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Partnering With Teachers to Co-design Justice-Centered Science Units

By

Kelly Billings-Yadav

A dissertation submitted in partial satisfaction of the

requirements of the degree of

Doctor of Philosophy

in

Education

in the

Graduate Division

of the

University of California, Berkeley

Committee in charge:

Professor Marcia C. Linn, Chair
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Spring 2026

Partnering With Teachers to Co-design Justice-Centered Science Units

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By

Kelly Billing-Yadav

Abstract

Partnering With Teachers to Co-design Justice-Centered Science Units

By

Kelly Billings-Yadav

Doctor of Philosophy in Education

University of California, Berkeley

Professor Marcia C. Linn, Chair

Teachers are increasingly motivated to incorporate local social justice issues, such as public health or environmental concerns, into science classes. Incorporating social justice into science, which connects science content to students' everyday lives and real-life problems that matter to them, has been shown to support student learning and motivation in science. However, traditional science curriculum and science-teacher education have often avoided issues of social justice, and though motivated, teachers need support to transform their existing science curriculum while still maintaining alignment with NGSS science standards. Communities where teachers and other experts in education can come together to co-design justice-centered science curriculum can provide teachers with pedagogical support, resources, and community to support them in integrating social justice into science. My dissertation project explores how participants within a Research Practice Partnership (RPP) engaged in co-design to design two justice-centered science units focused on public health issues. The RPP brought together several groups of participants (researchers, teachers, and computer scientists) who contributed differing expertise towards co-designing the curriculum. I discuss how participants were supported to leverage varying expertise to address major challenges in refining curricular designs and supporting student learning, and how activity structures in the RPP supported teacher learning and leadership during co-design.

The studies presented in this dissertation are guided by the following two overarching research questions: *What design tensions arose during the process of co-designing justice-centered science curricula, and how did the RPP integrate the expertise of participants to address these tensions? How did the RPP support the development of teachers' co-design capacities?* The work of the RPP leverages design-based research and co-design methodologies to support collaboration and refinement of curriculum. Two pedagogical frameworks, Knowledge Integration (KI, Linn & Eylon, 2011) and Justice-Centered Science Pedagogy (JCSP, Morales-Doyle, 2017), inform the design of the curriculum and serve as common languages through which participants discuss curricular designs, pedagogy, and student work.

The first two studies use the Design Tensions (Tatar, 2007) framework to analyze how challenges in designing justice-centered science curriculum emerged and were addressed by the RPP team. In the first study, I discuss the emergence of the first tension - persistent challenges in supporting students to integrate complex justice ideas - and discuss how RPP worked together to identify gaps in the units' ability to support students to integrate justice ideas and utilized the KI framework to inform refinements to the unit. In the second study, I discuss the emergence of a second tension aligned with a major design principle of the KI framework, making science

accessible through real-world examples. This tension - Balancing making SJSI accessible and integrating complex, publicly available data and data science topics unfamiliar to students - documents the trade-offs made by the team in identifying the right real-life data or examples to support students to integrate science and justice ideas with findings from data to understand social justice science issues. The final study turns to the teacher participants in the RPP. I explore how specific structures and activities within the RPP supported teachers' engagement in co-design and leadership within the RPP. Findings indicate that both novice and experienced co-design partners were supported to engage in RPP activities that supported their leadership and professional growth.

Taken together, these studies have implications for how the field designs justice-centered science curriculum and how teams with varying expertise can leverage their knowledge to address persistent challenges in supporting students to integrate science and justice ideas. Findings from these studies also have implications for expanding our understanding of KI to justice-centered contexts and demonstrate how merging KI and JCSP can inform the design of justice-centered science curriculum. Though focused on one RPP, this dissertation contributes to the field's broader understanding of how co-design occurs between researchers and practitioners within an RPP and the structures and resources within an RPP that help to facilitate collaboration. Implications reveal the important impact of teachers in co-design and how RPPs can be structured to uplift and leverage their contributions when designing justice-centered STEM curriculum.

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Chapter 1: Introduction and Theoretical Framework

Motivation and Research Questions

This dissertation contributes to our understanding of co-design work that happens in partnership with practitioners in Research Practice Partnerships (RPPs). The RPP at the center of this study is focused on the development of new curricula, teaching practices, and technologies aligned with justice-centered perspectives on STEM teaching and learning. To do this work, the RPP brought together several groups of participants (researchers, teachers, and computer scientists) who contributed differing expertise towards this common goal. My dissertation seeks to understand the mechanisms and structures that support co-design in the context of this specific RPP. Specifically, I investigate how participants in the RPP use co-design to tackle complex design challenges that arise when creating and refining justice-oriented science units, and how the RPP creates the conditions for participating teachers to feel empowered to grow in their teaching practice, engage in co-design, and take on leadership roles within the RPP. This work is guided by two overarching research questions: *What design tensions arose during the process of co-designing justice-centered science curricula, and how did the RPP integrate the expertise of participants to address these tensions? How did the RPP support the development of teachers' co-design capacities?*

This research is motivated by the growing need to design relevant, justice-centered science curricula that support students to investigate local social justice science issues (SJSI, Morales-Doyle, 2017). Many researchers and teachers have made strides in designing curricula that help students discover how science and issues of racial justice connect, empower students to take action, and create opportunities for students to build empathy and ally ship within their communities and with communities that are not their own (Davis & Schaeffer, 2019; Morales-Doyle, 2017; Upadhyay et al., 2020). Researchers have also highlighted continued challenges in supporting students' justice-centered STEM learning, including supporting students to think beyond broad assumptions about communities and navigate conflicting narratives about personal choice and systemic, racialized structures (Rubel et al., 2016; Visintainer, 2023). These are major challenges that both teachers and university partners must tackle if we are to support student learning around STEM and social justice.

Much of the work of designing curricula that integrate discussions of social justice and power into STEM learning happens in partnerships between teachers, community partners, and researchers. This dissertation is motivated by the need to understand how work within partnerships between researchers and practitioners (in this case, teachers) occurs. Teachers are experts in the classroom context. They have vital knowledge of pedagogy, their school sites, and students that is key in creating meaningful and supportive educational experiences for students (Kang, 2022; Li et al., 2024; Matuk et al., 2016). However, power hierarchies may position researchers as authorities in RPPs and teachers as enactors of curriculum, rather than co-designers and co-researchers. Understanding this RPP, which seeks to empower teachers as leaders and leverage their expertise to design curriculum and educational technology, can provide valuable insight that can inform practices within RPPs more broadly. Additionally, understanding the processes within this RPP can highlight areas in which we need to better structure the RPP to support more democratic research practice with teachers.

The dissertation is broken into three major studies. The third and fourth chapters focus on two design tensions that arose as the RPP engaged in the co-design of two public-health-focused justice-centered science units. In these chapters, the artifacts being designed by the RPP are the

units, and these chapters focus on the iterative refinement of the unit designs. In the third chapter, I explore how the members of the RPP navigated supporting students' integrated understanding of justice factors related to race, and how racialized systems in medicine and public health contribute to inequitable health outcomes for communities of color. The team refined designs in ways that made justice ideas more explicit for students and refined opportunities for students to distinguish between justice and science factors. Student work from the final implementation highlights progress and persistent areas for improvement with the designs. Study one is guided by the following research questions: *How did the co-design team refine the unit to support students in integrating justice ideas to explain public-health-related SJSI? How did these changes impact students' Knowledge Integration? What continued challenges persist in supporting students to integrate justice ideas to explain public-health-related SJSI?*

The second study focuses on tensions related to making justice content and data science concepts accessible to students to support their learning and ability to work with complex data sets. I outline how the RPP refined each unit and navigated the major tensions that arose: aligning content with student experience or aligning content in ways that prioritized complex questions about data privacy in medical sessions (Henrietta Lacks) and tensions between aligning data sets with student interest and curating data sets of the appropriate size and scope for eighth and ninth-grade students. While progress has been made in both units, this chapter suggests that there is still much work to be done to support students in reasoning about data in justice-centered science learning contexts. Study two explores the following research questions: *How did the co-design team refine the units in ways that centered on making data and data science concepts accessible to learners? How did changes to the unit support students to create investigable questions of publicly available COVID-19 data? What continued tensions exist in supporting students to work with data when learning about complex SJSI?*

Finally, the fifth chapter focused on the learning and participation trajectories of three focal teachers as they engaged in co-design in the RPP, shifting the focus from the designed units to the experiences of the teachers themselves. I examine how specific RPP structures and resources supported their learning and activity within the RPP. These structures, in addition to intentional relationship building, privileged the knowledge of educators, provided compensated opportunities to extend involvement into research, and created flexible and empowering opportunities for teachers to engage in co-design. Both expert and novice co-designers were supported to engage in ways that felt meaningful to their learning goals. The questions at the center of the final study are: *What are the trajectories of the three teachers? How does the co-design structure support each teacher? How does the RPP Workshop support the participating teachers' progress in co-design?*

Background and Theoretical Foundations

Social Justice in Science Teaching and Learning

Science classrooms can be the site of meaningful, relevant learning for students or a space where students feel that their ideas, communities, and issues that matter to them are unwelcome (Gutierrez & Rogoff, 2003; Bang & Medin, 2010). Recent research in science teaching and learning has sought to design spaces where students feel that their whole selves belong, where they feel that they have insights and ideas to contribute, and where they can use what they learn in the STEM classroom to support their local communities and families (Calabrese-Barton & Tan., 2020; Morales-Doyle, 2017). One way researchers and designers have sought to do this work is by centering localized, personally relevant social justice issues in science curriculum. Centering

justice in science teaching creates opportunities to not just make science content more relevant to students' lives, but also supports them to interrogate how power and white supremacy shape scientific practice and public health outcomes (Morales-Doyle, 2019; Visintainer, 2023). Restructuring science classrooms in ways that center social justice also positions students as leaders and transformative intellectuals within their school and local communities (Morales-Doyle, 2017; Calabrese Barton & Tan, 2020).

Findings from recent research highlight how integrating social justice into science curricula can support student learning and empower students to take action. Morales-Doyle (2017) demonstrated how incorporating social justice science issues, such as the impact of chemical pollution from coal power plants on students' communities, can support students to learn AP and NGSS-aligned chemistry content, reason about complex issues about race and power, and empower students to consider how they can make change in their own communities. Davis and Schaeffer (2019) demonstrated how social justice-oriented science units that center on water and water rights support elementary school students to learn about basic chemistry behind water and pollution and develop a sociopolitical understanding of water as a human right in ways that build ally ship with other communities. Others show how social justice science issues that are relevant to students' indigenous roots and communities support indigenous students in developing their socio-political consciousness while validating and uplifting their community knowledge as a key asset in supporting action (O'Neill et al., 2023; Upadhayay et al., 2020). All of these studies demonstrate how integrating localized social justice issues into STEM curricula can be a powerful opportunity to support student learning, empowerment, and identity development.

While there are major successes in supporting students' science and justice learning, persistent challenges remain, and certain questions remain unanswered. For example, researchers have highlighted how certain deficit framings, including blaming inequitable health or economic outcomes on personal choice, can still persist when students engage in justice-centered STEM learning (Rubel et al., 2016; Visintainer, 2023). Researchers and teachers need to work towards designing curricula that support students to distinguish between complex justice factors beyond deficit frames to understand how power systems and structures impact inequitable health and economic outcomes along racial lines. Continued work is also needed to improve the curriculum to support empathy and ally ship across communities, especially if students do not necessarily identify with a community or individual whose story is included in the curriculum (Esmode, 2014). Finally, challenges are also persistent in supporting authentic empowerment, especially when adults and systems beyond the classroom discount students' insight and knowledge (Van Wart et al., 2019).

This RPP represents a community of researchers and practitioners who are oriented towards a shared goal of supporting students' justice-centered STEM learning. The literature has highlighted the transformative impact of different curricula on students' learning and gaps in students' understanding of SJSI that still need to be addressed. However, more work is needed to surface design principles and design tensions that arise when designing justice-centered STEM curriculum. Integrating SJSI into STEM curricula integrates new resources, goals, and challenges that traditional, NGSS-aligned science curricula do not consider. Balancing justice-centered learning goals and state standards can sometimes feel at odds with one another (Morales-Doyle et al., 2019; Penuel et al., 2022). The RPP had to address these tensions and others that arose during co-design, and our work can guide the broader field in balancing different learning goals when creating justice-centered STEM curriculum. I elaborate on how we identified and addressed these tensions, and how teacher expertise was incorporated into the process through co-design.

Knowledge Integration and Justice-Centered Science Pedagogy

I bring together two theories of learning related to STEM education, Knowledge Integration (KI, Linn & Eylon, 2011) and Justice-Centered Science Pedagogy (Morales-Doyle, 2017). Both frameworks build on both constructivist (Inhelder & Piaget, 1958) and sociocultural (Vygotsky & Cole, 1978) theories of learning. Constructivism argues that students come to learning spaces with ideas and experiences from their lives, communities, and previous classroom learning that can be built upon and leveraged for further learning (Hammer et al., 2005). This prior knowledge is often fragmented (diSessa, 2018), and the work of learning designers and educators is to help students connect these ideas to newly discovered ideas to form coherent understandings of different concepts or phenomena. My work seeks to build on constructivist frameworks to create educational interventions that validate students' community and personal knowledge related to justice-centered science phenomena and support them to integrate those existing ideas with new ideas they may learn about science and justice from the curricular units.

Sociocultural theories of learning recognize that learning is not an individual act, but is mediated by communities (Gutierrez & Rogoff, 2003), tools, and technology that learners engage with (Philip, T., & Garcia, A., 2013; Walkoe, Wilkerson, & Elby, 2017). I recognize that historically, the ideas and learning mediated by students' home cultures and practices are often ignored or excluded in science classrooms (Gutierrez & Rogoff, 2003; Bang & Medin, 2010). However, these ideas are generative in supporting science learning, and exponentially more so when supporting students to understand complex social justice issues that impact their communities. My work seeks to create designs that include students' wide array of knowledge sources and epistemologies related to science, data, and justice, so that they may feel that their ideas and experiences are worth exploring and connect to classroom learning. The curriculum and educational technology discussed in this dissertation help to mediate their learning process.

Knowledge Integration centers on making scientific topics accessible to students by connecting new science learning to their lived experiences and prior knowledge. KI does not discredit or view students' ideas as something to be corrected. Rather, KI emphasizes that students' initial ideas are important building blocks for future knowledge and supports them to explore ideas different from their own to add to their understanding of scientific topics. For example, when supporting students to learn about complex physics topics such as thermodynamics, KI activities connect these concepts to situations students are familiar with, such as keeping a drink cold in the fridge, and use this scenario as a starting point for adding new ideas. Rooting science learning in a relevant social justice phenomenon, such as the inequitable impacts of COVID-19 or inequities in access to quality medical care, is a logical step forward for Knowledge Integration. Doing does not just mean making science accessible by connecting it to students' lived experiences. Designers and educators are also empowering students to use their expertise from their experiences and science learning to think about ways to disrupt unjust systems in their communities.

Research on KI has revealed four instructional strategies that support students in integrating their science (and in this case, science and justice) ideas. They include *eliciting* student ideas, *discovering* new ideas, *distinguishing* among ideas, and finally *sorting connections* between ideas. For example, in the existing genetics unit that the *Henrietta Lacks* unit discussed in this dissertation built upon, students are taken through the four steps of the KI cycle to support them in learning about how traits are inherited from parents to children. First, students' ideas about how traits might be inherited are elicited through brainstorming questions like "Why do siblings look similar, but not the same?" and "What's an example of a physical trait you think you may have

inherited from a parent?” These questions begin to elicit students’ ideas about the mechanisms for inheritance and examples from their own lives about how inheritance might work. Students then discover ideas about basic inheritance and how to model inheritance using Punnett squares, using eye color as an illustrative example. Students then distinguish between different types of alleles (dominant or recessive) and genotypes (heterozygous and homozygous), and use Punnett square to practice predicting inheritance of various traits that are familiar to them. Finally, students use checks for understanding questions to reflect their own learning and connect their ideas to revise their answer to one of the first prompts, “Why do siblings look similar, but not exactly the same?”

Research has also surfaced four design principles: (1) making science accessible to each learner with relevant examples (Linn & Hsi, 2000); (2) making student thinking visible by posing explanation activities that require linking ideas with evidence (Ritchhart & Perkins, 2008); (3) helping students collaborate to learn from others (Matuk & Linn, 2023) and (4) promoting autonomy by guiding reasoning rather than providing answers (Davis, 2003). Rooting learning in localized social justice issues, including environmental issues such as urban health islands or public health issues like COVID-19, helps make science accessible by providing familiar, real-world contexts in which students can root their learning (Bradford et al., 2023a; Billings et al., 2025). Educational Technology has been an aspect of addressing design principles two and three. AI tools, such as pedagogically aligned chat bots, surface a wide range of student ideas in written conversation, making students’ ideas visible to themselves and teachers (Bradford et al., 2023b; Gerard et al., 2025; Li et al., 2023). Collaboration tools, such as AI-informed online discussion tools (Billings et al., 2024) and idea-sharing tools (Matuk & Linn, 2023), support students in discovering ideas from their peers. Finally, integrating Open Education Resources (OERs) into KI-aligned curriculum supports students to engage in self-directed learning, supporting them to explore phenomena through inquiry (Gerard et al., 2022b). These design principles inform the design and refinement of the two justice-centered science units discussed in this dissertation.

