

Toward Climate Dataviz Literacy: An Initial Educational Agenda for the vis4climate Community

Cassia Fernandez

Inspir, Brazil

ABSTRACT

Climate change is one of the biggest challenges of our time. Yet climate datasets remain underused in data visualization education despite their pedagogical potential. In this paper, we argue that climate data offers a uniquely rich context for developing visualization literacy by combining technical, epistemic, communicative, and critical dimensions of visualization practice. We synthesize evidence for the educational value of climate datasets, examine the opportunities and tensions of integrating them into data visualization courses, and identify gaps in teaching resources, research, and community infrastructure. We conclude by proposing an initial agenda for the vis4climate community centered on shared datasets, remixable teaching materials, empirical research, and cross-disciplinary collaboration. We hope this reflection serves as a starting point for a broader conversation about positioning climate data as a pedagogical resource in data visualization education while recognizing its unique characteristics and challenges.

Index terms: Data visualization, data literacy, climate change.

1. INTRODUCTION

In many data visualization courses, whether in computer science, design, statistics, or other related fields, the domain of the datasets used in projects and exercises is often incidental. Where the pedagogical focus is on visualization techniques and ways of reasoning with data, datasets tend to be selected for their convenience more often than for their societal relevance. We argue that this dataset-agnostic premise is an opportunity at a moment when climate change is one of the most data-rich and consequential challenges of our time.

Given the urgency of engaging students more deliberately with climate change issues throughout their educational journey, we call on the visualization community to invest in a more intentional and coordinated effort to develop educational resources that bridge data visualization and climate education. Such efforts would allow data visualization courses to become one of the spaces where climate literacy is cultivated while simultaneously supporting the development of visualization literacy.

In this reflection paper, we discuss the motivations for this integration, examine the opportunities and tensions that may emerge, and outline an initial research agenda for what we call *climate data visualization literacy*.

2. RELATED WORK

A growing body of work across science education, data science, statistics, digital humanities, and data visualization suggests that climate datasets are valuable pedagogical media for supporting a wide range of learning outcomes. These efforts range from K–12 activities where middle school students explore large-scale data sets and author their own data stories [14] to university courses built around the statistical analysis of climate datasets with R [10], and approaches that encourage students to critically examine how climate visualizations are constructed and communicated [11]. Beyond formal education, visualization has also been used to cultivate climate engagement in public settings, including museum exhibits and multi-institutional outreach programs [7].

Students who work with authentic climate data can develop statistical reasoning around trends and uncertainty [10], sophisticated computational data practices [18], critical interpretation skills [11], as well as scientific reasoning and conceptual understanding of climate systems [3]. Together, this body of work demonstrates that climate data can simultaneously support domain learning, critical thinking, and visualization practices.

At the same time, both the climate education and data visualization education communities have identified a common need for more systematic educational infrastructure. Within visualization education specifically, recent work highlights the lack of shared teaching materials, the importance of authentic datasets, and the need for empirical research on how visualization is taught [2,6]. While climate education has demonstrated the pedagogical value of climate datasets, and visualization education has articulated the need for reusable educational resources, little work has connected these two agendas into a coherent framework for teaching data visualization through climate data or, put in other terms, to cultivate students' *climate data visualization literacies*.

Reading and producing climate visualizations requires what might be called a compound competency distinct from either visualization literacy or climate literacy alone. Visualization literacy is commonly defined as the ability to translate questions in the data domain into visual queries and to interpret visual patterns back into data [4,5,9]. Climate literacy, in turn, includes the capacity to understand the essential principles of the climate system, to assess the credibility of climate information, and to make informed decisions about actions that affect the climate [21], a construct that has been reviewed and modeled across the science education and science communication literatures [1]. However, to the best of our knowledge, this compound competency has not yet been formally defined, operationalized, or studied as a unified construct.

