

## Supporting Justice-Oriented Data Science in a Secondary Science Classroom: Pathways and Tensions

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**Abstract:** This study explores how a secondary science teacher enacted a justice-oriented data science module in a seventh-grade life science classroom. Co-designed by the teacher and a group of researchers, the module engaged students in investigating quality of life using real-world datasets about their own neighborhoods. Classroom observations and debrief interviews revealed that the teacher effectively connected data science to life science and students' lived experiences, facilitating discussions that linked data practices with justice issues. However, challenges emerged in addressing justice topics of relevance to students. These findings underscore the need for enhanced support and professional development to help teachers navigate the complexities of facilitating justice-oriented data science in diverse K-12 contexts.

### Introduction

Data science has garnered attention across education levels from K-12 to higher education (Lee & Delaney, 2021; Tang & Sae-Lim, 2016), with postsecondary education traditionally emphasizing technical training in statistics, computing, and domain-specific applications to prepare professionals (National Academies of Sciences, Engineering, and Medicine, 2018). However, this technical focus risks portraying data science as politically neutral, overlooking power dynamics and implicit biases that can harm society or specific populations (Philip & Sengupta, 2021; Taylor, 2017). Rather than treating justice as an afterthought, data science education must actively incorporate political and justice considerations (Green, 2021; Lee & Grapin, 2024), creating opportunities for broader participation in data work and the imagination of more equitable futures.

Colleagues working on advancing data science education have responded to this need. The notion of critical data literacies is proposed to focus on leveraging data science to address justice issues (Clegg et al., 2023; Polman et al., 2022). In K-12, emerging efforts expand data science education beyond teaching technical skills to help students connect data science with their personal experiences, cultural identities, and sociopolitical positions (Lee et al., 2021; Pangrazio & Selwyn, 2021).

Despite promising advances, integrating justice-oriented data science in K-12 classrooms is no simple task. While reasoning with data appears in curriculum standards, data science remains an emerging field that requires thoughtful integration into existing subjects. Teachers, particularly those without technical backgrounds, need substantial support to develop their own understanding and confidence in data science concepts. The additional layer of connecting data science to justice issues compounds these challenges further. Examining how teachers navigate these complexities in real classroom settings is crucial, as their instructional practices directly shape students' learning experiences and opportunities to engage with justice-oriented perspectives. This study addresses the critical need for practical guidance by investigating the following question: *How did a teacher enact a curricular module designed to support justice-oriented data science in a secondary science classroom?* By analyzing classroom implementation, we can better understand the pathways and tensions that emerge when teachers attempt to bridge data science, justice issues, and disciplinary learning in K-12 education.

### Methods

#### Context and participant

This study is situated in a design-based research project that aims to develop integrated, justice-oriented curricula, a web-based learning platform named DataX, and pedagogical practices for teaching secondary students about data science. Following a co-design approach, the project team co-developed several curricular units and iteratively refined the platform with three secondary science and social studies teachers from a large urban school district in the Midwestern United States. In this co-design partnership, the teachers first participated in five half-

day design workshops with the researchers over Zoom. Starting from making sense of data science, these workshops involved teachers to imagine how data science could be integrated in their respective subject area. During the second workshop, a justice-oriented data science (JODS) framework was introduced by the researchers to guide curriculum development. This framework, developed based on the literature, consists of five intersecting areas including *data practices*, *disciplinary inquiry with data*, *examining justice through data science*, *critical reflection on data science*, and *identity and cultural practices* (Chen et al., 2023). The JODS framework illuminates the rich intersection among these areas and is open to change. Design conjectures were created to document how design ideas could promote justice-oriented data science.

A seventh-grade life science teacher, Brett (pseudonym), is the focus of this study. Brett is a white male teacher who has a plant science background and nearly 20 years of secondary school teaching experience. At the time of the study, he was new to the school he was teaching. Although he was new to data science, Brett demonstrated considerable confidence in exploring this area. He participated in these design workshops, designed a curricular module, and enacted the module in his classroom.

### Curricular module: Quality of life

In collaboration with researchers, the teacher designed a curricular module on ecosystems that engaged students in investigating quality of life using real-world datasets. Each segment in the module covered one or more of the areas in the JODS framework. Brett implemented the module over the course of three, 50-minute sessions. Details of the module can be found on the project website: <https://penn-wonderlab.github.io/projects/datax/>.

### Data and analysis

This study draws on two primary data sources: (a) the classroom recordings, and (b) two debrief interviews with the teacher (one immediately following the implementation and the other a few months later). Secondary data sources, including video recordings and transcripts of the design workshops, were leveraged to interpret findings.