While KI offers a tested pedagogical framework through which to design both curriculum and assessment, until recently, the framework has not specifically attended to learning in the context of identity, race, and justice. To address these critical aspects of learning, I lean on Justice-Centered Science Pedagogy (JCSP) and merge it with the KI framework. JCSP helps to bring a social justice perspective to the KI framework by providing a pathway for connecting STEM learning to local justice issues. JCSP does this by honoring students’ epistemic diversity, maintaining high expectations for student learning, and centering critical consciousness. The framework brings together Culturally Relevant Pedagogy (Ladson-Billings, 1995, 2009) and Critical Pedagogy (Freire, 1970). The framework supports students in using their science knowledge to interrogate and propose solutions to local injustices in their community, positioning them as experts on community and science knowledge. JCSP has three key tenets: integrating social-justice science issues into STEM curricula, anti-racist and equitable teaching practices, and positioning youth as transformative intellectuals who can create change in their communities.

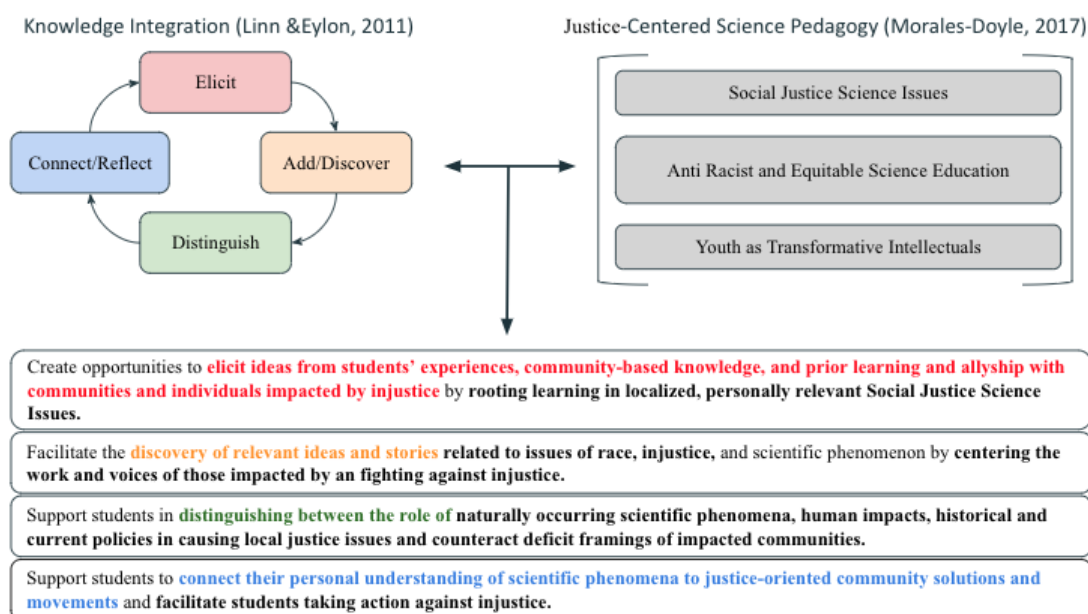
Morales-Doyle (2017) describes how the three key tenets were enacted in an AP chemistry curriculum. Students explored a local SJSI and the impact of pollution from a coal power plant in the students’ community. This SJSI required students to link AP-chemistry science concepts with community and social justice ideas to explain how the pollution occurred and the pollution’s impact on local communities of color. Morales-Doyle engaged in several anti-racist and equitable teaching practices, including centering environmental racism and scaffolding student learning in ways that supported them to engage in complex, standards-aligned scientific investigations. Finally, students were positioned as transformative intellectuals by participating in a family

science night, where they educated their families and broader community about the impacts of pollution on public health. The RPP uses JCSP's tenets to guide the design of the curriculum.

These two frameworks align in their emphasis on honoring and building on students' wealth of ideas to support STEM learning. KI offers a pedagogical framework through which to design both curriculum and assessment. Justice-centered science pedagogy provides a framework through which to think about integrating science and justice and empowering students as change makers. Together, these two frameworks provide insight into how to design learning environments to support students in integrating their ideas about science and justice to investigate injustices and propose solutions to those issues (Bradford et al., 2023) and can provide guidelines for the design of justice-centered science units (Figure 1). I also utilize the frameworks to analyze the co-design processes themselves. Both frameworks serve as anchors and a common language in the RPP, as they have been made explicit and visible to teachers during RPP workshops (Bradford et al., 2021; Gerard et al., 2022a). Design decisions and teachers' customizations can be linked to the key tenets of each framework, offering a way to examine how decisions about unit design are made in the RPP.

Figure 1

Merged Knowledge Integration and Justice-Centered Science Pedagogy Frameworks.



Each of the tenets above integrates a step of the KI framework (Elicit, Discover, Distinguish, Connect/Reflect) with social justice science issues and justice-centered STEM teaching perspectives informed by Morales-Doyle's (2017) framework. For example, tenet one merges the elicit step of the KI framework with Morales-Doyle's concept of SJSIs. By rooting student learning in a local and personally relevant SJSI, learning activities can prompt students to bring in a wide range of ideas when teachers or unit activities elicit their ideas. These include personal or community-based ideas related to the SJSI, science ideas that help explain the science behind SJSI, and justice ideas that help to explain why certain communities are more impacted by the SJSI than other communities. Studies one and two will provide details of how these tenets were

taken up in unit design, with study one focusing especially on tenets two and three, and study two focusing on tenet one.

Research Practice Partnerships and Co-design

The work discussed in this dissertation occurred within the context of a Research Practice Partnership (RPP; more information on the history and focus of this particular RPP can be found in chapter two). RPPs are long-term relationships among teachers, school leaders, designers, community members, and researchers who jointly seek to improve teaching practice, curricula, and pedagogy (Coburn et al., 2016). Many RPPs focus on conducting design-based research in partnership with teachers. Partnerships (though not all may specifically call themselves an RPP) have produced a variety of interventions to support student learning. Regarding STEM education, these partnerships have worked to produce NGSS-aligned curriculum (Penuel et al., 2007), educational technology (Gerard et al., 2010; Matuk et al., 2016), and STEM curricula informed by indigenous perspectives (Bang et al., 2007). More recently, several of these partnerships have become the site of important work to co-create justice-centered STEM curricula for K-12 classrooms and after-school programs (Calabrese-Barton & Tan, 2020; Bradford et al., 2023a; Kang & Nation, 2023; Vakil et al., 2022). However, these studies often focus on the products of RPPs, rather than investigating the ways tools, structures, and resources support co-design and redistribute power within RPPs as members engage in co-design. While insights into these products and how they support student learning and engagement in STEM are important, more work is needed to understand how learning and collaboration operate within RPPs and how the work within these partnerships can be made more democratic.

Work in this area has begun to provide insight into how various factors, including power dynamics, technology, and specific collaboration structures or activities, can support democratic collaboration and participation within RPPs. Several researchers have recently focused on how the tools and technology used by RPPs support collaboration, teacher agency, and learning for all participants. For example, Matuk et al. (2016) examined how certain strategies (such as discussing prototypes and writing user stories) elicit teachers' design requirements and feedback for the technology they can use in the classroom. These strategies also pushed designers to consider the needs of teachers and the limitations of classrooms. These structures also helped to position teachers as experts, fostering teacher agency. Kang & Nation (2023) show how a specific equity-centered framework and accompanying resources utilized by an RPP supported teachers to enact equity-centered instruction within curriculum, pedagogy, and assessment. The authors argue that making the framework explicit for teachers helped them to enact it in their practice. Penuel et al. (2022), Severance et al. (2016), and Jayathirtha et al. (2025) describe how structures and tools, including protocols for unpacking NGSS science standards, unit storylines, and unit descriptions, supported participants in learning practical design knowledge and clarified learning goals for students. These different tools also surfaced tensions and feedback from teachers, helping to improve the RPP as well as the curricula produced in the partnership. These studies speak to the importance of structures such as prototypes, frameworks, and tools to facilitate co-design and support teachers to use their voices in RPPs.

Others have looked beyond the impact of specific structures and resources to understand how teachers and other RPP participants navigate power and exert agency within RPPs. These studies often attend to how typical, hierarchical power structures are disrupted and how RPPs can take on more democratized models (Sjölund et al., 2023). For example, Philip et al. (2022) propose a teacher solidarity methodology that brings together co-design and participatory design

frameworks to support teachers and school communities. This framework emphasizes teacher expertise and considers the unique power dynamics navigated by teachers, such as the political terrain of schooling. Kyza & Agesilauo (2022) examine processes (like the exchange of resources and researchers positioning themselves as learners alongside teachers) within an RPP that support more democratized, empowered outcomes, such as teachers' increased involvement in decision making and increased sense of autonomy. While much progress has been made to document teacher agency and power navigation in RPPs, more work is needed to continue to consider how structures within RPPs can lead to more democratized outcomes, such as teacher agency and leadership (Goldman et al., 2022).

My final study focused on the experiences of three teachers within the RPP and how specific structures within the partnership supported each of them to exert agency during co-design. By doing so, teachers took on roles unique to their personal and professional goals and prior professional experiences. Previous research has highlighted how co-design supports collaboration between researchers and practitioners, thereby validating practitioners' perspectives and leveraging their expertise to create solutions to educational problems (Goldman et al., 2022; Voogt et al., 2015). I build on this work by illustrating how specific structures within an RPP support teachers to engage in co-design in ways that leverage and validate their expertise and help them achieve their professional goals, which can inform the design of other RPPs that seek to support teacher leadership.

Design Tensions Framework

For studies one and two, I utilize the Design Tensions Framework (Tatar, 2007) to help understand the trade-offs and decisions made by the RPP when co-designing the curricula. Co-design teams often navigate decisions and trade-offs as they design and refine curriculum and unit activities. For example, teachers and curriculum designers in this RPP had goals related to students' justice-centered learning. These justice-centered learning goals are sometimes difficult to align or are even at odds with NGSS-aligned STEM goals, which often avoid discussion of the socio-political contexts and harmful consequences of scientific "progress" (e.g., Morales-Doyle et al., 2019; Penuel et al., 2022). Aligning goals is a complex, iterative process that involves repeated negotiation of resources, goals, and activity structures. One decision often does not lead to a fixed solution that completely solves a design problem or concern. This requires co-design teams to engage in repeated cycles of reflection and refinement. Tatar (2007) calls these types of repeated, not-easily-solved challenges that come up during the design of educational interventions Design Tensions, defining them as "not a problem or a solution but rather a limited resource or choice across one or more criteria" (Tatar, 2007, p. 417). Tatar's framework emphasizes the active choices of participants in the design process, and these choices define and redefine the tension as time goes on.

Tatar's Design Tensions framework contains four levels: *Vision*, *Approach*, *Project Tensions*, and *As Created Situations* (Table 1). The vision is the highest level; it "is driven by a tension between what is and what ought to be" (Tatar, 2007, p. 417). The vision expresses the values and goals of a particular project. In the case of the RPP discussed in this dissertation, we sought to create meaningful opportunities for students to explore SJSI within K-12 science curricula. Though typical science instruction and the NGSS standards often emphasize connecting science content to relevant examples, there is often little opportunity for students to investigate SJSI or integrate science and justice ideas (Morales-Doyle et al., 2019). This is "what is." For our RPP, what "ought to be" is the inclusion of SJSI in K-12 science curricula.

Table 1*Components of a Design Tension and Design Tensions Documented in this Dissertation.*

Vision	Is: Typical science education and NGSS standards do not provide students opportunities to investigate issues of social justice and use science knowledge to understand and solve SJSI.	Ought: Teachers and curriculum designers should integrate SJSI into K-12 science curricula.
Approach	Project Drivers: Alignment with NGSS and existing 6-12 science topics Availability of OERs, data sets, and other resources Local and personally relevant SJSI School and teaching contexts	Values: KI Design Principles Elements of JCSP Integration with teachers' existing expertise and practices
Project Tensions	Chapter 3: Persistent challenges in supporting students to integrate complex justice ideas Chapter 4: Balancing making SJSI accessible and integrating complex, publicly available data and data science topics unfamiliar to students.	
As Created Situations	Examples of specific activities that resulted from the work of the RPP: - Chapter 3: Stop-and-prompt after activities focused on justice ideas (<i>Henrietta Lacks</i>), Expert video and sorting activity (<i>COVID-19</i>), Student learning as measured by the <i>Impacts</i> assessment item (<i>both</i>) - Chapter 4: Removal of data privacy focus, shift to patient advocacy (<i>Henrietta Lacks</i>), publicly available data sets embedded within the unit, and students' investigable questions (<i>COVID-19</i>)	

The approach is the different aspects of the intended implementation of the project. These include the project drivers, which are the constraints and realities that exist within the project, and the project values that impact the approach of the designers. Our project had several drivers informed by the contexts, available resources, and constraints of our work within 6-12 science classrooms (Table 1). The values are informed by our two major frameworks, Knowledge Integration and Justice-Centered Science Pedagogy. For example, the KI principle of making science accessible is a key value that informs how the RPP sought to design activities and support students to build on their existing repertoire of ideas to understand SJSI. Additionally, a major value for this work was alignment with our participating teachers' existing expertise and practice.

Project Tensions are the places within a project that are within designers' scope of influence where they can make choices and decisions informed by the vision, project drivers, and values. Tensions are also where different aspects of a project, such as constraints, values, or resources, can come into conflict with one another (such as conflict between what is covered in the NGSS science standards and topics that center on social justice in science). Tensions expose the messiness and repeated decision-making involved in the design of educational interventions. Chapters three and four will elaborate on two of the tensions that arose as members of the RPP were co-designing the two justice-centered science units.

Finally, as created situations are the new realities that result from the decisions of the design team. Some of these new realities may be intended, others unintended. In this case, the work of this RPP, as created situations are the new designs that resulted from our work, as well as the

impact on student learning. These include the specific activities that exist within the online, web-based unit, the ways that teachers facilitated student learning while using the unit in their classrooms, and the impacts on student learning.

The Design Tensions Framework has been leveraged by educational researchers to examine co-design interventions in math (Tatar, 2007; Johnson et al., 2016) and science education (Penuel et al., 2022; Penuel et al., 2025). Penuel (2022) outlines one design tension that arose as a co-design team composed of teachers and researchers worked to construct an NGSS-aligned science curriculum storyline for a nuclear chemistry unit. Brainstorming anchoring phenomenon for the unit storyline presented a tension between balancing NGSS science standards with student interest and justice-centered goals. While nuclear energy proved an initially engaging NGSS-aligned phenomenon, students asked questions during the anchor phenomenon activity about nuclear weapons and ethics that were not covered in the standards and existing curriculum. Designers then worked to refine the anchor phenomenon to include a bridge between nuclear energy generation and the development of nuclear weaponry. This refinement involved continuously balancing the NGSS science standards, which did not include historical or political perspectives about the use of nuclear chemistry to develop weaponry, with integrating primary source documents to support students in learning about the political context around the initial development of nuclear weapons. Though the framework is not explicitly named in studies on the design of justice-centered science curriculum, others have pointed to how co-design communities have addressed tensions in designing justice-centered chemistry instruction (Morales-Doyle et al., 2019). These interventions involve collaborations between large design teams that often encompass individuals from different backgrounds and perspectives, including teachers, researchers, and technology experts.

The Design Tensions Framework illuminates the dynamic process of co-design work and is particularly useful to analyze work that addresses complex factors, such as supporting science or data science learning goals, identifying new goals related to justice-centered learning, and building opportunities for cross-disciplinary student learning. Tatar's (2007) Design Tensions framework can help to illuminate the nuances of these challenges and how the co-design team in the ARISE partnership addressed them during the interactive design process. My analysis of the data from the co-design activities identified two major design tensions that arose during the co-design process. These tensions are the focus of studies one and two.

Overview of Chapters

This dissertation is organized into three major studies. The second chapter provides an overview of the RPP contexts, participants, and instructional units that are the focus of the dissertation. This chapter also outlines our use of co-design (Steen, 2013) as a guiding methodology for collaborating and refining curriculum in the RPP. I outline the broad spectrum of data sources collected for this work and the data analysis that informs the results discussed in studies one and two. Additional analysis unique to each study, as well as the data sources and analysis for the final study, are described in their specific chapters.

Chapters three and four focus on the two design tensions I identified in my analysis. I discuss how these design tensions emerged by outlining how (a) implementation and student data revealed initial gaps in pilot designs in supporting students' learning (b) how RPP participants discussed and negotiated initial changes to address these gaps in the first revision (c) how participants continued to reflect, iterate and refine the units to address the emergent tensions, and (d) and persistent challenges or dilemmas aligned with the tensions..

Chapter three, titled *Supporting Students to Integrate Justice Ideas to Explain Public-Health-Related Social Justice Science Issues*, focuses on a design tension related to challenges in supporting students to integrate systemic and racial justice ideas into their understanding of SJSI. The central research questions in chapter three are: How did the co-design team refine the unit to support students in integrating justice ideas to explain public-health-related SJSI? How did these changes impact students' Knowledge Integration? What continued challenges persist in supporting students to integrate justice ideas to explain public-health-related SJSI?

Chapter four, titled *Centering Students' Experiences Towards Making Complex Data Sets and Data Science Concepts Accessible* discusses the design tension of making data and data science concepts accessible vs. choosing complex, publicly available data sets and data science concepts to integrate into justice-centered science curriculum. Chapter four's research questions are: How did the co-design team refine the units in ways that centered on making data and data science concepts accessible to learners? How did changes to the unit support students to create investigable questions of publicly available COVID-19 data? And what continued tensions exist in supporting students to work with data when learning about complex SJSI?