We use climate data visualization literacy to refer to the capacity to read, critique, and produce visual representations of climate data in ways that are technically sound, scientifically faithful, and attentive to the stakes of what is being represented. It draws on visualization literacy for the construction and interpretation of visual encodings, and on climate literacy for an

* cassiaofl@insper.edu.br

understanding of what the underlying data represents and how it came to exist, but it is reducible to neither. At least four dimensions appear to be involved. The *technical* dimension includes constructing and interpreting encodings suited to the forms climate data takes (such as long time series, geospatial data, and model ensembles), which presupposes familiarity with the variables climate science works with. The *epistemic* dimension involves reasoning about how the data was produced and about the uncertainty, baselines, scales, and aggregations that determine what a given representation can legitimately support. The *communicative* dimension includes designing representations for audiences who hold different relationships to the same evidence, from scientists to policymakers to the general public. The *critical* dimension involves recognizing that framing choices carry rhetorical and political weight, and being able to treat such representations as evidence in public reasoning. We offer this as a working definition: specifying, operationalizing, and empirically studying it is part of the agenda proposed below.

3. THE EDUCATIONAL AFFORDANCES OF CLIMATE DATA

The datasets chosen for data visualization tasks shape how students engage with the learning process. Working with data that is personally or socially meaningful has been associated with stronger perceptions of relevance, higher motivation, and greater investment in interpretation than working with generic or synthetic datasets [14, 20], and has long been a premise of approaches that treat data literacy as a situated and creative practice rather than a purely technical one [6]. Likewise, authentic data has been shown to push students beyond the mechanical production of charts toward questions about the data's provenance, limitations, and implications [12, 18]. Dataset choice also influences the kinds of visualization challenges students encounter. For example, simple datasets with only a few variables may be sufficient for introducing basic visual encodings, whereas richer datasets support more advanced learning goals, such as making design decisions for different audiences and communicating uncertainty.

Climate datasets are particularly well suited to support common goals around data visualization literacies since they embody many of the core concepts that data visualization education seeks to develop. First, the diversity of datasets associated with climate topics can support different learning objectives across a data visualization curriculum. Instructors can draw on time series, geospatial data, satellite imagery, climate model outputs, emissions inventories, biodiversity records, and policy datasets, each lending itself to different visualization concepts and pedagogical goals. Some datasets are well suited for introducing basic chart types and visual encodings, while others may support topics such as temporal analysis, geospatial visualization, multivariate representations, uncertainty, or storytelling with data. Likewise, climate data spans multiple temporal and spatial scales, allowing instructors to revisit the same domain as students develop increasingly sophisticated visualization skills throughout a course or curriculum.

Second, climate data naturally foregrounds many of the representational challenges that visualization educators seek to teach. These datasets frequently involve uncertainty, incomplete observations, model projections, derived variables such as anomalies, and complex temporal trends.

Third, climate data connects visualization to diverse audiences and authentic communication contexts. Climate information is relevant to scientists, policymakers, journalists, educators, local communities, and the broader public. Designing visualizations for these different audiences makes questions of accessibility, storytelling, annotation, and audience-centered design concrete.

4. THE MISSING INFRASTRUCTURE FOR CLIMATE DATAVIZ EDUCATION

Despite this potential, efforts to integrate climate-related topics into data visualization education remain fragmented and incipient. Existing work is distributed across fields such as science education, statistics, digital humanities, and climate communication, each with its own technical vocabulary, pedagogical traditions, and publication venues. As a result, much of this knowledge remains largely invisible to educators teaching data visualization across formal educational settings. The absence of a shared infrastructure that translates these efforts into reusable resources and empirical knowledge for the data visualization community is therefore a challenge that needs to be addressed. We identify three areas where the vis4climate community is particularly well positioned to address it.

Pedagogically curated datasets and teaching materials.

Although many studies successfully integrate climate datasets into educational activities, these resources are typically developed on an ad hoc basis for individual courses or research projects. Instructors who wish to incorporate climate data into their courses must still assemble datasets, design assignments, and develop supporting materials largely from scratch.