Our analytical approach began with a thematic analysis of teacher debrief interviews, where we engaged the teacher in reflecting on implementation experiences in relation to our documented design conjectures. This initial analysis focused on the teacher's perspectives regarding successes and challenges, generating preliminary themes that categorized productive and emerging aspects of the design (Chen et al., 2024). We then refined these themes through iterative cycles of collaborative analysis, during which researchers collectively re-examined the data, resolved discrepancies, and modified coding categories through negotiated agreement (Campbell et al., 2013). After establishing the thematic framework, we applied these codes to classroom recordings, examining instructional moves and discourse patterns that illuminated how the teacher enacted the module. Throughout this process, we developed more nuanced sub-themes to capture specific pedagogical practices applied by the teacher.

### Findings

We first provide a brief chronological account of Brett's instructional moves in this module. We then present three key moments that illustrate emerging pathways of exploring justice-oriented data science he facilitated.

#### Teacher instruction in the module

On the first day, Brett reintroduced the concept of ecosystems, previously explored through lessons on orangutans, by connecting it to students' own neighborhoods. To engage students in thinking about their ecosystems, he first elicited students' ideas about components of their environment, and then asked them to complete a five-point Likert scale survey about their neighborhood based on the three domains of *Childhood Opportunity Index* (COI): education, health and environment, and social and economic. After students submitted their responses, Brett projected bar graphs of the results on the whiteboard and facilitated a class discussion.

After the discussion, Brett introduced quality of life in relation to the COI domains and walked through how to use the DataX platform to analyze patterns. First, he showed students how to create their own copy of a template project, which included childhood opportunity scores and Census data for their area. Then, he demonstrated the process of creating map visualizations by dragging variables onto a map and asked students to create their own maps. To build map-reading skills, Brett used a familiar example—a colored map of the U.S. showing regional terms for carbonated beverages (pop, soda, coke)—and modeled how to interpret geographic patterns using his home state.

On the second day, Brett showed a colored U.S. map of regional terms for light-emitting insects (fireflies/lightning bugs), asking students about their preferred term and why some map areas appeared darker. He then connected back to their discussion on ecosystems by having students share what they valued in their neighborhoods. Next, students participated in a gallery walk of peer-generated maps, posting comments that Brett later highlighted. After reviewing the three COI domains and displaying a neighborhood COI score map, he

guided students to identify notable patterns. The session concluded with scatter plot instruction, first reviewing a previously studied example of villi height and food absorption, then demonstrating how to create scatter plots in DataX by dragging variables onto axes. Finally, he presented and discussed a scatter plot showing education and socioeconomic status relationships in their area.

On the last day, Brett showed students a double line graph of the divorce rate in a northeastern state in the U.S. and the per capita consumption of margarine in the U.S. from 2000 to 2009. He prompted students to think about why the two variables are seemingly related and shared his own ideas. Next, Brett re-visited the scatter plot of education and socioeconomic status from the previous session and led a discussion about factors that could affect teachers' socioeconomic status. Then, he displayed a scatter plot of socioeconomic status and education in the students' area and guided students to understand what the two clusters of data points in the graph represent. For the remainder of the session, he tasked students with creating a graph using the same dataset and explaining a pattern shown in the graph in a way that effectively conveys a message to the mayor of their city.

**Figure 1**

*Data Visualizations in the Quality of Life Module Include Bar Graphs (a), Maps (b), and Scatter Plots (c)*



## Emerging pathways of exploring justice-oriented data science

One emerging pathway could be seen when Brett engaged students in analyzing the bar graphs of their neighborhood survey results. He entered the pathway from the *identity and cultural practices* area of the JODS framework, making the discussions about the graphs personally relevant for students by centering their perceptions of their neighborhood as the source of data. Next, he navigated to the *data practices* area of the JODS framework by getting students to read the graphs to share aspects of the results that stood out or surprised them. To support them in reading the graphs, Brett modeled how to identify the most common rating(s) in each graph by pointing out the tallest bar(s) and stating aloud the respective rating(s). This created space for students to justify their ratings and compare their ratings to their peers' ratings. For example, when examining the graphs for economy (see Figure 1a), a student voiced his disagreement with his classmates who rated the quality of shops, food, barbers/salons, etc. in their neighborhood as "OK" compared to other neighborhoods, arguing that the rating "should be max level." Brett asked the student to elaborate on his definition of "max level" to which the student replied that the graph "should only be green" ("Pretty good"). Brett highlighted the student's use of the word "should" and prompted the class to think about how they would ideally want the graphs to look like. When a student suggested that the graphs should be "all green," Brett added that they should ideally be all green and/or purple, pointing to the legend where purple represents "Great." He then extended into the *disciplinary inquiry* area of the JODS framework by eliciting students' opinions about what it would look like to live in a "perfect" environment and have "a green and purple" quality of life, which touches on *justice issues* revealed by data.