The fifth chapter, titled *Teachers' Co-design Trajectories in an RPP Focused on Justice-Centered Science Instruction*, focuses on the experiences of three partner educators who were heavily involved in the design and refinement of the *COVID-19* and *Henrietta Lacks* units. Each of the three teachers had unique co-design trajectories informed by their teaching experience, prior experience within the RPP, and professional goals. Findings illustrate how the RPP supported both experienced and novice teachers to engage in co-design. I explore how specific RPP structures and activities supported their engagement in co-design, leadership within the RPP, and progress in integrating KI-aligned customizations to the curriculum. The central research questions in this final study are: What are the trajectories of the three teachers? How does the co-design structure support each teacher? How does the RPP Workshop support the participating teachers' progress in co-design?

Chapter 6 discusses implications across the three studies. Implications are organized into four sections. The first discusses the value of merging KI and JCSP to design justice-centered science curricula. Second, I discuss how the Design Tensions framework supported the understanding of challenges in co-designing justice-centered STEM curriculum and how participants within an RPP work together to address persistent challenges. Third, I elaborate on how the structures and activities within the RPP supported co-design. Finally, I discuss how these structures supported teacher learning within the RPP and how these structures can inform how partnerships support teacher learning and engagement more broadly.

The chapters in this dissertation are organized as follows:

Chapter 1: Introduction and Theoretical Foundations

Chapter 2: RPP Context and Overarching Methodology

Chapter 3: Iterative design of curriculum to support students to integrate justice ideas about SJSI

Chapter 4: Centering students' experiences towards making complex data sets and data science concepts accessible

Chapter 5: Teachers' Co-design Trajectories in an RPP focused on Justice-Centered Science Instruction

Chapter 6: Discussion and Conclusion

Chapter 2: RPP Context and Overarching Methodology

WISE/ARISE Research Practice Partnership

This dissertation focuses on co-design work and teacher learning within the WISE (Web-based Inquiry Science Environment)/ARISE (Anti-Racism Interactive Science Education) research practice partnership (RPP). This 25+ year-long partnership integrates the expertise of secondary science teachers in classroom teaching and student learning; learning scientists in pedagogy and assessment; computer scientists in software design and technology; and curriculum designers in linking science and justice in instructional materials to create curriculum and technologies aligned with Knowledge Integration (KI, Linn & Eylon, 2011; Hoadley, 2017; Kali, 2015). The major goals of the RPP include advancing and refining KI pedagogy, curriculum design, and articulating design principles for justice-centered science curriculum, providing professional development for educators, and deepening our understanding of how students learn. The RPP produced standards-aligned web-based science units that have been adapted by teachers worldwide (e.g., Bichler et al., 2021). It developed educational technologies, including interactive computer models (Gerard & Linn, 2025), AI-powered automated guidance (Gerard et al., 2025), and collaboration tools (Matuk & Linn, 2023). The RPP has impacted the uptake of Knowledge Integration across the field (Kali, 2006; Krajcik & Mun, 2014) and modeled the use of the structures for iterative design (Matuk et al., 2016).

The partnership's teachers' interest in social justice motivated the RPP to seek funding from several sources starting around 2015 (Gerard et al., 2022a). This resulted in the eventual creation of five justice-centered science units that either built on existing NGSS-aligned units (such as the *Henrietta Lacks* unit discussed in this dissertation) or were entirely new to the WISE unit collection (such as the *COVID-19* unit discussed in this dissertation). Like the units that came before them, these units were designed using the Knowledge Integration framework, and the refinement, implementation, and study of these units in classroom contexts advances our understanding of KI. The RPP leaned on an additional framework, Justice Centered Science Pedagogy (JCSP), to inform the incorporation of Social Justice Science Issues and anti-racist teaching practices into the curricular units. This dissertation focuses on the co-design of two of these justice-centered science units, specifically, and the co-design trajectories of three teachers who were heavily involved in the design and refinement of the two units.

Participants within the RPP engage in the collaborative design and refinement of curriculum via three participation structures (Table 2). Research staff and computer scientists meet weekly to discuss projects, including ongoing data analysis, unit design, education technology, and writing. Teachers can join these meetings during the summer as part of university internships. Bi-yearly RPP workshops bring together all participants to refine units, learning technology, and KI pedagogy. KI informs the workshops and includes several activities that scaffold participants to engage in reflection and co-design. The workshops allow participants with multiple perspectives to share ideas, and are the place where teachers have the most time to learn from one another and engage in co-design together with research staff.

The third component is the teacher-researcher collaborations that occur during unit refinement and implementation. Each unit has a lead researcher (I was the lead on the *COVID-19* and *Henrietta Lacks* units) who works closely with the teachers who use the unit in their classroom. The lead researcher meets with the teacher before unit implementation, visits the classroom during implementation to support the teacher and collect data, and meets with the teacher after implementation to reflect on student learning and discuss feedback on the unit. Co-design between

teachers and researchers usually occurs during the RPP workshops and the teacher-researcher collaborations.

Table 2

Overview of RPP Structures and the Participants, Activities, Resources, and Data Sources From Each Structure.

RPP structure	Participants	Activities	Open Educational Resources (OERs), RPP products	Data Sources Used in Analysis
Weekly Research Group Meetings	Researchers (faculty, visiting scholars, graduate and undergraduate students)	Coordination of RPP activities	Web-based, customizable curriculum units	Curriculum designs and customizations
		Work in progress reports	KI-aligned curriculum visualizer	Data analyses, interpretations (Elaine only)
	Classroom teachers, summer interns	Workshop planning	KI Assessments	Publication drafts (Elaine only)
	Computer scientists	Consultancies on educational technology, research designs, proposals, and report drafts	Student work and related data analyses Research reports and literature reviews	
		Technology updates		
Workshops focused on refining curricular units and supporting teachers' professional growth	Learning scientists	Analyze logged student work	Analyses of logged student work	Workshop activity transcripts, learning scientist field notes
	Classroom Teachers			
	Computer scientists	Customize unit in response to student work and reflections	Customized unit with updated technologies	Logged teacher work, reflections
		Refine classroom practice	Classroom practices aligned with unit Curriculum Visualizers	Customized units Collaborative documents
Co-design partnerships featuring teacher and learning scientist collaborations	Lead learning scientist	Plan implementation: Reflect on needs; revise unit, classroom practices	Implemented Web-based unit	Planning meeting transcripts, email communication
	Lead classroom teacher		Logged student work, including pretests, posttests	Enactment field notes
	RPP collaborators	Enact and observe		
		Discuss observations between class periods	Classroom activities aligned with unit	Memos on between-class conversations Analyses of pretest, posttest progress
		Reflect on practice and student learning, plan next steps	Reflective interview questions	Reflective interview transcripts

Participants

Participants in this study include the teachers (N=9, Table 3), learning scientists (N=5), and a computer scientist who worked to refine two ARISE units: *COVID-19*, *Data Science*, and *Equity and Genetics*, *Cell Division*, and *Henrietta Lacks*. Over the course of this three-year study, participants engaged in co-design of the curriculum at different levels of involvement, depending on the individual participant.

Teacher participants included the six teachers who used either the Henrietta Lacks unit or the COVID-19 unit (or both). Though all six participated in co-design in some way, they did so at different levels of involvement (Table 3). Teachers ranged from high involvement (Gregory, Elaine, and Beatriz) to minimal involvement that included implementation and some post-implementation interviews (Jaime). This reflects the RPP's emphasis on allowing flexibility for participating teachers to use units and engage in co-design in ways that feel meaningful and reasonable for them, given their goals and commitments outside the RPP.

Learning scientist participants included the primary researcher for both units (myself, the author) and three other members of the WISE research group. I was the main collaborator who worked with the teachers during the co-design process. I created and refined different versions of the unit based on other participants' ideas and feedback, led co-design meetings and workshop activities focused on the units, and worked with teachers during implementation. I also collected and analyzed a majority of the student data, observations, and co-design data related to both units. The other three researchers supported my work by providing feedback on unit prototypes and data analysis and assisting with data collection when needed. They also supported teachers' engagement in co-design in the RPP workshops.

Finally, the computer scientist supported the creation and refinement of certain designs in WISE, particularly new technologies such as a data visualization tool for the *COVID-19* unit. They also provided feedback on designs throughout the co-design process.

Study 3 focuses on the co-design trajectories of a subset of three specific teachers, Elaine, Gregory, and Beatriz (Table 3). Each of these three teachers utilized both the *Henrietta Lacks* and *COVID-19* units, and were three out of the entire set of participants who consistently attended all types of RPP activities, including workshops, pre-implementation meetings, and post-implementation interviews. Each teacher did not use all three versions of each unit. Gregory initially used both *COVID-19* and *Henrietta Lacks* in the first year, then dropped COVID-19 to focus on the Henrietta Lacks unit in years two and three. Beatriz and Elaine did not use the pilot of the *Henrietta Lacks* unit (which was only used by Gregory and his partner teacher, Jaime) and added it in years two and three. They both used the *COVID-19* unit for all three years.

Elaine: Elaine identifies as a Black woman and has been teaching in the same district for nine years. The first author, who used to teach at the same school as Elaine, recruited her to join the RPP in 2020. Elaine has been part of several educator communities focused on social justice. She was motivated to join the RPP because she felt it would expose her to new ideas that could help her “learn something new” (reflective interview, 6/6/2025) about her practice. Elaine participated in a summer research internship that supported (and compensated) her to work with the RPP in a research capacity for two summers. This additional opportunity and corresponding artifacts are included in the analysis. Elaine switched to a different school within the same school district during the last year of the study.

Gregory: Gregory identifies as a white male. He joined the RPP when he started teaching at his school 13 years prior. He has implemented over twenty units during his time with the RPP and regularly participates in activities. Gregory initiated discussions of social justice in the RPP. During our reflective interview (11/7/2023), Gregory said that discussions of social justice and race are “important to teach in all classrooms.” He stated that he values the RPP because “It allows me to do action research in my own classroom that feels fun and easier than if I were doing my own thing.”

Beatriz: Beatriz identifies as a Latina. She has over twenty years of teaching experience, mostly at her current school. Beatriz joined the RPP along with her colleagues at the school. When the RPP incorporated social justice in 2020, Beatriz was motivated to regularly participate in workshops. Beatriz earned a Ph.D. in public health before becoming a teacher and feels that public health and access to healthcare are a through line with which to center social justice in science.

Table 3
Teacher Participants

Name	School	Involvement in Co-design	Units Taught	Grade level
Gregory	Hill View MS	Workshops, Implementation, Pre and Post Interviews	Year 1: COVID + HeLa Year 2-3: HeLa	8
Jaimie	Hill View MS	Implementation, COVID pilot post-interview	Year 1: COVID + HeLa Year 2-3: HeLa	8
Elaine	Years 1-3: Bayview HS Year 4: Forrest HS	Workshops, Implementation, Pre and Post Interviews, Summer research internship	Year 1: COVID pilot Years 2-3: HeLa and COVID	9
Beatriz	Valley HS	Workshops, Implementation, Pre and Post Interviews	Year 1: COVID pilot Years 2-3: HeLa and COVID	9
Rachel	Valley HS	Implementation Post-implementation interviews	Year 2-3: COVID	9
Lacey	7City MS	Implementation Workshops	Year 2-3: COVID and HeLa	7

Researcher Positionality

It is important to understand my background and positionality before going further in analyzing the work or participants in this partnership. I joined the RPP as a new graduate student, but also as

a former science teacher who taught in one of the districts in which some of the teachers in this RPP (such as Elaine) work. I pursued a PhD to further my own questions and research interests in culturally relevant and justice-centered STEM education, which I initially developed through my classroom teaching. I come to this work deeply informed by my teaching practice and closely aligned with partner teachers. I share a similar professional language, goals, and practice-focused orientation to the work. I value the teachers' ideas, opinions, and concerns highly, as I have been in their shoes recently. My research seeks to work in solidarity and partnership with teachers and uplift their voices in the research and design process (Philip et al., 2022).

Technologies and Unit Descriptions

WISE Platform

The units discussed in this dissertation were built using the WISE (Web-Based Inquiry Science Environment, wise.berkeley.edu) platform. The platform is an open-source and customizable learning environment that supports student inquiry in science. WISE is used by teachers worldwide, and units on the platform are regularly updated by the WISE staff to better support student learning, address grade-level content, integrate new learning technology (interactive simulations, online discussion tools, and AI technologies, to name a few), and respond to the needs of teachers. WISE also provides a platform to support research, and units on the platform are often the center of research studies focused on supporting students' science learning and refining learning technology.

WISE is informed by Knowledge Integration (KI) pedagogy. The platform utilizes various open educational resources, including online simulations, modeling tools, peer discussion tools, videos, maps, and data sets to support students in exploring phenomena. These activities can be created within WISE or can be embedded into the platform from another website or program. As students engage in the online units, the WISE platform logs their work, making it accessible to students' teachers and the research staff. Teachers can use various tools to view student work and display information about student learning (Billings et al., 2021; Wiley et al., 2024). Additionally, this logged student work is utilized in workshops, co-design meetings, and interviews to support the co-design and refinement of units (Bichler et al., 2021; Bradford et al., 2021).

The WISE authoring tool allows all co-design participants to make changes to the unit easily, though this work is usually done by researchers and learning scientists. Participants can use the authoring tool to re-order steps, create new steps, upload or link new open-educational resources and data sets, and create various forms of assessment questions. Pre-authored, KI-aligned activity structures allow participants to easily create new activities that are informed by KI pedagogy. All unit versions are stored in the WISE platform, allowing participants to easily build and modify revised units from previous unit iterations.

Finally, the platform can be used to support professional development. Previous unit drafts and logged student work in the platform can be leveraged during workshops to discuss unit designs and changes to designs. The platform can also be used to create professional development units, which can be utilized in teacher workshops or interviews. These professional development units can help to structure workshop or interview activities and allow teachers to write written responses to prompts. Similar to student data, these written prompts are logged within the WISE platform and can serve as a data source for research. Professional development units were made for all the workshops in this study, and some of the pre-implementation meetings during the teacher-researcher partnerships.

COVID-19 Unit

The *COVID-19, Data Science, and Equity (COVID-19)* unit focuses on the inequitable health and socio-economic impacts of COVID-19 on marginalized communities (Table 4). The central SJSI that students explored in this unit is using data to investigate the inequitable impacts of COVID-19 on minoritized communities, including the racialized and power systems that led to these outcomes. Students also explore how they can use data to make informed decisions about COVID-19 to advocate for the needs of their communities. A graphing tool called the Data Explorer supports students in examining publicly available data sets, choosing relevant variables, and creating different types of graphs from the data. Students also engage in various activities that help to provide context to the data they are exploring, including activities around data collection, reliability, and case studies to help explain some of the inequitable impacts they uncovered in the data.

This unit centers on justice in data science by positioning students as investigators into the ways in which COVID-19 impacted some communities more than others. Students are prompted to use data to tell a story about COVID-19's impact, but also discover ways in which data sets can be limited or can leave out certain stories, connecting to the cultural aspect of data science (Lee et al., 2021). The final lesson focuses on uncovering why different groups were impacted more than others, highlighting issues like access to health care, divestment from communities, and the distribution of pre-existing communities as possible reasons why students see certain trends (Whitacre et al., 2021). The goal in this lesson is for students to walk away with a robust understanding of the racialized system that contributed to the inequitable impacts of COVID-19 on minoritized communities despite community solidarity and action. Students are also prompted to reflect on the unit by creating a plan for helping to educate their communities about COVID-19 and accessing COVID-19 vaccines using data.

Table 4*Overview of COVID-19 Unit Storyline and Resources Used to Support Student Learning*

Lesson	Topic/Central Focus	Simulations, Open Educational Resources, and Curated Data Sets
1 - COVID-19 data collection and variables	Students discover how data about COVID-19 is collected and engage in questions around validity, reliability, and limitations of COVID-19 data.	Video about credible sources and a list from Johns Hopkins University about how to evaluate credible sources California Department of Public Health Vaccination Dataset by County A map documenting the different COVID-19 data that states are collecting
2 - How did age impact COVID-19 outcomes?	Students use the data explorer to discover how COVID-19 impacts differed by age. Students pick from three questions and are taken through a scaffolded data investigation.	California demographic data (age) and COVID-19 outcomes (deaths and cases) by age
3 - How were communities impacted by COVID-19?	Students choose between three data sets focused on uncovering inequitable impacts of COVID-19 on different groups (race/ethnicity, gender, and other risk factors). Students create questions, identify relevant variables, create graphs, and answer their questions based on the graphs they created.	Within one county in CA - vaccination case and death rates by race/ethnicity and gender Across multiple counties in CA - Vaccination, case, and death rates by risk factor (percent in poverty, health insurance). Vaccination case and death rates by race/ethnicity and gender.
4 - How do we explain the trends we see in the data?	Students use several OERs to explore why inequitable COVID-19 impacts occur. Students discover examples of local and youth-led actions and brainstorm how they can support their community to continue to address COVID-19 and other public health concerns.	Video from a public health expert explaining why we see disparate impacts of COVID-19 on communities of color Demographic information of essential workers in the U.S. Maps documenting case rates and demographic information for neighborhoods in San Francisco Video explaining community-led vaccination initiatives in Oakland, CA. Articles reporting on youth-led activism

Technology: Data Explorer

The COVID-19 unit utilizes a tool called the Data Explorer (DE) to support students in constructing graphs from large data sets. This tool is embedded into WISE and was developed by the WISE computer scientist and research team, with input from teachers. The DE consists of two linked components, a table component (Figure 2) and a graphing component (Figure 3). These linked components allow students to take data from the table, such as specific variables, and automatically graph them within the graphing component.