Precedents for community curation exist outside our field. The Climate Literacy and Energy Awareness Network (CLEAN), for instance, maintains a peer-reviewed collection of climate and energy education resources, sustained by a distributed community of contributors [15]. Its focus, however, is on climate and energy content more broadly, rather than on data visualization as a learning goal in itself.

We see an opportunity for a community-maintained open collection of curricular units, activities and datasets specifically curated for data visualization education around climate change. Beyond simply providing data, such a repository could annotate datasets with provenance, domain context, learning objectives, visualization tasks at different levels of expertise, and accompanying teaching materials such as assignments, rubrics, discussion prompts, and examples of student work. Such an infrastructure would lower barriers for instructors and foster transferable educational practices across the community.

Research on climate data visualization literacy. Existing scholarship has advanced visualization literacy and climate literacy as largely separate constructs, but little work has examined their intersection. Beyond creating teaching materials, the community has an opportunity to establish climate data visualization literacy as a distinct area of research. This includes investigating learning progressions, pedagogical strategies, assessment methods, and the role of visualizations in supporting critical engagement with climate data. Defining and operationalizing climate data visualization literacy therefore represents an important research agenda for the community.

Sustained partnerships across communities. Climate data visualization education cannot be advanced by the visualization community alone. Effective educational resources require ongoing dialogue between visualization researchers, climate scientists, educators, designers, and communicators, each contributing complementary forms of expertise. We envision long-term partnerships in which teaching materials, datasets, and research agendas are co-developed and iteratively refined by an educational community around climate visualization literacy.

5. POTENTIAL RISKS AND TENSIONS

While climate data offers significant educational opportunities, its integration into data visualization education also raises important pedagogical and conceptual tensions. Rather than treating these as obstacles, we see them as productive questions that should inform future research, curriculum development, and community discussion. Below, we outline some of them.

The first tension concerns the relationship between *understanding* climate data and *acting* upon that understanding. Well-designed learning activities may help students interpret complex datasets and reason about uncertainty, yet still leave them without a clear sense of how those insights may translate into meaningful action. This challenge is particularly evident because many climate datasets point to systemic drivers of climate change, including energy infrastructures, land-use policies, and global supply chains, rather than individual behavior alone. Educational activities that reduce climate action to personal lifestyle choices risk creating a disconnect between the systemic patterns students observe in the data and the forms of action they are encouraged to consider.

A second, closely related tension concerns *climate anxiety*. Working with climate data can be emotionally demanding, and seeking information about climate change has been associated with higher levels of climate anxiety [22]. If concern is proportionate to risk, a learning experience that leaves students entirely untroubled by what the data shows may not have succeeded pedagogically. Visualizations are, among other things, instruments for making problems more perceptible, and, in this sense, some degree of concern related to climate change is a condition of having understood the magnitude of the problem.

However, climate anxiety is not a uniform phenomenon. Pihkala [17] distinguishes between forms of anxiety that become paralyzing and lead to disengagement, and forms that foster reflection and constructive action. Similarly, Whitmarsh et al. [22] found that some forms of climate anxiety are associated with greater engagement in pro-environmental behaviors, particularly those that challenge prevailing patterns of consumption. Thus, instead of treating climate anxiety as an educational outcome to be avoided, it may be more productive to ask how different learning experiences shape students' emotional responses to climate change and how these responses influence their understanding of agency and action.

This discussion also exposes a deeper tension that connects back to the question of climate action. One common response to the risk of paralyzing anxiety is to design learning experiences that provide opportunities for action, helping students transform concern into a sense of agency. Such an approach may become naive, however, if it frames the climate crisis as a problem to be solved through individual action alone, or if it assumes that improved climate literacy is a sufficient condition for adequate responses. The climate crisis is rooted in structural conditions of our political and economic systems, including capitalism and militarism, that lie beyond the reach of individual choice [19]. Framing climate action primarily as a matter of personal choice has been critiqued as an individualization of responsibility that displaces attention from these structures [16], and categorized among the discourses that function to delay collective action [13]. Fostering students' agency therefore requires helping them understand these structural conditions, which may, paradoxically, deepen a sense of paralysis, since they are hardly addressable at the individual level. Even so, while awareness alone will not resolve the climate crisis, it may still be a necessary condition and a first step worth pursuing toward systemic change.