A similar pathway arose when Brett guided students to describe and interpret the patterns in the map of education in their neighborhood (see Figure 1b). He entered the pathway from the *identity and cultural practices* area of the JODS framework, helping students personally relate to the dataset by connecting their own experiences attending Head Start (a national preschool program) to the education domain of COI. He explained that the percentage of children enrolled in an early childhood education program, along with other indicators, make up the education domain of COI. Next, Brett oriented them to the map (co-created by him and a researcher) by pinpointing where their school and a neighboring school are located. Then, he moved to the *data practices* of the JODS framework by asking them to read the map to share their observations of patterns in the map. When a student noted that he sees darker green and lighter green, Brett prompted him to specify the areas that corresponded with the different color saturations. To engage students in interpreting the map, he shifted to the *disciplinary inquiry* area of the JODS framework by having them consider the meaning of the differences in color saturation in regard to education. When a student expressed that the neighboring school area has better education than their school area, Brett emphasized that "we're not making judgments as far as better or worse" and explained that the map is showing the neighboring school area scored higher in the education domain of COI.

Another pathway emerged when Brett engaged students in looking at the scatter plot of education and socioeconomic status in their area (see Figure 1c). He entered the pathway from the *data practices* area of the JODS framework by asking students to share the patterns they see in the graph. To guide students in reading the scatter plot, he asked them to locate where the data points were the most concentrated. Next, he pivoted to the *disciplinary inquiry* area of the JODS framework by eliciting students' perspectives on what "status" means in society and who gets respect in the world. Following this discussion, Brett moved back to the *data practices* area of the JODS framework by having students consider where professionals, such as CEOs and teachers, would be located on the graph. He scaffolded students' thinking by first asking them about the level of education necessary to be a CEO, followed by the status of CEOs. Based on students' responses of high education and socioeconomic status, he suggested that CEOs would be in the top right corner of the scatter plot. Next, he questioned students about the level of education required to be a teacher and the status of teachers. According to students' responses of mid to high education and socioeconomic status, he proposed that teachers would be located somewhere in the middle of the scatter plot. When a student asked whether teachers could control their socioeconomic status, Brett said yes and added "I'm not just a teacher; I'm also a white person so that affects things." By bringing up his own identity in the discussion, he turned himself into an example to help students understand that factors such as race/ethnicity can impact one's status, touching on *justice issues* in data and society.

### Tensions in supporting justice-oriented data science in a secondary classroom

Throughout the module, Brett engaged students in justice-oriented data science by examining real-world datasets about themselves and their neighborhoods. However, several tensions surfaced during implementation that highlight the challenges teachers face in this work. A primary tension pertains to the COI dataset and how it did not portray students' neighborhoods in a positive light. During his debrief interview, Brett reflected that although there were "positive conversations" about Head Start, he felt that the stark contrast between childhood opportunity scores in the students' school area and the neighboring school area was "a little painful to look at." This emotional response reveals how data visualizations can make structural inequities uncomfortably visible, creating pedagogical dilemmas for teachers who must decide how deeply to explore these disparities with students.

Another tension emerged around approaching and navigating sensitive topics (e.g., students rating the amount of crime in their neighborhood as "Terrible" and "Pretty bad" in the survey). While Brett displayed critical awareness of his personal identity as a white male teacher working with a diverse student population, he showed noticeable hesitance in leading students to dive into justice issues pertinent to their neighborhoods. Relatedly, as a new teacher in the school, Brett mentioned that he was still working on fostering psychological safety in the classroom, which further complicated his ability to facilitate deeper discussions about systemic inequities. These tensions and challenges ultimately influenced Brett to stick to more surface-level interpretations of the data visualizations and avoid more difficult and uncomfortable conversations with students. His experience demonstrates the need for more robust tools, frameworks, and professional development that specifically address how teachers can effectively navigate their own positionality while facilitating justice-oriented data science discussions, particularly when working across differences in identity and lived experience.

### Discussion and conclusions

This study explored how a teacher enacted a data science module in a secondary science classroom, shedding light on the emerging pathways and challenges of integrating justice-oriented data science (JODS) in K-12 education. Findings revealed that the teacher effectively connected data science to students' lived experiences, identities, and sociopolitical contexts through a combination of data visualizations and interactive discussions. By anchoring lessons in students' neighborhoods and guiding them to analyze patterns in real-world datasets, the teacher facilitated critical reflections on quality of life and justice issues, aligning with prior work on critical data literacy (Clegg et al., 2023; Polman et al., 2022). Moments of teacher instruction demonstrated ways a teacher could guide students to traverse multiple JODS areas.

However, significant challenges and tensions emerged. To navigate these JODS areas, a teacher would need stronger support to address sensitive justice issues in depth. This is especially important when data reveal inequities personally relevant to students or when diverse social identities are present in the classroom, especially when the teacher's identity is different from those of the students. These findings highlight the need for teacher support in navigating the complexities of justice-oriented pedagogy (Clegg et al., 2023; Lee et al., 2021). Future work should focus on developing robust professional learning opportunities that help teachers build confidence in integrating justice issues into data science lessons, foster classroom environments conducive to open dialogue, and navigate the emotional complexities of addressing justice topics. Further research is needed to refine curricular frameworks, such as JODS, and to explore practical strategies for bringing justice-oriented data science into diverse K-12 contexts.



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