Teachers or unit designers can upload datasets to the table component using the WISE authoring tool. Once uploaded, they can modify the data set through the authoring tool, connect the data set to a graphing task, and adjust the components of the graphing task to fit learning goals. This allows designers and teachers to easily make adjustments to both the data set and the graphing component during unit design and refinement.

Figure 2

The Table Component of the Data Explorer (COVID-19 Unit, Revision Two). Component Can Be Customized By Teachers

COVID-19 Demographic Data for California

Sources: [Population](#), [Vaccinations](#) (as of 5/25/23), [Race/ethnicity](#) (as of 5/9/23), [Male/female and total cases/deaths](#) (as of 6/1/23)

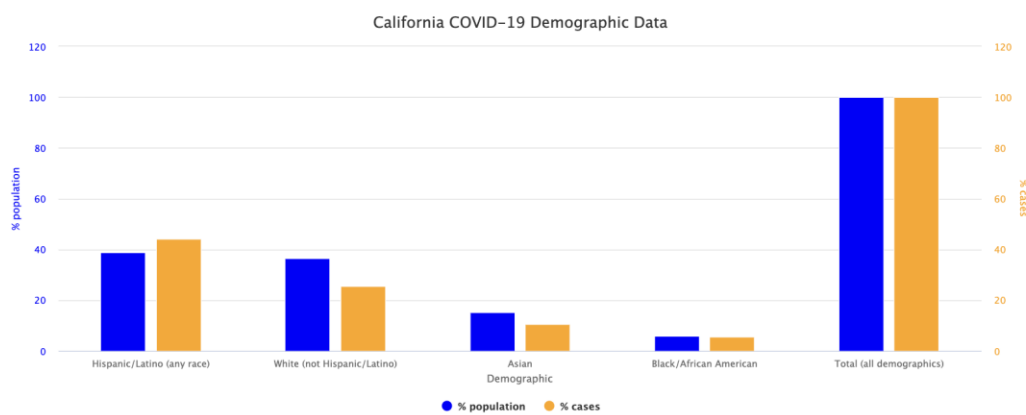
☒ Demographic	% population	% vaccinated	Cases per 100,00	% cases	Deaths per 100,000	% deaths
☒ Hispanic/Latino (any race)	38.9	57	25553	44.3	269.2	41.9
☒ White (not Hispanic/Latino)	36.6	72.6	16917	25.7	265.3	36.2
☒ Asian	15.4	79.8	15904	10.5	190.4	11.3
☒ Black/African American	6	61.1	22602	5.5	324.8	7.1
☐ American Indian/Alaska Native	0.5	58.2	25846	0.5	297.8	0.5
☐ Native Hawaiian/Pacific Islander	0.3	90	46493	0.8	403.6	0.6
☐ Female	50.3	87.8	29678	52	217.2	42
☐ Male	49.7	85.7	26571	46	303.5	58
☒ Total (all demographics)	100	72.9	28708	100	260.1	100

Figure 3

The Graphing Component of the Data Explorer (COVID-19 Unit, Revision Two). Component Can Be Customized By Teachers

Choose the table data you want to graph:

X Data:
 Y Data 1:
 Y Data 2:
 Y Data 3:



Once set up, students can use the DE to visualize data from a large data table. After reviewing their data set, students can select one X and up to three Y variables. The DE then automatically displays variables in a bar, line graph, or scatter plot with labeled axes. When presented with larger datasets, students can also narrow variables by only choosing some variables within a subset (for example, choosing two specific age ranges of interest from a longer list of age ranges).

The DE is in its third iteration, and I have reported on findings from the first two iterations in a conference paper (Billings et al., 2023). Two investigations in the current unit use the Data Explorer. The first allows students to graph COVID-19 cases, hospitalizations, and deaths over time. The second investigation asks students to compare summative COVID-19 outcomes across groups or locations. Data sets in the second investigation include demographic information (race/ethnicity, gender), COVID-19 case rates, death rates, vaccine rates, age, and pre-existing medical conditions. Students can choose to investigate data within a certain county in California or across large counties in California.

Henrietta Lacks Unit

The *Genetics and Henrietta Lacks (HeLa)* unit focuses on the story of Henrietta Lacks and issues of medical racism and data privacy. This unit connects NGSS-aligned genetics content to the story of Henrietta Lacks by integrating her story and a larger discussion about medical racism and privacy into an existing genetics unit (Table 5). Henrietta Lacks was a Black woman living in Baltimore, Maryland, who went to Johns Hopkins Hospital, a public hospital that served African-American patients, for medical treatment. Doctors collected her cancer tissue without her consent and inadvertently discovered the first immortal cell line. Her cells would prove to be revolutionary for medical research, though her family would be unaware of this for many years. Henrietta Lacks' story has been taught in biology and biotechnology classrooms at the high school, college, and graduate levels (Kraig-Turner, 2016; Dimaano, C., & Spigner, C, 2017; Virtue et al., 2018) to discuss issues of medical racism and segregation in medical care, as well as issues of data privacy and research ethics. Lessons involving Henrietta's story often involve teaching with *The Immortal Life of Henrietta Lacks* (Skloot, 2017), which documents Henrietta's story, the use of her cells in scientific research, and the work of her family to regain the decision-making rights and compensation for the use of Henrietta's cells.

One of the RPP's participating teachers (Gregory) brought the idea of integrating Henrietta Lacks' story into the genetics unit in 2021. I had Henrietta Lacks' story in a biotechnology elective when I was a classroom teacher and was excited to take on the role of lead researcher for this unit to build on the work I had originally done in the classroom.

This unit uses a variety of open educational resources and case studies to support students to explore how patient care and medical ethics have changed over time in the U.S, and ways in which issues of bias and inequitable treatment of people of color persist in the medical system. Embedded videos allow students to hear about Henrietta's story from Rebecca Skloot (author of *The Immortal Life of Henrietta Lacks*) and Henrietta's family members. Publicly available data from national patient surveys support students to explore how patients feel about their care today. In each case study, the voices of patients and family members are centered to humanize the issue of medical racism and research ethics. Table 5 outlines learning activities in the version of the unit used in spring 2025, which resulted from the co-design work discussed in this dissertation.

Table 5
Overview of Henrietta Lacks Unit Storyline and Resources Used to Support Student Learning

Lesson	Topic/Central Focus	Simulations, Open Educational Resources, and Curated Data Sets
1 & 2 - Why do we look the way we do	Students explore how certain traits they are familiar with, such as eye color, are determined via inheritance. Students use Punnett square to predict the inheritance of certain traits and explore how mutations in genes cause variation.	Punnett Square Simulations Annotator Activities
3 - Predicting Disease	Students use data from a medical file to create a pedigree for Eric, a young person who has cystic fibrosis. Students use the pedigree to determine who else in Eric's family has cystic fibrosis and predict the likelihood of him having children with the disease.	Pedigree creator
4 - Meeting Eric's Goals	Students help Eric communicate his medical and fitness goals to his doctor and reflect on how Eric advocated for himself and how the doctor responded. Students help Eric decide whether he should participate in medical research.	
5 - The Story of Henrietta Lacks	Students learn about the story of Henrietta Lacks through reading short excerpts from Skloot (year) and videos featuring Henrietta's family. Students explore how segregation and medical racism contributed to her treatment. Students help Henrietta's family decide whether or not HeLa cells should be used for a particular research study.	Video highlighting Henrietta's story and centering the voices of her family National Institute of Health language and resources about the agreement between the NIH and Henrietta's family
6 - Can Patient Care Still Improve	Students explore data from a national patient survey to discover how patient care is still impacted by bias today. Students reflect on how patient care can be improved, and students reflect on how they can advocate for themselves at the doctor's office.	Curated national survey data focused on patient care Doctor and patient demographic data in the United States

Methods

Design-Based Research

This dissertation leverages design-based research (Bell, 2004). Design-Based Research (DBR) rests on the premise that we can uncover insight about learning through creating and refining curriculum, educational technology, teaching practices, and other learning interventions. DBR allows for innovative, contextualized study designs that attend to the rich contexts and goals of participants. This includes the goals and perspectives of both practitioners and researchers, as well as the unique contexts of individual school sites and classrooms. The studies in this

dissertation take place within the broader RPP. The professional development and classroom environments that make up the RPP are highly contextualized and dynamic. DBR attends to these complexities by applying educational theory and engineering design practices to address problems of practice within these highly contextualized, complex spaces (Sandoval & Bell, 2004).

Co-Design

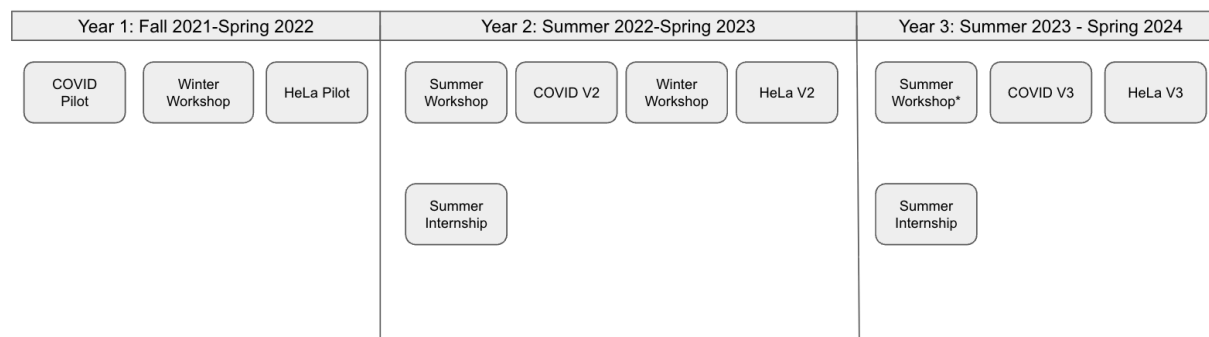
The RPP utilizes co-design as a methodology to support unit and education technology refinement and collaboration between participants of different perspectives. Co-design bridges research and practice by enabling practitioners and researchers to negotiate the application of pedagogy to classroom practices and curriculum designs (Sandoval & Bell, 2004; Steen, 2013). Co-design builds on DBR frameworks by attending to who is in the room in DBR. Co-design includes practitioners (in this case, teachers) as experts in the design and refinement of learning environments (Matuk et al., 2016; Penuel et al., 2007). Previous research has highlighted practitioners' key contributions to the refinement of educational environments through co-design. When practitioners shaped the design of a teacher dashboard, the technology became more useful in everyday practice (Matuk et al., 2016). When practitioners' expertise is respected, their insights can help the RPP integrate meaningful and relevant social justice issues into the curriculum (Bradford et al., 2023a; Kang & Nation, 2022; Penuel et al., 2025). In this way, co-design seeks to democratize education research by directly involving practitioners in research and design. Co-design can also be the site of learning for participants, and many researchers have investigated how the co-design process impacts the learning of participants, especially practitioners (Engstrom et al., 2014; Penuel et al., 2022).

In this RPP, co-design primarily occurred during RPP workshops and teacher-researcher partnerships. Workshops provided an opportunity for all participants to come together to engage in co-design, allowing teachers to share and build on one another's ideas. Teacher-researcher partnerships supported close collaborations between individual teachers and lead researchers, building relationships that helped to facilitate co-design and providing opportunities for teachers to share detailed feedback rooted in their teaching experience and student learning. Research meetings were primarily a space of co-design among researchers and computer scientists, though Elaine participated in co-design in this space when she participated in the summer research internship.

Co-design Timeline

Figure 4 includes a general timeline of RPP activities, including unit initiation, implementation, and key feedback sessions in RPP workshops. The initiation of the justice-centered focus of the RPP occurred in the fall of 2020, which coincided with my first semester as a graduate student at UC Berkeley. Gregory (and other teachers who had been involved with the RPP for several years) were part of the group that initiated this change. Elaine and Beatriz were brought into the RPP by participants who were already involved. The first justice-centered units used in this study were implemented in the fall of 2021.

Figure 4
Timeline of Co-Design Activities



The *COVID-19* unit was created first and initiated by the research team. We felt that the COVID-19 pandemic served as a contemporary, highly relevant SJSI with which to support students to learn about injustice in health care and support the engagement and development of NGSS-aligned data science practices. I took the lead on the unit and spent the winter and spring of 2021 creating the pilot. During this time, the WISE research team provided regular feedback on the developing unit, and a summer workshop provided teachers with an opportunity to provide feedback on the developing unit as well. The unit was first used in the classroom in the fall of 2021 by Gregory, Elaine, Beatriz, and two additional partner teachers (of Gregory and Beatriz) who were not involved in the additional RPP activities but were interested in using the units. Elaine and Beatriz continued to use the next two versions of the unit (in fall 2022 and fall 2023), but Gregory decided to focus his attention on the Henrietta Lacks unit.

The Henrietta Lacks unit was proposed by Gregory in the fall of 2021 during a post-interview following his use of the COVID-19 unit. During this interview, Gregory and I discussed additional topics, and he emphasized the need for authentic (rather than surface-level) connections between science and social justice. To him, Henrietta Lacks' story felt like an authentic way to connect big issues of medical racism and privacy to the genetics content he was already teaching. This subject area was familiar to me, as I had taught the book *The Immortal Life of Henrietta Lacks* as a teacher in a biotechnology and bioethics elective. After the initial unit initiation, I worked to create an initial draft of the unit, which Gregory and other teachers were able to provide feedback on during the winter 2022 workshop. I revised the unit, and I received feedback from the WISE team during this revision phase. Gregory and his partner teacher then used the pilot in May 2022 with their students. After seeing the unit at the summer workshop, Elaine and Beatriz decided to use it as well, and all three teachers used the next version in the spring of 2023. Elaine, Beatriz, and Gregory used the final version in the spring of 2024.

Data Sources

Each co-design event within the RPP leveraged specific resources to facilitate co-design, which have been refined in prior research from the RPP. All three studies utilize data from co-design activities that partnerships participated in, though certain data sets or analyses are leveraged in different ways depending on the research questions in the chapter. Table 2 above outlines the data sources available from the three RPP structures. Here, I outline the methods used to collect and analyze data for chapters three and four, which focus on two design tensions that emerged when co-designing these two justice-centered science units. The analysis of various sources of co-

design data (the units, workshop data, implementation data, and interviews) is outlined below. Each study has a different analysis of student work that contributes to the tension, and these analyses are described in their respective studies. I conducted a different analysis of the co-design data for chapter five, which is outlined in that chapter.

Prototypes and “Finalized” versions of web-based units: Both unit drafts (or prototypes) and finalized versions of the pilot, Revision one, and Revision two of each unit were collected as material artifacts documenting the progress of the unit designs. These material artifacts document the changes that occurred in the unit as it was iterated on by the co-design team. They serve as a digital documentation of the team's collaboration and provide insight into how discussions between participants resulted in changes to the unit itself (Wickman, 2010).

Workshops: RPP Workshops were opportunities where all co-design participants (teachers, researchers, computer scientists, and social justice experts) came together to engage in co-design. The COVID-19 and Henrietta Lacks units were two of several units that participants worked on during the workshops. These workshops had several different types of activities, including: Positioning activities, reviewing student work, unit prototype discussions, customization sessions, and problem-of-practice discussions. Data sources collected during RPP workshops include (a) workshop agendas that serve as digital artifacts documenting workshop activities, (b) online workshop units in the WISE platform that elaborate on unit activities and resources available to support collaboration among participants, and (c) field notes captured by research participants during RPP activities. For this dissertation, only data related to activities that focused on the *Henrietta Lacks* and *COVID-19* units were analyzed.

Pre and Post Interviews: Teachers participated in interviews with the lead researcher (me) before and after using the curricular units. These interviews lasted approximately thirty minutes. Pre-interviews focused on last-minute feedback from teachers and finalizing any changes or customizations to the units. These interviews were led by the needs of the teacher prior to implementation, and were less structured. Pre-interviews typically lasted thirty minutes. Post-interviews focused on feedback, reflecting on teaching, and an initial look at student work using teacher tools in WISE. Post-interviews were more structured and followed interview protocols. Interview protocols for the post-interviews can be found in Table 29 in the appendix. Interviews were audio-recorded and transcribed.

Unit Implementation: One or more researchers observed classrooms during the duration of the justice-centered portion of the units. At least two periods were observed, unless the teacher had only one period. During observations, the researcher wrote field notes documenting the activity in the classroom. Field notes described the actions of the teacher, activities or customizations that the teacher added to the units, actions of focal groups of students (focal groups were chosen based on students who returned consent forms), and the ways in which students or the teacher interacted with the online, web-based unit. The researcher also attempted to transcribe to the best of their ability whole-class conversations or conversations between the teacher and focal groups of students. If teachers provided feedback on the unit during implementation, their feedback was also included at the end of the field notes for the class period in which the feedback was provided. Finally, after each day, the researcher wrote short analytic memos summarizing activity in the

classroom, informal co-design conversations, and researchers' initial analysis of the activity that occurred within the classroom (Erikson, 1986).

