eleanor to Students



Problem B:

Demonstrate why food deserts are prevalent in the Upper Peninsula of Michigan.

Resource Layers:

Social Vulnerability Index
2020 Michigan Food Insecurity by Census Tract
Michigan Open Supermarket Large Grocery Store
MiEJScreen Sensitive Populations Category
(You can use the styles → field feature to view total population in this layer)

Getting Started:

- You can read information about each layer at the link above. To add them simultaneously to your map, you may need to search for the name of each layer from the "add layers" icon on your home mapping screen.
- To view **specific data** within the "Index" layers (which show composite, or grouped data), click ***styles*** and then ***add field*** from the right side of the screen.

As students shifted to focus on their semester-end capstone papers, Eleanor centered "demonstration" even more. She designed a requirement for students to incorporate a map (as evidence) into the larger argument of their paper. The inclusion of these maps in students' year-long research projects helped emphasize their organizing power as an analytical tool across educational contexts.

The year of mapping culminated with students creating StoryMaps to illustrate the "story" of a familiar produce item, including emphases on: potential variations in the quality of the produce available in different areas of the city; reciprocal impacts between growing this food and climate change; and the human and labor impacts of growing and distributing this food, especially in the climate crisis. Here Eleanor placed particular emphasis on what one student described as "weaving" different sources of evidence and information together, offering prompts like: "How do multiple modes of information contribute to tell a compelling story?".

Eleanor's approach is exemplified by a multi-day jigsaw-style investigation of Vanilla that she created for students. She designed multimodal resources (including text, videos, audio, and maps) for four different groups, who explored Vanilla across Cultures, Vanilla Production, Vanilla & Climate Change, and Vanilla & its Human Impacts. At the end of the jigsaw, Eleanor asked students to reimagine more socially and environmentally sustainable modes of vanilla production. Maps offered the organizing principle and product for the exercise, but it was the layeredness of Eleanor's approach that demonstrated CCC. In this culminating activity and the multi-project buildup to it, Eleanor illustrated several important considerations for teachers' instructional design around maps and layering and associated analyses.

Teacher Professional Learning Community Experiences

Most of our experience working with teachers around maps comes from our engagement with a professional development program co-developed with members of the Oakland Education Association's Environmental Justice Caucus over the past five years. Although engagement with our program has varied from year to year, participating teachers are roughly racially representative of teachers across the Oakland Unified School District (21% African American, 13% Asian, 41% white, 21% Latino). 82% of students in the district are eligible for free or reduced-price lunch and 20% are African American, 10% Asian, 11% White, 48% Latino (OUSD, 2024). We stumbled into an emphasis on cartography by chance, when we found a grant call emphasizing local geographies that matched our ambitions to stipend teachers. However, maps quickly became a compelling medium through which teachers and students could learn, communicate, and even organize action around local issues of climate justice.

With the exception of teachers like Eleanor who have both cartographic knowledge and deep familiarity with web-based mapping tools, asking teachers to use CCC as a framework for engaging students with local climate change phenomena can feel like tall order. Most teacher participants come into our program with little to no experience using maps as teaching tools and have needed varied forms of support from program team members.

To support students' reasoning across data layers and their engagement with multiple dimensions of the climate crisis, it is helpful for teachers to have local knowledge, fluency with technical tools, and comfort drawing on multiple layers. These skills contribute to the creation of activities through which students integrate layers to construct narratives of local climate events, especially related to their many "wicked" dimensions.

Local Knowledge: Leaning on Partnerships and Learning from One Another

Although not academically enshrined the way that core subjects might be, we hold that teacher knowledge around local environmental justice is an important subject-matter expertise. Over time, teachers develop a complex and flexible repertoire of understanding ways that students may engage in the subject. Teachers' expertise in climate justice-related content varies according to the length of time they had lived in Oakland, involvement in local politics and activism, racial and other identities, and academic training. As a result, much of our workshop content has focused on engaging teachers in this content as adult learners, often with help from community partners. For example, the first mapping-related workshop our group hosted was in partnership with a local activist who had created a list of Oakland and Bay Area-specific maps of

environmental hazards. As a group, we explored the curated set and listened to the activist tell us stories about the maps. Over the years, we have engaged in local histories of place via workshops led by a local Indigenous group, high school and middle school student activists, city and school district officials, and fellow teachers. We also engage teachers in sharing their own personal knowledge through storytelling workshops, and in making sense of physical science data through workshops we have led ourselves and in partnership with scientists and data education experts.

Fluency with Web-based Map Tools

Our move into cartography coincided with the onset of zoom teaching during the pandemic, as teachers were called upon to imagine new ways of teaching students that relied heavily on technology to facilitate classroom interaction. To meet the times, we dove into learning how to use web-based mapping tools: to represent data we might add to a map, to layer our own data with data created by others, and to use these layered creations as a story-telling tool. We hosted tutorials of two web-based mapping tools and weekly office hours for teachers troubleshooting these new tools. Although we saw amazing web-based student projects, many teachers also found important affordances in the tactile nature of hand drawn and paper-based maps.