The last tension refers to the risk of *tokenism*. Simply replacing generic datasets with climate-related ones will not necessarily produce meaningful climate literacy or stronger visualization

skills, as climate data can easily become another thematic wrapper around conventional visualization exercises. This may leave educators and institutions feeling that they have ticked the box of climate education, without exposing students to the underlying social, political and scientific complexities of the issue.

Identifying and debating these tensions is itself an important direction for the vis4climate community. Doing so requires collaboration among experts from different domains to deepen these discussions, articulate research agendas, and better understand the limits of the proposed approach.

Practical Challenges for Implementation

The agenda outlined above assumes that instructors are in a position to adopt climate data in their courses. In practice, several conditions of the educational environment make this non-trivial.

The first is time. Curricular time is a scarce resource in educational contexts, and in-depth climate data visualization activities compete with content that is already established. Time is also needed to prepare instructors to teach these topics: in a study of school science teachers who declined an invitation to participate in climate change professional development, time to participate and to teach the curriculum were the dominant reported barriers, ahead of concerns about content knowledge and administrative support [8].

The second is domain expertise. Teaching climate data visualization literacy in depth, while avoiding the risks discussed above, requires knowledge that is not part of standard visualization training, and content knowledge is itself a recognized barrier in climate education [8].

Although these challenges may limit the adoption of climate data visualization in educational settings, we believe that an effort to establish a more systematic infrastructure around climate visualization education is a path worth pursuing. Such an infrastructure could help address these constraints by providing reusable resources and pedagogical guidance that lower the demands required to engage with climate data meaningfully.

6. CONCLUSION

The idea of teaching data visualization through climate data is not new. Researchers and educators across several fields have already demonstrated the potential of climate datasets for developing data-related practices and disciplinary understanding. What remains missing is a coordinated effort to develop a research agenda and teaching materials that may equip educators with high-quality, reusable resources that make it easier to integrate authentic climate data into existing curricula. Realizing this vision will require an interdisciplinary effort to develop shared datasets, curricular units, empirical evidence, and collaborative partnerships that make these approaches accessible and sustainable across educational contexts.

We acknowledge that integrating climate data into visualization education alone will not solve the climate crisis. Meaningful societal change depends on coordinated action across institutions and sectors, and education is only one part of that broader effort. Yet preparing students to engage more critically and systematically with climate evidence is a contribution that the visualization community is uniquely positioned to make.

We hope this reflection paper serves as the beginning of a broader conversation within the vis4climate community, inviting researchers and practitioners to work together in advancing this agenda and establishing climate data visualization literacy as a vibrant area of research and practice.