Teacher summer internship: One teacher (Elaine) participated in a summer research internship with the RPP during the summer of 2022 and 2023. She primarily worked on the COVID-19 unit during her internships. She and I met weekly to work on the COVID-19 unit. I collected running agendas and any other digital co-design artifacts generated during the internships (Examples: revised visualizers or new data sets for the COVID-19 curated by the teacher). These physical artifacts served as sources of our collaboration, reasoning, and notes during unit refinement (Wickman, 2010). I also wrote weekly analytic memos documenting key design changes, discussions related to unit design, and my initial interpretation of our changes and ideas on unit refinement (Erikson, 1986) during the duration of her internships.

Data Analysis for Chapters Three and Four

Analysis of the data sources occurred in multiple stages. Previous stages were revisited throughout the process to revise interpretations of the data and triangulate findings among the different data sources.

First, I analyzed the different versions of the web-based units to create unit maps that documented changes within the major units over time. These maps were created in an Excel spreadsheet and contained each unit activity, the KI process that motivated the design of each activity, and a description of the activity (Figure 5, see Figures 23 and 23 in the appendix for full maps for each unit). Once the activities in each version were documented in the maps, Elaine and I independently reviewed each activity through the different iterations and flagged any changes, including dropped activities, added activities, or changes to activities between iterations (adjustments to activity content, adjustments to activity structure, adjustments to resources, and minor usability or readability adjustments). We met and discussed our identified changes, discussing any changes that we had disagreements about in our individual maps. Once agreed upon, these changes were recorded in a separate table. Elaine and I reviewed each of the changes and engaged in independent inductive coding (Saldaña, 2013) to identify common themes among unit changes. We then met to discuss, group, and revise our codes, integrating our insider knowledge as members of the co-design team into our understanding of the changes and emergent codes. These common themes were then revisited and refined using the additional analyses below to establish the emergent design tensions.

Figure 5

Screenshot of the Unit Map for the Henrietta Lacks Unit.

Revision 1 Lesson Sequence - spring 2023	Driving Question	Objective	
Lesson 4 - Making decision about health data (Eric)	How does Eric make decisions about his health data?	Students can explain how a young person might make decisions about their health data.	
	KI Step	Activity Description	Challenges, opportunities, changes to this step
4.1 Who is involved in supporting Eric's health?	Discover, distinguish	Students discover the stakeholders involved in eric's health and distinguish between the different roles they have in supporting eric.	Kept
4.2 What data does each person have?	distinguish	students distinguish between the different data each stakeholder has.	narrowed activity to focus on info doctor and researcher has.
4.3 what data should eric share with the doctor?	Elicit	Students' ideas about what data eric should share with his doctor are elicited.	kept

The next phase involved analysis of the additional co-design data sources from the workshops, interviews, unit implementations, and teacher summer internship. I first sequenced each of the data sources into co-design timelines, which allowed me to match the different data sources in time with unit timelines documented in the unit maps. Next, Elaine and I coded the various data sources to identify co-design events within the entire data corpus that documented conversations about the units between RPP participants. This served as a key method for reducing the extensive data corpus (Goetz, J.P. & LeCompte, 1981). We defined co-design events as discussions between participants that addressed an emergent issue or needed revision with the unit to better support student learning, constraints, or design goals. We also discussed and agreed on the analysis process for each of the different data sources (detailed below). Once we established the definition and processes together, we independently coded data sources from the *COVID-19* unit to identify the co-design events. After independently coding the *COVID-19* unit data we met to discuss disagreements and solidify the co-design events. I then independently repeated this process for the *Henrietta Lacks* unit data. The analysis of each of the RPP activities to identify co-design events is as follows:

Workshops: To analyze the workshop data, we began by reviewing the workshop agendas to identify the activities where the *COVID-19* and *Henrietta Lacks* units were discussed by the team. We then reviewed the online workshop units to clarify activity details and resources used during the co-design activity. Finally, we reviewed field notes from each of the workshop activities to identify the specific co-design events within the discussions that occurred between RPP participants. For each coded event of the field notes, we reviewed the resources referenced in the field notes (for example, specific resources mentioned in the discussion or student work referenced by a participant), and noted any additional context they provided to the discussion. These events were then pulled into a separate co-design event Excel sheet for further coding, which is described below.

Pre and Post Interviews: We open-coded the interview transcripts from both pre and post interviews to identify co-design events within the discussions that occurred between the participating teacher and researcher. Any artifacts mentioned during these discussions (such as a unit activity, customization artifact, or student work) were reviewed, and we noted any additional context they provided to the discussion. The events identified in the interviews were added to the separate co-design event Excel sheet for further coding.

Unit Implementation: After each day of observation, I reviewed the field notes from that day and created daily analytic memos. These memos focused on several aspects of the research: (a) summarizing the activity of the students, especially how they interacted with the unit and unit content (b) summarizing the activity of the teacher and any customizations they implemented (c) how the teacher supported student learning, (d) any feedback provided by the teacher (or students, though this rarely occurred) on the unit that day. Analytic memos were open-coded to identify co-design events that occurred during unit implementation. Field notes related to the events identified in the analytic memo were isolated as well. Any artifacts or student work mentioned in the memos were reviewed, and we noted additional context they provided to the co-design events identified in the analytic memos. These artifacts (memo sections, field notes, and additional artifacts) were also added to the co-design event Excel sheet for further coding.

Teacher summer internship: We opened coded agendas and analytic memos from the internship to identify co-design events that occurred during the summer internships. Any digital artifacts mentioned during these discussions (such as curated sources or data sets, customization artifacts, or student work) were reviewed, and we noted any additional context they provided to the discussion. These co-design events were also added to the Excel spreadsheet.

Once all the data sources were coded independently, the teacher and I met to discuss the co-design events we identified and added to our individual spreadsheets, reconciling disagreements about which events we identified. Once we discussed the events, we compared the entire sequence of events to the unit maps to link specific changes in each of the units to the co-design events identified in the data. Finally, we reviewed our entire corpus of co-design events and unit changes to identify emergent design tensions. To do this, we first independently inductively coded (Saldaña, 2013) each of the co-design events to identify discussions or deliberations about an issue or change within the unit that involved balancing constraints, design goals, and findings from student data. We then met to discuss our codes, and identify any repeated discussions or deliberations, similar challenges, constraints, or issues in supporting student learning. This process identified emergent tensions that were repeatedly navigated by the co-design team. We also used this time to identify illustrative examples of the tensions. Once emergent tensions were established for the COVID-19 unit, I independently repeated the process for the Henrietta Lacks unit.

Once initial emergent tensions were identified in each unit, the tensions were brought to an additional researcher for feedback and to discuss commonalities in the tensions across the two units. This discussion helped to further refine the tensions and solidify three overarching tensions that cut across the co-design of both units. After solidifying the overarching tensions, I returned to the data to clarify the illustrative examples of the tensions in each of the co-design data sources. Chapters three and four document two of these tensions.

Chapter 3: Supporting Students to Integrate Justice Ideas to Explain Public-Health-Related Social Justice Science Issues

Introduction

Research Practice Partnerships (RPPs) are key sites of innovation for the design of science curriculum, including innovative science curriculum that centers on issues of social justice (Bradford et al., 202; Calabrese-Barton & Tan, 2020; Kang & Nation, 2023; Vakil et al., 2022). These partnerships bring together experts, such as teachers, curriculum designers, researchers, and social justice leaders with differing expertise, allowing for teams to leverage the vast strengths and knowledge bases of participants to merge science and justice-centered content to help students form a coherent understanding of Social Justice Science Issues (SJSI). SJSI are phenomena that are explained by integrating science topics and social justice factors, including discriminatory policies, differential impacts of public health and environmental issues on communities of color, and community-led civic action (Morales-Doyle, 2017). Supporting students to understand SJSI requires scaffolding learning in ways that support students to leverage their personal and community knowledge to make sense of science phenomena and factors that contribute to injustice, including racialized systems of oppression (Bradford et al., 2023a; Visintainer, 2023).

The design of justice-centered science curriculum requires co-design participants to attend to students' science and justice ideas, including their ideas about issues of race, power, and systems of oppression (Morales-Doyle, 2017; Philip et al., 2016). At times, supporting student learning in these two areas can feel at odds. Science and other STEM fields have traditionally been situated as a set of subjects that are removed from ethical, moral, and racial considerations. This traditional perspective has trickled down into K-12 science teaching, including the NGSS science standards (Morales-Doyle, 2017; Vakil & Higgs, 2019). However, science, math, and technology are deeply interwoven into racial and social projects, facilitating systems of oppression and harm in some cases and providing avenues for impactful social change in others (Gunkel & Tolbert, 2018; Skloot, 2017). Curriculum ought to include issues of social justice, as they are interwoven with scientific progress and applications of science to real-world problems. However, designing justice-centered science curriculum requires repeated conversations and co-design sessions that attend to balancing student learning goals that might be in tension with one another, such as goals set by the NGSS standards and justice-centered learning goals. Previous research has highlighted how RPPs have leveraged co-design to address design tensions that arise during the co-design of math and science education (Johnson, 2016; Penuel et al., 2022; Penuel et al., 2025; Tatar, 2007). In this chapter, I discuss how the RPP navigated and attended to a specific design challenge that arose related to supporting students' learning with the design of the justice-centered science units: persistent challenges in supporting students to integrate complex justice ideas. Supporting students to integrate justice ideas was not a streamlined process. It involved balancing goals and ideas related to unit foci, activity structures, and facilitation. Navigating this tension resulted in different "as created situations" (Tatar, 2007), including activities that named social justice factors and supported students to distinguish ideas and changes to teachers' facilitation that further centered social justice ideas.

I investigate how participants in an RPP collaborated to design and refine two justice-centered science units that center public-health-related Social Justice Science Issues: the disproportionate impact of the COVID-19 pandemic on communities of color, and the story of Henrietta Lacks. The refinement of the two units occurred over three years and involved three

iterations of each of the units. RPP Participants engaged in a variety of co-design activities focused on supporting collaboration between participants in ways that centered on frameworks that informed our vision, Knowledge Integration pedagogy, and Justice-centered Science Pedagogy. This chapter focuses on one design tension that arose during co-design: persistent challenges in supporting students to integrate complex justice ideas.

- How did the co-design team refine the unit to support students in integrating justice ideas to explain public-health-related SJSI?
- How did these changes impact students' Knowledge Integration?
- What continued challenges persist in supporting students to integrate justice ideas to explain public-health-related SJSI?

Background

Supporting Students to Integrate Science and Justice Ideas

Over the last several years, educators and researchers have worked to create NGSS-aligned science curricula that center on localized Social Justice Science Issues (SJSI) and support students to integrate their understanding of science concepts and social justice issues. Several authors have outlined the successes of integrating SJSI into science instruction in classrooms and STEM-focused summer or afterschool programs. For example, connecting STEM content with local social justice issues such as environmental racism and lead pollution (Morales-Doyle, 2017), water justice (Davis & Schaeffer 2019), and local public health issues (Upadhyay et al., 2020) support students to learn NGSS aligned STEM content, develop an understanding of sociopolitical factors related to justice issues, and take activist stances to serve and support their communities. These designs allow students to bring together science, community, and justice-related ideas (including ideas about race and power) and position students as experts who can leverage these ideas to contribute to community-based solutions to SJSI (Morales-Doyle, 2017). These authors show us the successes of science curriculum that center SJSI, and how certain curricular products, when coupled with justice-centered teaching practices, support robust student learning, identity development, and ally ship (Barton & Tan., 2020; Billings et al., 2023; Davis & Schaeffer, 2019).

Several challenges in supporting students' justice-centered STEM learning have been identified. Supporting students to think beyond person-person bias or racist actions of individual actors to consider macro sociopolitical processes that contribute to oppression continues to be a persistent challenge for educators and curriculum designers (Rubel et al., 2016; Visintainer, 2023). Students' perceptions of Black and Brown bodies informed by experiences and learning beyond the classroom interweave with their ability to reason about the impacts of SJSI on communities of color, sometimes leading to harmful or deficit framings (Philip et al., 2018). Broadening the scales when discussing the impact of oppression on SJSI (such as inequitable health outcomes related to climate change) is key to understanding how racial projects impact the lives of everyday people and communities of color (Omi & Winant, 2014). Curricular units must support students to sort through their ideas to come to more robust understandings about these phenomena and how systems of oppression impact communities and individuals of color at multiple scales, while also pushing students to move beyond deficit framings of communities and individuals of color.

Given these challenges, teachers need support in creating relevant, justice-centered science curricula to meet justice-centered teaching goals. Communities where educators, curriculum designers, and other experts come together to co-create justice-centered STEM curriculum present a unique opportunity to support curricular design and teacher learning. These spaces afford

opportunities for teachers to get the support they need to implement justice-centered curriculum and for researchers to get valuable insight and feedback on curriculum from educators who will use the materials in their classrooms and are connected to their school communities. This study examines how an RPP created opportunities for participants to wrestle with how to support students' integrated understanding of justice ideas, including how the team addressed tensions as they arose, and continued questions for scaffolding students' learning.

Overview of Science and Justice Ideas in Curricular Units

The participants in the RPP had two major shared goals around the design of these units: to support students in integrating their ideas about science and social justice and to center localized SJSI within the science content. These goals supported participants in aligning their work with one another, particularly in the science and justice ideas we were hoping to support students to integrate with their prior learning and community knowledge to explain the two SJSI. Table 6 outlines the ideas that were addressed in the final version (Revision Two) of the unit. Our shared goal of supporting students' justice-centered science learning guided our work. In this chapter, I focus on how the RPP refined both of the units to support students in integrating complex justice ideas and the challenges that the RPP is continuing to address as we work to refine the designs.

Table 6

Relevant Science and Justice Ideas Used to Explain the SJSI in Each Unit

Unit	SJSI	Science and Science Practice Ideas	Justice Ideas
COVID-19, Data Science, and Equity	The inequitable impact of the COVID-19 pandemic on communities of color in California and the Bay Area	-Health factors that contribute to COVID-19 outcomes (age, pre-existing conditions) -Infectious diseases -Vaccination and disease prevention -Data Analysis and -Graphing (generating questions, choosing appropriate variables and graphs) -Interpreting data and graphs	-Ability to identify differing impacts from data and graphs on communities of color -Access factors that contribute to COVID-19 outcomes (affordability and availability of healthcare) -Racialized policies related to the distribution of health resources and community divestment -Economic and job impacts -Health and vaccination policy

Genetics and Henrietta Lacks	The story of Henrietta Lacks and issues of medical racism and data privacy in healthcare	-Medical research practices (sample size, informed consent) -Contributions of HeLa cells to medical research -Reading and understanding consent forms and research overviews -Cell division in healthy cells -Cell division in cancer cells -HPV vaccines and cancer prevention	-Bodily autonomy and consent -Research ethics and medical care -Bias in medical care (institutionally and individually) -Segregation and segregated medical care in the 1950s -Doctor-patient respect -Patient Advocacy -Doctor-patient matching and cultural understanding
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Methods for Analyzing Student Work

Chapter 2 outlines the data sources and analysis of co-design data to identify overarching design tensions. However, a unique analysis of student data related to a specific assessment item, the *Impacts* item, is outlined here as a measure of how Revision Two of each unit supported students to integrate their science and justice ideas.

***Impacts* Assessment Item:** Each unit had an accompanying assessment item, called *Impacts*. The item asks students to explain how a certain SJSI impacts people differently. For the COVID-19 unit, the item asked students, “Do you think all people are impacted by COVID-19 the same way? Explain your answer.” For the Henrietta Lacks unit, the item asked students, “Do you think everyone is equally likely to have the privacy of their health data respected by others who have access (ex, doctors, researchers, companies) to that data? Why or why not?” Each of these assessment items calls on students to link science ideas to explain the inequitable impact of the SJSI. For example, students can link science ideas related to pre-existing conditions, age, and viral transmission with justice ideas such as access and proximity of healthcare, affordability of healthcare, and the divestment of health infrastructure in communities of color to answer the COVID-19 *Impacts* question. For the Henrietta Lacks unit, students can link science ideas related to research practices and health to justice ideas about segregation, privacy, and medical racism. The *Impacts* item was given as a pretest and posttest assessment during all three versions of the unit. For the Pilot and Revision One, the results from the *Impacts* post assessment are discussed in the context of the co-design narrative of each unit, but not analyzed in depth. The *Impacts* item in Revision Two is analyzed in more depth to evaluate how each of the refined units supported student learning. The data corpus used in this final analysis came from two participating teachers at two school sites who used Revision two of both the COVID-19 and Henrietta Lacks units (Table 7). Students who did not answer both the pre- and post-assessment for each item were removed from the sample, resulting in 120 students for the COVID-19 *Impacts* item and 111 students for the Henrietta Lacks assessment item.

Table 7*Participating Classrooms Used in Revision Two Impacts Analysis*

School	Teacher	Grade Level	N COVID <i>Impacts</i>	N HeLa <i>Impacts</i>	School demographics
Forrest	Elaine	9	66	53	Hispanic/Latino, 21% Black, 14% AAPI, 13% White, 10% 2+, 2% not reported 73% free and reduced lunch
Valley	Beatriz	9	54	58	42% White, 29% Hispanic/Latino, 15% AAPI, 13% 2+ races, 2% Black 22% Free/reduced lunch

Revision Two Analysis: Each assessment item has an accompanying Knowledge Integration assessment rubric (Liu et al., 2008) used to score students' responses to the assessment item. KI rubrics reward students for linking ideas together, rather than the correctness of specific ideas. KI rubrics score student responses on a 1-5 scale, with higher scores indicating more links between ideas. Students are not penalized if their response contains a mix of accurate and inaccurate or non-target ideas. Table 8 outlines the KI rubric for the COVID-19 *Impacts* assessment item, and Table 9 outlines the KI rubric for the Henrietta Lacks assessment item. I hand-coded each of the responses, as I had previously been trained on each of the assessment items during their development.