Subject Context

In our current regime of testing and standards, the pressure that teachers feel to adhere to district curriculum can present a challenge to engaging their students in CCC. One teacher interested in integrating multiple layers into her practice asked “[...] how do you meld like air quality with, like, redlining, in a way, where students don't think of two separate things?” described finding such integration much more difficult in her freshman

biology course than in her senior capstone course. She commented: “building curriculum around like a very scientific based thing like my biology class, just like I have less confidence in it. Because it's so content oriented and driven. And scientific, like NGSS skills, whatever. But I think I want a little help on like, how do you meld? …” We believe that approaches like CCC can help teachers engage in such “melding”.

Drawing on Multiple Layers

Finally, to engage students in CCC, teachers must generate activities that allow students to make sense of data from multiple layers. To model this type of activity, we have expanded our teacher workshop offerings beyond learning local context and engaging with mapping technology to activities that ask teachers to pair maps and data we provide to participate in critical tasks: This has included using personal knowledge, economic and racial demographic maps, and current locations of grocery stores to suggest the location of a new food co-op, or using historical documents to create a guided “tour” (as in Figure 2) linking histories of racism in the Bay Area (e.g., Redlining, Highway construction) to the white supremacist environment of the present.

Discussion

The cases we described here emerged from different learning environments. Each highlights different aspects of participation in those environments, from students’ map-making practices to teachers’ professional learning. Despite their differences, each case demonstrates the utility of maps as an organizing framework for supporting sensemaking around different aspects of the climate crisis, especially its local drivers and impacts (vignettes 1 and 3). At the same time, they illustrate certain challenges common to this work, particularly around different pedagogical considerations

necessary to support students' work with spatial data and maps (vignette 2). The complexity of the climate crisis, its place- and identity-based specificity, and the transdisciplinary approaches required to address it are such that no single case can represent a "model" approach or a fully representative set of challenges. Taken together, though, these cases suggest a set of practices that we believe can support a broader take-up of CCC, as well as considerations around some of its defining challenges.

First, each of these cases affirm the difficulty and importance of distinguishing the "environmental" from the "climate"-related. Our work challenges us to identify the threshold at which classroom inquiries engage climate change. For us, maps' ability to facilitate *students' thinking about and across scales* is a defining characteristic of what makes a given inquiry climate-focused. In particular, this multi-scalar quality of maps helps support students' reasoning about the multi-directionality of human, ecological, and climate impacts.

This starts with centering the local, a practice well-described in literatures of place-based (e.g., Gruenewald, 2003) and spatial justice education (e.g., Rubel et al., 2017; Van Wart et al., 2020). Inquiries emerge as climate-focused as teachers and students begin to think across scales, using maps as analytical lenses: when they engage oil refineries across contexts (vignette 1); when they explore relationships between food production, food consumption, and climate change (vignette 2); and when they think with local knowledges about global injustices (vignette 3). Given that a central goal and central challenge of critical climate change education asks us to focus on both "micro"/local and "macro"/global-level phenomena (Kagawa & Selby, 2010; Reid, 2019;

Stevenson et al., 2017), maps and mapping can help us think across scales with a relational lens. As vignette 3 illustrates, leveraging mapping is not trivial and requires significant scaffolding. However, we argue that the benefits of cartography lay an important foundation for what is necessarily complex engagement with a complex subject matter.

Second, these practices of zooming across scales highlight the challenge of developing teachers' and students' facility with mapping tools across the curricular trajectory. Even as maps may help facilitate students' transdisciplinary reasoning, learning to leverage maps themselves is non-linear. Because the majority of existing literature on spatial justice approaches to classroom teaching has focused on students' experiences, rather than teachers' (e.g., Rubel et al., 2016, 2017), we know less than we should about how teachers may seek to situate mapping experiences in the context of a yearlong curriculum sequence. Each of our vignettes suggest different ways in which this is possible at the level of individual learning environments and teachers' professional learning.

Third, we find that teachers and designers may encounter difficulty in aligning their mapping work with disciplinary standards that neither respect nor reflect the transdisciplinary nature of teachers' goals. The lack of standardized curricula (or even standards themselves) that incorporate the naturally scientific alongside the socially scientific, the historically-engaged, and the personally-experienced means that teachers who seek to develop CCC in their classrooms will likely be building their work as they go.

Teachers will be better positioned to succeed and continue such work to the extent that we can provide them with meaningful and relevant support. This includes broad reorganization in how we prepare teachers to address the climate crisis from a range of disciplinary perspectives. It also includes addressing disciplinary standards themselves, which often disaggregate the interwoven social and scientific causes and effects of climate change to be studied in different courses, through different constructs, if at all.

Conclusion

CCC is a transdisciplinary framework that asks teachers and students to engage each of its three main components simultaneously. Maps and mapmaking can bring layers of wide-ranging data together in a single analysis, highlighting the transdisciplinary and multi-scalar nature of the climate crisis. Holding climate science alongside other forms of disciplinary inquiry can support the kinds of nuanced reasoning about the climate crisis necessary in the fight against it. As we seek to build practices with teachers and students that inform climate-just action, CCC can play a meaningful role in advancing a just and sustainable future across a wide range of teaching and learning contexts.

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