REFERENCES

- [1] J. Azevedo and M. Marques. Climate literacy: a systematic review and model integration. *International Journal of Global Warming*, 12(3/4):414–430, 2017.
- [2] B. Bach, M. Keck, F. Rajabiyazdi, T. Losev, I. Meirelles, J. Dykes, et al. Challenges and opportunities in data visualization education: A call to action. *IEEE Transactions on Visualization and Computer Graphics*, 30(1):649–660, 2023.
- [3] D. Bhattacharya, K. C. Steward, M. Chandler, and C. Forbes. Using climate models to learn about global climate change. *The Science Teacher*, 88(1):58–66, 2020.
- [4] K. Börner, A. Bueckle, and M. Ginda. Data visualization literacy: Definitions, conceptual frameworks, exercises, and assessments. *Proceedings of the National Academy of Sciences*, 116(6):1857–1864, 2019.
- [5] F. Chevalier, N. H. Riche, B. Alper, C. Plaisant, J. Boy, and N. Elmqvist. Observations and reflections on visualization literacy in elementary school. *IEEE Computer Graphics and Applications*, 38(3):21–29, 2018.
- [6] C. D'Ignazio and R. Bhargava. Creative data literacy: A constructionist approach to teaching information visualization. 2018.
- [7] B. A. Eagle and E. Sylvan. Cultivating climate action through multi-institutional collaboration: Innovative data visualization educational programs and exhibits for public engagement. *IEEE VIS Workshop Viz4Climate*, 2024.
- [8] M. Ennes, D. F. Lawson, K. T. Stevenson, M. N. Peterson, and M. G. Jones. It's about time: perceived barriers to in-service teacher climate change professional development. *Environmental Education Research*, 27(5):762–778, 2021.
- [9] L. W. Ge, M. Hedayati, Y. Cui, Y. Ding, K. Bonilla, A. Joshi, et al. Toward a more comprehensive understanding of visualization literacy. In *Extended Abstracts of the CHI Conference on Human Factors in Computing Systems*. ACM, 2024.
- [10] N. Guimarães, K. Vehkalahti, P. Campos, and J. Engel. Exploring climate change data with R. In *Statistics for Empowerment and Social Engagement: Teaching Civic Statistics to Develop Informed Citizens*, pp. 267–296. Springer International Publishing, Cham, 2023.
- [11] H. Houser. Climate visualizations as cultural objects. In *Teaching Climate Change in the Humanities*, pp. 162–171. Routledge, 2016.
- [12] M. K. Kjølvik and E. H. Schultheis. Getting messy with authentic data: Exploring the potential of using data from scientific research to support student data literacy. *CBE—Life Sciences Education*, 18(2):es2, 2019.
- [13] W. F. Lamb, G. Mattioli, S. Levi, J. T. Roberts, S. Capstick, F. Creutzig, et al. Discourses of climate delay. *Global Sustainability*, 3:e17, 2020.
- [14] K. Lanouette, K. L. Cortes, L. Lopez, M. Bakal, and M. H. Wilkerson. Exploring climate change through students' place connections and public data sets. *Science Scope*, 47(3):18–25, 2024.
- [15] T. S. Ledley, A. U. Gold, F. Niepold, et al. Moving toward collective impact in climate change literacy: The Climate Literacy and Energy Awareness Network (CLEAN). *Journal of Geoscience Education*, 62(3): , 307–318, 2014.
- [16] M. F. Maniates. Individualization: Plant a tree, buy a bike, save the world? *Global Environmental Politics*, 1(3):31–52, 2001.
- [17] P. Pihkala. Anxiety and the ecological crisis: An analysis of eco-anxiety and climate anxiety. *Sustainability*, 12(19):7836, 2020.
- [18] H. Sanei, J. B. Kahn, R. Yalcinkaya, S. Jiang, and C. Wang. Examining how students code with socioscientific data to tell stories about climate change. *Journal of Science Education and Technology*, 33(2):161–177, 2024.
- [19] I. Stoddard, K. Anderson, S. Capstick, W. Carton, J. Depledge, K. Facer, et al. Three decades of climate mitigation: Why haven't we bent the global emissions curve? *Annual Review of Environment and Resources*, 46:653–689, 2021.
- [20] I. Thacker, R. Schroeder, S. Shields-Menard, S. Ramirez, and C. Lopez. Grounded relevance: How exploring soil data can promote perceptions of data relevance, data literacy, learning, and motivation. *Journal of Microbiology & Biology Education*, 0:e00332–25, 2026.
- [21] U.S. Global Change Research Program. *Climate Literacy: The Essential Principles of Climate Science*. Washington, DC, 2009.
- [22] L. Whitmarsh, L. Player, A. Jiongco, M. James, M. Williams, E. Marks, and P. Kennedy-Williams. Climate anxiety: What predicts it and how is it related to climate action? *Journal of Environmental Psychology*, 83:101866, 2022.