Table 8
COVID-19 Impacts Item KI Rubric

Item prompt: Do you think all people are impacted by COVID-19 the same way? Explain your answer.

Target ideas (Categories of ideas that explain whether or not all people are impacted by COVID-19 in the same way)		
• Health Factors (pre-existing conditions, age, vaccination status, specific differences in health impacts) • Access Factors (affordability of healthcare, medication, PPE, or vaccines; availability of quality healthcare, medication, PPE, or vaccines) • Social Factors (Race/ethnicity, SES, Loss of job, increased exposure due to job, housing, etc.) • Policy Factors (specific policies that impacted COVID-19 outcomes)		
KI score	Criteria	Example Response
1	No answer, irrelevant, I don't know	I don't know
2	On topic but non-normative All people are impacted in the same way Normative but vague (without explanation)	Yes, COVID-19 impacted all people the same because they had to wear masks and stay away from each other for 6 feet.
3	Partial link: One target idea	No, I think that different people are affected differently than others. Like a healthy little kid would not have the same reaction to COVID as an unhealthy elderly. The child would most likely be unaffected by the virus. The elderly person would be impacted very greatly and might even die. (<i>Health Factor - Age</i>)
4	Full link: Links two target ideas	No, some people don't have good access to help, tests, vaccines, or medical centers (<i>Access factor</i>), and might have to interact with a lot of people if they have a frontline essential job (<i>social factor - increased exposure</i>)
5	Full links: Links three or more target ideas	No, not all people are impacted by COVID-19 in the same way. Many factors contribute to the impact of COVID-19 on different communities, including age, location, occupation, and race. Age can contribute because, while younger people are more vulnerable to getting COVID because they are exposed more (what with jobs, school, etc.), older people are more likely to be impacted more by it (they have a higher death rate) (<i>health factor - age, social factor - increased exposure</i>). Location matters also because where you live and work affects your access to healthcare, and sometimes how close you are to the nearest hospital is the difference between life and death (<i>Access factor - availability of medical care</i>). Occupation affects the impact of COVID because if you have a job where you're more exposed to COVID and can't work from home, you are more likely to catch COVID (<i>social factor - increased exposure</i>). Finally, race affects the impact of COVID because, since there is a lot of bias and racism in our community, communities of color end up being more at risk of COVID (<i>social factor - Race/Ethnicity</i>).

Table 9*Henrietta Lacks Impacts Item KI Rubric*

Item prompt: Do you think everyone is equally likely to have the privacy of their health data respected by others who have access (ex, doctors, researchers, companies) to that data? Why or why not?

Target ideas:

- Violations of consent, trust, or privacy by medical providers or medical companies
- Practices that protect an individual's privacy
- Biases of individual medical providers
- Henrietta's story or Eric's story as illustrative examples
- Societal factors (ex, systemic racism) lead to POC or low SES being less respected by medical providers
- Human error and/or data leaks due to mistakes or under-resourced medical providers.
- Doctor-patient matching and cultural understanding

KI score	Criteria	Example Responses
1	No answer, irrelevant, I don't know	I don't know
2	On topic but non-normative All people are impacted in the same way Normative but vague (without explanation)	Everyone should respect patients' privacy equally. Why wouldn't you?
3	Partial link: One target idea	No, some black people and people of other ethnicities and races do not have their privacy respected by doctors. (<i>Biases of providers</i>)
4	Full link: Links two target ideas	No, because of inherent bias in healthcare providers (<i>Biases of providers</i>). One example of this is when Henrietta Lacks had her cells taken without consent, in which her skin color may have contributed to the decision (<i>Henrietta's story</i>).
5	Full links: Links three or more target ideas	I think that not everyone is equally likely to have the privacy of their health data respected by others, because, as seen with Henrietta Lacks, researchers sometimes take samples and information without letting you know or asking for consent (<i>Henrietta's story, violation of consent</i>). Even though it was a while ago, the fact is, doctors/health professionals can often be biased, which will cause different levels of respect towards privacy, as seen with the graphs in 6.3 (<i>Biases of providers</i>).

After scoring student responses, I calculated average scores for the pre-test and post-test for each unit to see if there were differences in KI between pre- and post-test scores. Then I conducted a paired T-test to test whether the change in average KI from pretest to posttest was statistically significant (Moore et al., 2012).

Results

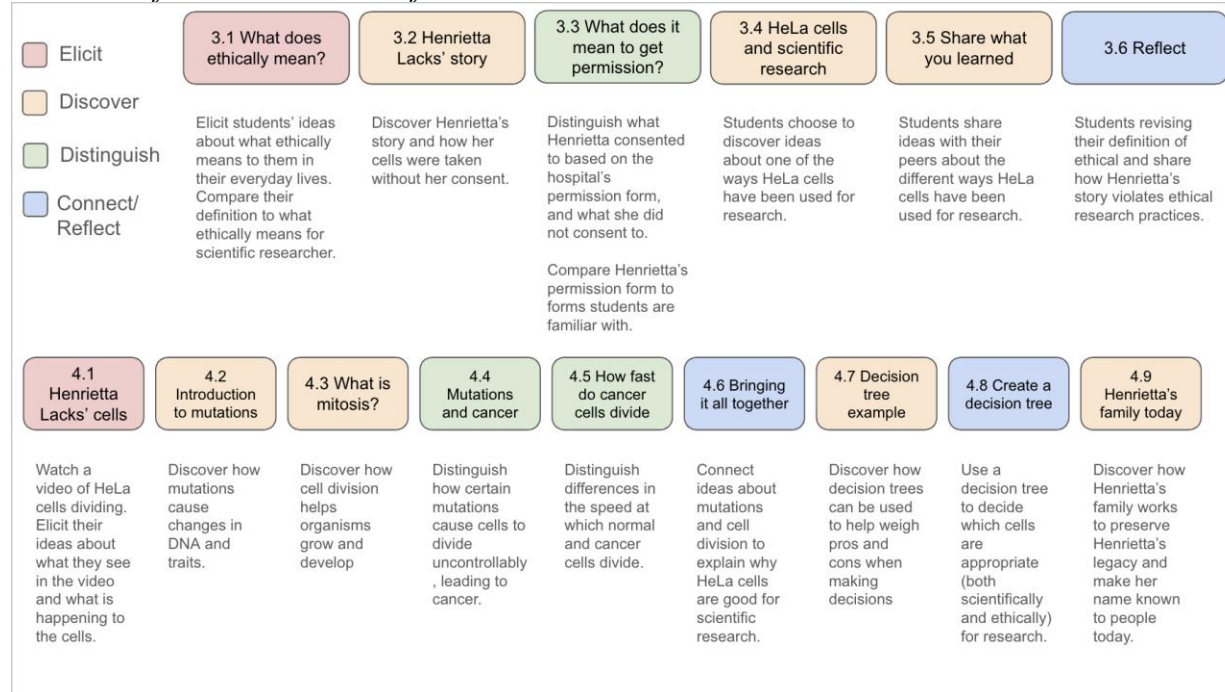
Students had challenges integrating their ideas about science and justice in both the Henrietta Lacks and COVID-19 units. In the Henrietta Lacks unit, students needed more support to consider how racialized systems play a role in receiving quality medical treatment, including how policies like segregation impact access to medical care. In the COVID-19 unit, students needed more support in moving beyond individual actions and health factors to integrate ideas about the limitations of health systems and access by race. Continued refinement of both the units and teachers' justice-centered instruction helped to better support students in integrating ideas in later iterations. Student work from the most recent iteration (revision two) indicates that more work is needed to continue to refine the units to support all students in integrating ideas.

In the two sections below, I outline how the tension was revealed and addressed in the co-design of each of the units and the RPP structures that supported participants to identify gaps in student understanding and work towards improving the unit and teachers' facilitation to better support students to integrate ideas. Teachers' open and honest reflection about their practice was especially evident in this tension, including their perceived limitations in their practice and desire to improve their ability to discuss race in the classroom. This resulted in major changes within both units.

Henrietta Lacks Unit

Pilot Design

The pilot version of the unit presented Henrietta Lacks' story as an example of unethical research practices and a violation of patient privacy and bodily autonomy in a larger conversation about ethical research. The broader scope of the two justice-centered lessons in the unit focused on ethical research practices, and two steps of the unit centered on Henrietta's story and used an open educational resource (a video from the *Immortal Life of Henrietta Lacks* book tour featuring the author of the book and Henrietta's family) to help students discover how racial policies such as segregation limited her and other Black patients' access to care (See Figure 6 for pilot version lesson overview). Unit scaffolds focused on supporting students to discover the general narrative of what happened to Henrietta, rather than focusing specifically on the role of structural systems of oppression in health care. This led to limited engagement with race and justice ideas central to Henrietta's story.

Figure 6*Overview of the Pilot Version of the Henrietta Lacks Unit***Pilot Implementation Findings**

Upon reflection, the co-design team acknowledged a missed opportunity to center race and racial policies within the unit and support students to distinguish how Henrietta's identity as a Black woman and policies like segregation led to the violation of her rights. In focusing on science ideas, in this case, research ethics and the role of scientists in making ethical and scientific choices when conducting research, students were provided limited opportunities to discover and distinguish between justice ideas, including ideas about race and racial policies. See Table 10 for an overview of findings from the pilot implementation.

Table 10*Summary of Findings From Pilot Implementation of the Henrietta Lacks Unit and Resulting Revisions to Revision One*

Data Source (participants)	Summary of findings	Planned Revisions
Online web-based unit	While the unit created opportunities for students to discover how race was a factor in Henrietta's story (Step 3.2), it did not provide students enough opportunities to distinguish how racial policies (like segregation) impacted her access to care.	Henrietta's story is revised to include an increased emphasis on the role of segregation and racist medical practices in Henrietta's story, including how healthcare was segregated in the 1950s and how

Observations from unit implementation (Lead researcher, Gregory, Gregory's students)	No evidence of discussions (whole class or student to student) of systemic or race-based justice ideas. Gregory missed opportunities to support students in reasoning about racial justice in relation to Henrietta's story.	Henrietta's only option for medical care was going to a public ward. Language about the role of segregation is refined based on teachers' feedback from the workshop.
Student work, <i>Impacts</i> item (Gregory and Jaime's students)	Average KI score on posttest <i>Impacts</i> question: 2.99. On average, students used one idea to answer the <i>Impacts</i> question and did not connect ideas to answer the question. Most students discussed science ideas. Only one student discussed race and racism as aspects of Henrietta's unfair treatment. Overall, students did not connect ideas about racial injustice and racist policies to answer the <i>Impacts</i> question.	Stop and Talk was added to the unit to prompt teachers to hold a class discussion about medical racism and Henrietta's story.
Teacher Interview (Lead Researcher and Gregory)	Gregory felt that the unit needed a larger focus on racial justice in Henrietta's storyline. He reflected that his facilitation did not support students in making connections with racial justice. "I wish I had done a better job with [focusing on race]. I think you saw some stuff come out. There were some moments where [students] were making the link. Like, oh she's Black, I heard kids say that... like it's more than just they took her cells." (<i>HeLa</i> pilot post-interview, 6/6/2022)	
Workshop (2 researchers, 6 teachers)	During unit prototype discussions, RPP discussed how to build on initial changes made by the lead researcher to better emphasize segregation in Henrietta's story. Teachers discussed how they might customize the unit or hold discussions in their classrooms to address race and racism while teaching.	

The focus on the role of the researcher and conducting ethical research, rather than race, was reflected in the types of classroom conversations that were documented in the observation field notes from Gregory's classroom. My field notes did not contain any evidence of discussion of Henrietta's identity or the impact of medical racism on her story between students. Gregory's conversations with students also did not center on race, instead focusing on other justice ideas, such as defining consent as a class (See Table 11 for a transcript from observation field notes) and on how researchers might make decisions about which cells to use for research, given scientific and ethical constraints. Though race is central to Henrietta's story, the framing of the unit, which was taken up by the teacher, de-emphasized the role of race, particularly racist policies (justice ideas), to emphasize the role of individual choices made by doctors and researchers (science ideas).

As a result, race and racial policy went undiscussed. Gregory noted that he missed opportunities to center race during his post-interview, though he felt some students were making the connection.

I wish I had done a better job with [focusing on race]. I think you saw some stuff come out. There were some moments where [students] were making the link. Like, oh she's Black, I heard kids say that... like it's more than just they took her cells. (HeLa pilot post-interview, 6/6/2022)

These findings highlighted initial limitations in the unit in supporting students to bring together their science and justice ideas.

Table 11

Transcript From the Pilot Implementation of the Henrietta Lacks Unit in Gregory's Classroom. Pilot Observation Field notes, 5/18/2022.

Turn	Speaker	Transcript
1	Gregory	What does it mean to give consent?
2	Student 1	Like permission. Permission to do something.
3	Gregory	Permission. Ok, does anyone want to add on? Is it just as simple as permission?
4	Student 2	When I first heard the word, it means the right to do something (inaudible). But otherwise, it means someone allowing something. Like use their computer or pencil.
5	Gregory	It can be permission. But it can be more formal. What is that about?
6	Student 3	A waiver. Like paper stuff involved to give your consent. Like, if you can go to a place, a field trip.

The focus on science ideas, rather than the integration of science and justice, was reflected in students' written responses to the *Impacts* assessment question at posttest. On average, students only expressed one idea in their responses (see Table 10), rather than demonstrating integrated understanding by linking ideas. While many students expressed ideas related to the SJSI, they were mostly science ideas (for example, the importance of asking for consent when conducting research or the role of doctors and researchers in protecting patients). While certain justice ideas were present (the right to free healthcare, concern about implications for Henrietta's family and descendants), only one student discussed race, and this idea is disconnected from any ideas related to policies or systems that lead to discrimination in medical care ("I'm assuming that since she was a Black woman, they would have taken her cells even if she didn't give consent to it. I don't think it was right for them to take her cells without an agreement with her"). While students had ideas related to patient privacy, specifically ideas about why taking Henrietta's cells was wrong, they were not connecting those ideas to ideas about how discrimination and racism impacted the medical treatment of People of Color. This reflected the limited support and focus on race within the unit and in Gregory's facilitation. Initial unit changes (see Table 10) sought to address these limitations.

In summary, early iterations of the pilot version of the Henrietta Lacks unit did not support students to consider how Henrietta's identity as a Black Woman impacted how she was treated by medical professionals, and few students considered race when integrating their ideas about her

story. Gregory's reflection about his enactment of the unit and field notes highlight how there were several missed opportunities to support students to reason about how race and racial policies impacted Henrietta's access to care and treatment. Student work indicates that students were unsupported to integrate justice ideas, particularly those about race and racialized systems of oppression, into their understanding.

Refinement and Revision One Design

These findings led to an updated prototype, which was presented to the larger RPP at the following workshop. The RPP workshop served as an important space to facilitate the refinement of new unit activities designed to help students distinguish among justice ideas and to provide teachers with space to discuss how they might facilitate discussions about race in their classrooms. Unit prototype discussions were key to eliciting teacher feedback on changes, particularly regarding increasing the emphasis on the role of segregation in determining who has access to medical care. For example, one teacher highlighted how changes in unit language might shift the conversations students could have in class about Henrietta's story.

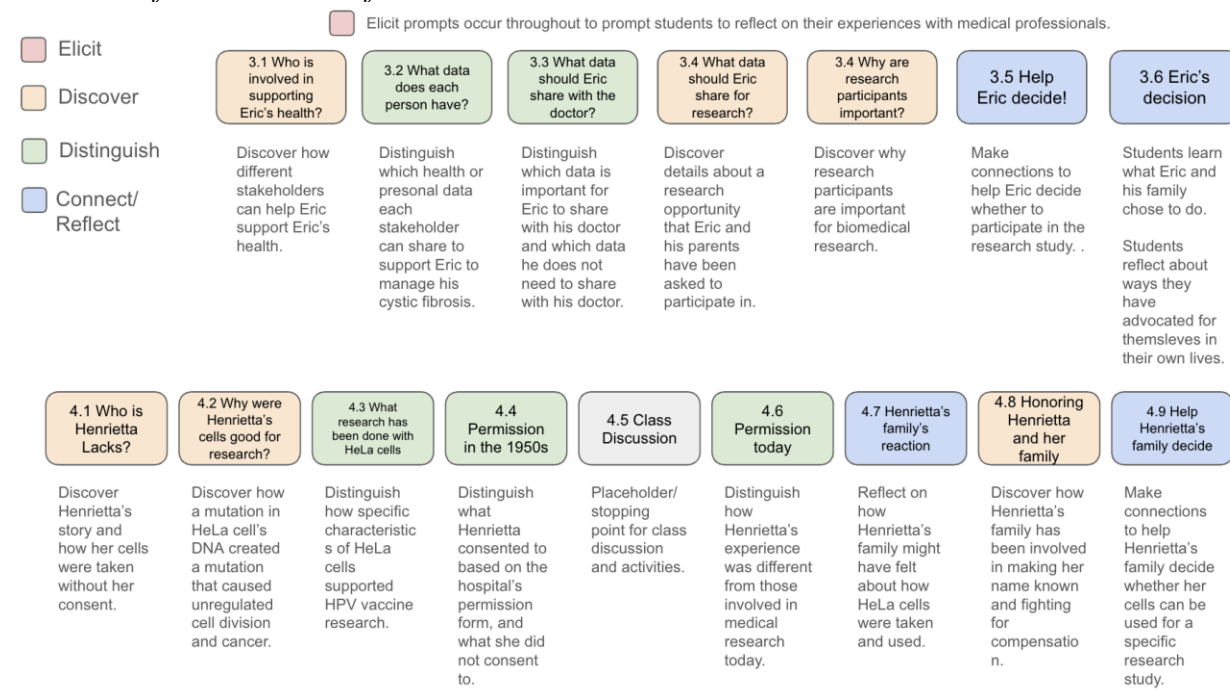
I wonder what conversations this can bring up [references new unit language about segregated public wards]. Students can share thoughts and ideas on what was problematic about this and who it affected. Maybe bringing in data of who is accessing free public wards, and reference race. (Workshop field notes, 1/21/2023)

Overall, teachers viewed these changes as positive, and the unit prototype served as an anchoring resource to ground their thoughts and wonderings about supporting students to integrate justice ideas.

Unit prototype discussions also served as a collaborative space for teachers to begin discussing unit facilitation and unit customization. As with the feedback, having a concrete resource (the unit prototype) was important for anchoring the discussion. Teachers focused on the teacher's role in creating opportunities for students to discuss and distinguish their ideas about race and systems of oppression. "I would personally do it as a class. Like we're going to sit around and talk about it. But I guess having a segue in that unit of like OK, now you're going to talk with your class." (Workshop field notes, 1/21/2023). Their ideas prompted an additional change to the unit (addition of a stop-and-prompt that instructed students to pause for a class discussion) to help guide teachers and signal when important conversations should happen to help distinguish justice ideas. The prompt occurred after the steps focused on supporting students to discover how segregation impacted Henrietta's care (Figure 6). Though teachers' conversations during the unit prototype discussion focused on discussing their own teaching with colleagues, their discussion inspired additional changes to the unit to help guide and support teachers' justice-centered STEM instruction while using the Henrietta Lacks unit.

These changes resulted in a revised unit that further emphasized the role of segregation and race in Henrietta's story, while also prompting teachers to tackle justice ideas with students in their instruction. Figure 7 outlines the flow of Revision One. Steps 4.1, 4.4, and 4.5 specifically addressed justice-centered ideas regarding how racial policies impacted Henrietta's access to healthcare and mistreatment, with 4.1 and 4.4 supporting the discovery of ideas, and the stop-and-prompt activity in 4.5 supporting students to distinguish justice ideas in Henrietta's story.

Figure 7
Overview of Revision One of the Henrietta Lacks Unit



Revision One Implementation Findings

Changes to the unit design and the addition of the stop-and-prompt created opportunities for students to share ideas and distinguish between different justice ideas. Students in several classrooms demonstrated engagement in justice-related ideas in verbal discussions that occurred between students while they worked on the web-based unit or during larger class discussions that were facilitated by the teacher (See Table 13 for an overview of findings). Teachers took a more active role in facilitating the unit. Gregory, Elaine, and Beatriz were observed holding class discussions after the stop-and-prompt step (and for Gregory and Elaine, at additional points within the unit). While not observed, Jaime and Lacey later reported that they also held a class discussion. Teachers focused on a variety of justice ideas during the discussion, including patients' rights to privacy and bodily autonomy (Gregory, whole class discussions), students' ideas about the meaning of consent (Gregory and Elaine), and empathizing with Henrietta and her family (Gregory, Elaine, and Beatriz). Gregory and Beatriz specifically focused on race-related ideas, including defining and distinguishing the impact of segregation and connecting Henrietta's story to racial justice issues today. Table 12 captures observation field notes from the discussion in Beatriz's class. While not all students participated in the verbal discussions, and my notes did not capture the ideas of all students, students across classrooms shared justice-related ideas.

Table 12

Transcript From Revision One Implementation of the Henrietta Lacks Unit in Beatriz's Classroom. Revision One Observation Field notes, 3/10/2023.

Turn	Participant	Transcript
1	Beatriz	Asks a student to read question one (What is a public ward?) and provide an answer.
2	Student 1	What is a public ward... it treats people who can't... It's a hospital.
3	Beatriz	(to the class) Do you agree? Is it a hospital?
4	Students	Most students raise their hands.
5	Beatriz	Public wards are hospitals where you don't have to pay, a free hospital. Prompts students to read question two (Who is more likely to use a public ward?) and prompts a student to answer.
6	Student 2	(Reads question 2). Poor people
7	Student 3	People used it during the time of segregation.
8	Beatriz	Who was using it then?
9	Student 4	People of color
10	Beatriz	Right, people of color, Black Americans, weren't allowed to use the other hospitals because of segregation, so they went to public wards.

Table 13

Summary of Findings From Revision One Implementation of the Henrietta Lacks unit and Resulting Revisions to Revision Two

Data Source (participants)	Data/Examples	Summary of findings	Planned Revisions
Online web-based unit	Unit changes provided students more opportunities to distinguish between justice ideas related to Henrietta's story (Step 4.4) and encouraged teachers to hold discussions in their classrooms that centered on race to support students in distinguishing and connecting ideas (Stop-and-talk prompt on step 4.5).		An additional graph reading activity was added after Henrietta's case to support students in discovering how inequities in medical care continue to exist today. Activity included graphs on cultural respect, involving patients in decision making, and doctor/patient match
Observations from unit implementation (Lead researcher and Gregory, Jaime, Elaine, Beatriz, Lacey, and their students)	The stop-and-talk prompt signaled to most teachers to hold class discussions and was supportive in scaffolding teachers' facilitation. Gregory, Elaine, Beatriz (observed), Jaime, and Lacey (reported) enacted customizations at the stop and prompt step. Gregory and Beatriz's customizations attended to the role of medical racism and racist policies in Henrietta's story. Students shared justice ideas related to race and racial policy.		Add a step focused on comparing and contrasting Eric and Henrietta's cases, including practices or

	Not all teachers emphasized medical racism and segregation (Elaine), indicating that teachers need more support to have conversations about race in their classrooms.	policies that led to differences in experiences.
Student work, <i>Impacts</i> item (Gregory, Jaime Elaine, Beatriz)	Average KI score on posttest <i>Impacts</i> question: 3.05. This score is similar to the pilot. On average, students used one idea to answer the <i>Impacts</i> question and did not connect ideas to answer the question. More, but still few students (n=7) express ideas about race and medical racism.	
Teacher Interview (Lead Researcher and Gregory, Elaine, and Beatriz)	Teachers continued to grapple with how to emphasize segregation and racist policies in Henrietta's story and how to integrate other topics related to her story into conversations about race. "There are so many different ways to go into her story. Like what did segregation look like? or what... for you to go into specifically bioethics. I think it's a good way to bring the message home for students about what consent was in the past and what we're building towards." (Elaine, <i>Hela</i> Revision one post-interview, 3/27/23)	
Workshop (lead researcher and Gregory)	Gregory and the lead researcher engaged in focused co-design work together. Gregory sought to support students in contrasting cases in the unit (Eric, Henrietta) to support students in distinguishing justice ideas "Maybe we need a clearer comparison. How do different situations affect people's access or lack of access?" (Workshop field notes, 6/16/2023)	

Students' written answers to the *Impacts* question at post-test still indicated limited integration of race-based ideas, despite additions to the unit and evidence of students engaging with race-related ideas during classroom discussions. Only seven students discussed race-based ideas in their written explanations. Additionally, the average KI score across Revision One's cohort was similar to the pilot cohort (3.05), indicating that, on average, students were expressing only one idea in their explanation and not making connections between ideas. Though the unit and classroom discussions provided students more opportunities to engage in justice ideas, this did not translate to an increase in students integrating justice ideas into their written explanations. Though the RPP team felt that these issues were further emphasized in Revision One of the unit, it is clear that the unit needs improvements in supporting students to distinguish how larger systems of power and discrimination impact the treatment of different communities by medical professionals and researchers.

Post-interviews with participating teachers also indicated a need to continue to support teachers to enact justice-centered science instruction and facilitate conversations about race. Despite teachers' progress in creating opportunities to discuss race and justice ideas, teachers were concerned and unsure if they were scaffolding student learning correctly during conversations with students. For example, Elaine wanted guidance on what to focus on, given the variety of science (bioethics) and justice (segregation) conversations central to Henrietta's story.

There are so many different ways to go into her story. Like what did segregation look like? or what... for you to go into specifically bioethics. I think it's a good way to bring the message home for students about what consent was in the past and what we're building towards. (Elaine, *Hela* Revision one post-interview, 3/27/23)

The RPP activities, particularly RPP workshops, were an important place that could support teachers' development in this area. Continuing to provide teachers space to work through problems of practice with colleagues, reflect on their teaching, and identify resources from the unit or other places that can help them feel more prepared to scaffold students' justice-centered learning.

Implementation findings highlight how, despite changes to the unit and teachers' increased focus on justice in class discussion, students still needed more support in integrating justice ideas. Though teachers made progress in facilitating justice-centered conversations, they felt that continued support was necessary to improve their facilitation and identify salient justice ideas for themselves, given the complexity of Henrietta's story. These findings emphasize the continued need for refinement of the unit and support for partner teachers.

Refinement and Revision Two Design

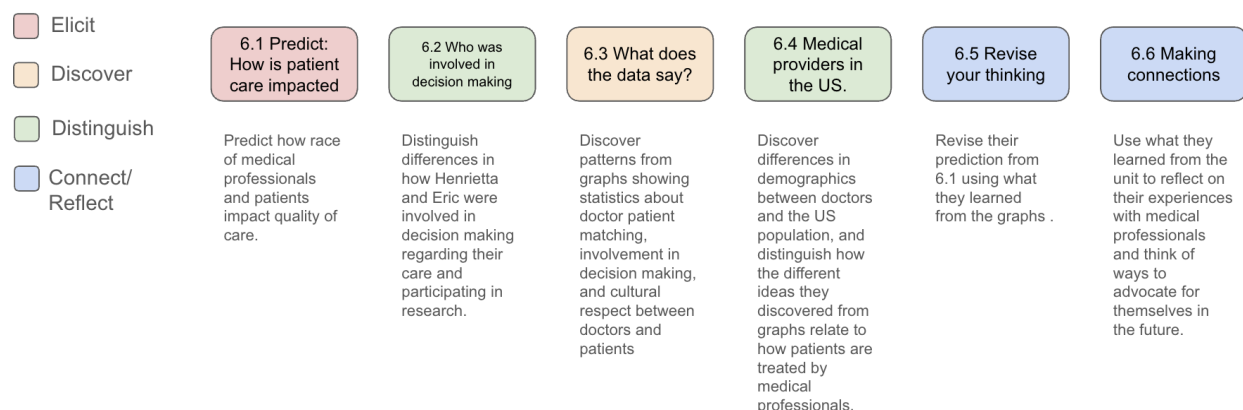
The subsequent workshop (summer 2023) provided space for Gregory and me to engage in deep co-design work to refine the unit. Gregory was the only teacher working on the Henrietta Lacks unit at the workshop, as other participating teachers did not attend or focused on units they were planning to use in the fall. At this point, Gregory had become an expert on the Henrietta Lacks unit as he had used both the pilot and Revision One, had acted as a leader during previous workshops, and was motivated to continue to improve the unit and his facilitation of justice-centered discussions in his classroom. (See Chapter 5 for a more in-depth analysis of his role in the RPP). We viewed Revision One together, and Gregory used his expertise and familiarity with the unit to suggest concrete revisions to support students in continuing to distinguish and connect their ideas. His feedback centered on creating more opportunities for students to make comparisons between Henrietta and Eric's stories. "Maybe we need a clearer comparison. How do different situations affect people's access or lack of access?" (Workshop field notes, 6/16/2023). Teacher expertise was key in providing concrete next steps for pushing the unit forward during the workshop, and Gregory was supported and empowered to provide his expertise during our discussion.

Initial changes made to Henrietta's story for Revision One were kept in Revision Two (4.1, 4.4, and the stop and prompt in 4.5), and I used Gregory's suggestions to inspire an additional scaffolding activity that highlighted how medical racism and discrimination in healthcare occur today (Figure 8). This provided additional opportunities for comparison (suggested by Gregory) and connected Henrietta's story to persistent issues of medical racism and data privacy (inspired by his discussions during Revision One implementation). Students engage with graphs that document differences in patient treatment by race, and prompts students to connect what they

discover from the graph to discuss how patient care is “impacted by the race of the patient and by the race of their doctor or nurse?” The activity specifically calls out race and asks students to distinguish racial justice ideas that they discover from the graphs.

Figure 8

Outline of the Additional Graph Activities Added After the Henrietta Lacks’ Case in Revision Two



Revision Two emphasizes racial justice ideas and creates multiple opportunities for students to distinguish racial justice ideas in Henrietta’s story (steps 4.1, 4.4, and 4.4) and distinguish how medical racism still occurs in medicine today (6.1-6.6). These revisions are the “as created situations” (Tatar, 2007) that resulted from the RPP team working together to better support students in integrating justice ideas. Progress in improving the unit involved examining multiple data sources (online web-based units, observations, student work, and teacher post-interviews), and teacher input was key in both improving unit activities and adding additional scaffolds to support teachers to engage in justice-centered discussions with their students. The Pilot highlighted some major gaps and missed opportunities, including major gaps providing students opportunities or support to discuss or write about race and racial policies. Revision One provided students with more opportunities and supported teachers to engage in more justice-centered science learning, but students needed more support to connect justice ideas in their written responses. The workshop following Revision One was a space for deep design work with a teacher with deep familiarity with the unit, and led to specific, detailed refinements and a new lesson that centered on medical racism today.

COVID-19 Unit

Pilot Design

The pilot version of the COVID-19 unit (See Figure 9 for an overview) positioned students as data scientists who could use publicly available data to tell stories about how the COVID-19 pandemic impacted their communities. During the first lesson, students were introduced to Data 4 Black Lives (D4BL) and the organization's founder. At the time, D4BL, a data advocacy organization focused on telling stories about the Black community in the United States, was using publicly available data to create a map to visualize the impact of the pandemic on Black communities across the United States. The map was integrated into the unit as an Open Educational

Resource, and quotes from an interview with the founder were used to help students discover how data science can be used to advocate for marginalized communities.

Figure 9

Overview of the Pilot Version of the COVID-19 Unit

Lesson 1: Data Collection and Variables	- Elicit student's ideas about the stories they want to tell about COVID-19 - Distinguish how challenges in collecting and using COVID-10 data	- Discover how D4BL uses data to tell stories about how the Black community is impacted by COVID-19 - Reflect on how challenges impact the stories you can tell using data
Lesson 2: COVID-19 trends overtime	- Elicit student's predictions about the changes in COVID-19 outcomes overtime - Distinguish how predictions and actual outcomes were similar or different	Graph data to Discover how COVID-19 outcomes changes overtime
Lesson 3: COVID-19 in populations and risk factors	- Elicit student's predictions about the differences in COVID-19 outcomes for demographic groups in one local county - Distinguish how environmental, economic, and pre-existing health factors impact COVID-10 outcomes	- Graph data to Discover differences in COVID-19 outcomes for demographic groups in one local county - Connect ideas to explain how different factors help explain trends discovered from the county data
Lesson 4: Using data responsibly	- Elicit student's ideas about how data can be used to help or harm communities - Distinguish between misleading and truthful data visualizations	- Discover how COVID-19 data has been used to inform targeted public health interventions for local communities - Connect ideas to propose one way students want to help their families or communities during the pandemic

Students then completed two data investigations. In the second investigation, students are given various demographic and COVID-19 variables to explore from their local community or other communities heavily impacted by the COVID-19 pandemic (see study two for a more detailed overview of these variables). However, limitations in available data at the time (2021) constrained the types of demographic or other factor variables that could be included in the data sets. This, in turn, constrained students' ability to explore factors beyond gender or race/ethnicity. To accommodate these limitations, the final lesson involved a jigsaw activity where students explored one of three factors that, at the time, public health officials focused on as underlying factors for inequitable COVID-19 outcomes. These factors included pre-existing conditions (health), frontline worker status (SES and ability to social distance), and household size (SES and ability to social distance). Open Educational Resources (articles, videos) were used to help students discover ideas about each factor. Students then shared what they learned with peers who explored different factors.

At the very end of the unit, students explored a local case study about vaccine distribution in a predominantly Black neighborhood in their area. This article highlighted how, despite specific programs seeking to support communities of color, challenges in logistics and follow-through in checking if recipients were actually from the neighborhood made it so that a large number of the vaccines went to predominantly white non-residents who drove in from other cities to acquire the vaccine. By including this case study, designers hoped students would discover ideas about a localized public health intervention that, while it had good intentions, highlighted inequities in access to care for Black residents and people of color more broadly.

Pilot Implementation Findings

Similar to findings from the *HeLa* implementation, field notes from implementation contained few examples of students or teachers centering race and racism as contributing factors to COVID-19

outcomes during conversation. Only Elaine explicitly called out the inequitable impacts of COVID-19 outcomes by race, centering the story told by D4BL. “We have this story here, this data scientist using her skills to launch D4BL. She’s seeing the data, seeing the impact, and wants to use it to make Black people’s lives better.” (Observation field notes, 8/16/2021). Beatriz and Gregory focused discussions with students on technical skills related to graphing and data analysis. Few students across the three classrooms investigated outcomes by race/ethnicity. Students in Gregory and Elaine’s classes discussed a variety of ideas as contributing factors to the outcomes they observed, including “social standing or access to healthcare” (Observation field notes, Gregory’s class, 9/15/2021) and location-based factors. For example, students in Elaine’s class noticed that “Texas has more cases for black people than everywhere else; COVID isn’t good for people like me there.” (Observation field notes, Elaine’s Class, 8/19/2021). However, these conversations indicated limited understanding and no teachers aside from Elaine provided structured opportunities for students to explore factors related to race. An overview of these findings and other findings from the pilot version of the unit can be found in Table 14.

Table 14

Summary of Findings From the Pilot Implementation of the COVID-19 Unit and Resulting Revisions to Revision One

Data Source (participants)	Data/Examples	Summary of findings	Planned Revisions
Online web-based unit	Steps 1.1-1.3 highlighted the work of Data 4 Black Lives (D4BL), an organization using data to uncover inequitable impacts of COVID-19 and gun violence on Black communities. Data sets focus on ethnographic variables available at the time (age, race/ethnicity) and case, death, and hospitalization rates. Limitations of available data sets and detailed information in the jigsaw activity (focused on factors like pre-existing conditions, frontline workers, and household size) allowed students to discover some relevant ideas but prevented them from distinguishing between the impacts of individual choice and systemic factors.		D4BL connection remains. Refinement of the unit was focused on the Data Sets, Data Explorer, and data investigation scaffolding activities. Data Sets and Data Explorer: Data sets were expanded to include additional variables related to underlying factors that contribute to inequitable COVID-19 outcomes (exposure, healthcare access and affordability, job loss, and pre-existing conditions).
Observations from unit implementation (Lead researcher, Teachers Gregory, Elaine, Beatriz) Implemented but not observed: Jaime	Across classrooms, some student groups examine differences in impact by race in their data investigations. Elaine has the most students who investigate COVID-19 outcomes by race. Some of Gregory and Elaine’s students begin to reason about why differences exist. Beatriz’s students show no evidence. Gregory and Beatriz’s support for students focuses on scaffolding the technical skills required for graphing and data-based investigations, not justice-centered content. Elaine scaffolds technical skills required for data-based investigations and directly engages students in		Data explorer: No major changes to the capabilities of the data explorer Steps 3.7-3.9 removed

conversations about race, including discussing D4BL, highlighting differences in outcomes by race in the data, and limitations of data in capturing stories from communities.

Student work,
Impacts item
(Gregory, Jaime,
Elaine, Beatriz)

Average KI score on posttest justice question: 2.87. On average, students used one idea to answer the *Impacts* question and did not connect ideas to answer the question.

Most Students discussed individual choice factors (getting vaccinated, choosing to mask) and individual health factors (age, pre-existing conditions) or listed factors but did not explain them. The list of factors often reflected the topics of the jigsaw activity with no explanation.

Some deficit framing in students' responses.

This suggests that students did not connect ideas about racial injustice and systemic factors to explain COVID-19 outcomes, instead focusing on individual choice or listing unexplained factors.

Teacher Interview
(Lead Researcher
and Teachers,
Gregory, Jaime,
Elaine)

Teachers felt that students were not linking ideas, particularly ideas related to race and justice (Gregory, Jaime, Elaine). Teachers felt that students' responses reflected their limited understanding (Elaine) or possible ideas they were exposed to before the unit (Jaime).

Workshop (2
researchers,
Gregory, Elaine,
and an additional
teacher who ended
up not using the
unit)

Teachers review student work and bucket responses by KI. Teachers come to similar conclusions to interviews: Students are limited in their ability to link ideas, and few include justice-related ideas.

Teachers discuss potential impacts not included in responses, which reflect limitations of the data sets (ex, essential worker status and exposure).

Teacher Research
Internship (1
researcher, Elaine)

The teacher and Elaine curated data sets based on newly published data and student interest. Student interest was gauged by categorizing students' responses to a question embedded into the pilot version that asked students, "What story do you want to tell about COVID-19?"

Curated data sets included variables like vaccination status, job loss, essential worker status, and distribution of pre-existing conditions. Data sets also include demographic information (age, gender, race/ethnicity, and poverty levels).

Student work from the pilot implementation also pointed to students' limited ability to integrate ideas about race, likely because of the lack of support from the unit and teachers' facilitation. At posttest, the average KI score for the *Impacts* item was 2.87, indicating that most students had an incomplete or one complete idea related to the impact of the COVID-19 pandemic. This was not a statistically significant difference from the pretest. Students emphasized individual choices (such as social distancing or choosing to wear a mask) age, or health factors ("I think that COVID does not affect everyone the same because if you are older or have a certain health condition, I feel like it would affect you more") in their answers, rather than how systemic inequities in access to care and exposure to COVID-19, to explain how communities were disproportionately impacted by the COVID-19 pandemic. Others mentioned or listed factors from the data sets or the jigsaw without further elaboration ("They are not due to factors like employment, age, weight, gender, race, and more"). These responses indicated a limited understanding of how factors worked together to impact COVID-19 outcomes, particularly for marginalized communities.

Elaine, Gregory, and Jaime participated in post-implementation interviews, during which we reflected on students' responses to the *Impacts* assessment. All three pointed to a positive outcome: most students stated that people were impacted differently by COVID-19. They highlighted how students had a wealth of ideas about how SJSI are connected to health-related variables and individual choices, but very few suggested system factors such as access to healthcare and differences in exposure. Elaine specifically mentioned students' superficial understanding of race as a contributing factor to their low KI scores. "Their ideas about race are so superficial where they're not getting the nuances behind it. I don't quite know how to address that... like make it work for them." (Elaine, *COVID-19* pilot post-interview, 9/16/2021). Jaime highlighted how her students appeared to be using mostly their prior knowledge to answer the question, rather than integrating this knowledge with what they learned from the unit activities and data sets. "A majority of them think that it would just be things like age or pre-existing conditions because that was the stuff that you know is big in the media" (Jaime, *COVID-19* pilot post-interview, 10/1/2021). Teachers examined student work further in the following workshop, using a Knowledge Integration rubric to help sort and discuss student responses with their colleagues. Teachers shared similar ideas to what was said in interviews (Workshop field notes, 6/14/2022). Students had ideas related to health or age ("Students made comments about pre-existing conditions, some access to healthcare," Gregory), but were missing ideas related to race ("They're not mentioning race," Elaine), or the impact of exposure due to essential worker status ("I'm not seeing anything about exposure. If you have to go to work, or are an essential worker," additional teacher). These insights from teachers on their students' learning indicated that while the unit supported students to discover that certain communities were impacted differently, students needed more support to integrate ideas about macro-scale racial policies and structures that lead to inequitable outcomes, specifically for communities of color.

Refinement and Revision One Design

I worked closely with Elaine, who was participating in a summer research internship with the RPP, to refine the unit to address teachers' feedback, including feedback aligned with supporting students to integrate justice ideas. Several changes were made to the unit, which are outside the scope of this study but outlined in Figure 10 below. To address students' justice-centered learning, Elaine and I focused on curating new data sets that could support students to

investigate a broader list of factors that attended to some of the justice ideas missing from students' explanations in the pilot, including differences in exposure to COVID-19 due to socioeconomic status, jobs, or other factors, and access to or affordability of healthcare. Data sets in the pilot implementation were limited to COVID-19 outcomes (including cases and deaths) and basic demographic variables due to limitations in publicly available data at the time. As a result, students were limited in their ability to investigate the impacts of COVID-19 beyond simple summaries of which demographic groups had the highest case or death rates. While these data sets could support students to see that different racial/ethnic groups had different COVID-19 case and death outcomes, the data did not help them to explore why these trends in the data existed. Elaine and I spent the summer of 2022 re-designing data sets to include additional variables that could support students to uncover more nuanced impacts of COVID-19, such as variables related to job loss, pre-existing conditions, and variables that lead to increased exposure (essential worker status) or decreased access to care (health insurance). These variables were coupled with demographic variables so that students could use the graphing tool to explore how different variables related to one another. In making these changes, we hypothesized that students would have more opportunities to investigate issues of exposure and access, supporting the integration of these justice-related ideas into their understanding of the impacts of the COVID-19 pandemic on communities of color.

Figure 10

Overview of Revision One of the COVID-19 Unit.

Lesson 1: Data Collection and Variables	- Elicit student's ideas about the stories they want to tell about COVID-19 - Distinguish how to determine if a source or set of data is credible and use criteria to determine the validity of a data set	- Discover how D4BL uses data to tell stories about how the Black community is impacted by COVID-19 - Reflect on how challenges with data reliability and completeness impact the stories you can tell using data
Lesson 2: COVID-19 trends overtime	- Elicit student's predictions about the changes in COVID-19 outcomes overtime - Distinguish how predictions and actual outcomes were similar or different	- Discover the characteristics of informative graph. Graph data to Discover how COVID-19 outcomes changes overtime - Reflect on learnin by helping a peer choose the right data visualization for their research question and data
Lesson 3: COVID-19 impacts on communities	- Elicit student's questions about the differences in COVID-19 outcomes due to exposure, vaccination, economic, and pre-existing health factors. - Use findings from the data to distinguish how different factors impact COVID-19 outcomes	- Graph data to Discover differences in COVID-19 outcomes due to exposure, vaccination, economic, and pre-existing health factors. - Connect ideas to answer students' questions about COVID-19 outcomes.
Lesson 4: Using data responsibly	- Elicit student's ideas about how data can be used to help or harm communities - Distinguish between misleading and truthful data visualizations	- Discover how COVID-19 data has been used to inform targeted public health interventions for local communities - Expanded activity that prompts students to work together and connect ideas to propose and execute a community building or public health action

The Jigsaw activity was also removed, as several resources now contained inaccurate information as the field's understanding of COVID-19 (especially regarding pre-existing conditions and COVID-19 outcomes) improved. The vaccine distribution case study was kept as a local example of the impact of public health policy and access to vaccines on the local community's ability to address the COVID-19 pandemic and to protect residents' health.

Revision One Implementation Findings

Teachers and students engaged in more conversations related to justice ideas during the implementation of revision one as compared to the pilot implementation. Elaine frequently

highlighted disparities in COVID-19 outcomes between different racial/ethnic groups in the data and called out issues of limited access to resources or healthcare for people of color as a major contributing factor to COVID-19 outcomes. She also continued to highlight the work of D4BL. This resulted in students having more frequent conversations about justice factors, including race, with Elaine and one another. For example, Elaine asked students to share hypotheses for why the data showed that Black and Latinx communities were more heavily impacted by COVID-19 deaths (Table 15). When a student shared the hypothesis that “African Americans might be living in harsher environments,” she gently pushed back on the students’ assumptions, while also acknowledging their efforts to make sense of the data. This is just one example of several conversations Elaine had with students that centered on race. Additionally, several of Elaine’s students chose variables related to racial demographics or justice factors during their data investigations, more than any other teacher. Elaine embodied centering the racial and justice aspects of the SJSI in her facilitation, and this was somewhat taken up by her students. An overview of these findings can be found in Table 16.

Table 15

Transcript From Revision One Implementation of the COVID-19 Unit in Elaine’s Classroom. Revision One Observation Field notes, 8/23/2022.

Turn	Participant	Transcript
1	Elaine	Does anyone have a hypothesis for why we saw this trend in the data?
2	Student 1	Because African Americans might be living in harsher environments, like with gang and gun violence.
3	Elaine	[Turns to student 1] Do you think this is true for all Black people?
4	Student 1	No
5	Elaine	[Turns to entire class] Do other communities experience these issues
6	Multiple Students	Yes
7	Elaine	To build ally ship in communities we need to try and understand the complex ways different factors come together and that part of doing that works means we cannot generalize characteristics of groups of people. [turns to student 1] It’s great that you have a hypothesis, but we need to investigate and discover. We need to find out if our hypothesis is true, not just assume that it is.

Table 16

Summary of Findings From Revision One Implementation of the COVID-19 unit and Resulting Revisions to Revision Two

Data Source (participants)	Summary of findings	Planned Revisions

Online web-based unit	While the expanded data sets provided students with more choice and included several new economic, health, and exposure factors related to COVID-19 outcomes, students struggled to make sense of the complex variables, create investigable questions, and identify trends within the data	Added expert video featuring a public health expert who discussed the factors that impact COVID-19 outcomes for communities of color (higher rates of chronic disease due to segregation and environmental factors, less protection against COVID-19, like access to masks or paid leave from work) and factors that do not impact outcomes (genetic differences between people). Students complete a sorting activity after the video to distinguish between factors.
Observations from unit implementation (Lead researcher, Elaine, Beatriz, and Rachel) Used by no observations: Lacey	Elaine emphasized holding discussions that center on race and the impact of COVID-19 on marginalized groups. Elaine had the most students who investigated outcomes by race, and there was some evidence that some students were beginning to reason about why differences in outcomes exist. Beatriz and Rachel's scaffolds focused on supporting the technical skills required for graphing and data-based investigations, not justice-centered content. Beatriz's students begin to discuss race in their small group conversations, including how data might not reflect the true impact on certain groups due to limitations in collecting data.	
Student work, <i>Impacts</i> item (Elaine, Beatriz, and Rachel)	Average KI score on posttest justice question: 2.6. No significant gains from pretest. On average, students used one idea to answer the <i>Impacts</i> question and did not connect ideas to answer the question. Though there was a decrease in deficit framing, students did not connect ideas about racial injustice and systemic factors to explain COVID-19 outcomes. They instead continued to focus on individual choice or health factors.	
Teacher Interview (Lead Researcher Elaine, Beatriz, and Rachel)	All three teachers highlighted that students were not making the connections between justice ideas. Rachel suggested specific feedback related to elaborating on case studies that illustrate inequitable access to vaccines for marginalized communities, which is used as a starting point for considering changes to the final lesson.	
Workshop (2 researchers, 6 teachers)	During a customization/resource gathering session, participants identified new OERs to support student learning related to integrating justice ideas. Several of these OERs were then added to the unit by the lead researcher.	

Beatriz, who did not discuss justice factors with her students the previous year, added a short lecture that focused on disparities in healthcare access for low-income communities of color as compared to wealthier white communities. During a pre-implementation meeting with me, she also suggested adding a map from the CDC that documented COVID-19 outcomes by race in

different states, which was integrated into the unit for her students (then kept for later versions of the unit). There is some evidence of her students taking up conversations about race related to interpreting the data, though less frequently than Elaine's students. For example, as students reviewed the new map, they discussed how some demographic groups, such as American Indian/Alaska Native and Pacific Islander, were listed as 0% of COVID-19 cases in certain states. Students were concerned about this, saying, "I have friends who are Pacific Islander, you can't have zero people," and discussed how data must be missing for this group and how the map was unable to show the COVID-19 impact on the community (Observation field notes, 10/7/2022). In this example, Beatriz's students show evidence of reasoning about the data in ways that attend to the ability of certain data sets to tell accurate stories about marginalized communities. While not a target idea for the *Impacts* assessment item, it does speak to students' ability to integrate ideas about data and ideas about social justice.

Beatriz's teaching partner, Rachel, and her students did not discuss racial factors. This was Rachel's first time using this unit, or any justice-centered science unit, with her students. Like many teachers new to our web-based inquiry unit, she largely used it as is. As a result, her inexperience with justice-centered STEM instruction and the WISE platform contributed to the facilitation choices she made while using the unit.

While there is evidence from observations to suggest that more students were integrating justice ideas into their understanding, this was not reflected in students' answers to the *Impacts* assessment item. The average KI at posttest was 2.6, with no statistically significant change from pre-test. Like the pilot, this indicates that most students had an incomplete or one complete idea about the disparate impacts of the COVID-19 pandemic. Students again focused on individual choice factors (with an increase in the importance of vaccines). Though we saw less deficit framing in students' answers to the *Impacts* question, most students continued to emphasize personal choice and describe the impacts of COVID-19 in ways that were superficial or disconnected from larger systems of oppression and social determinants of health. Though the expanded data sets supported students to engage in more diverse lines of data inquiry in their classroom discussions, students still needed more support to discover and integrate ideas about race, healthcare access, and broader systems of oppression to explain the trends that they saw in the data. This is unsurprising, as the wake of the COVID-19 pandemic has made apparent that many adults struggle to integrate these same ideas.

In their post-implementation interviews, teachers noted that students continued to struggle with integrating ideas about race and justice into their understanding of COVID-19 outcomes. Elaine mentioned that her students "are not taking up race as much as I hoped they would" (Elaine, Revision One post-implementation interview, 9/6/2022), despite trying to center justice ideas during her conversations with students. Beatriz said something similar, noting that students were not sharing elaborated ideas in their writing despite clearly articulating that groups are impacted differently. "They have mostly short comments. I don't think that students expanded on their answers in the post-test. But they seemed to realize everyone wasn't impacted the same" (Beatriz, Revision One post-implementation interview, 11/2/2022).

Of the three teachers, Rachel was the only teacher who suggested specific changes to the unit to try to address the issue during the post-implementation interview. She suggested expanding on the case studies at the end of the unit to emphasize who was impacted by inequities in vaccine distribution more clearly.

How they administered certain doses and those went mainly to... 40% people of

color I think. Maybe on the previous step you can compare that percentage to the percentage of people of color in [case study city]. Like do those numbers match?”
(Revision One post-implementation interview, 2/13/2023)

This helped to initiate ideas related to updated lesson four, which are discussed in more detail below.

Refinement and Revision Two Design

The data inquiry activities were not enough to support students in discovering and integrating ideas related to macro-systems of oppression that contribute to inequitable COVID-19 outcomes. This prompted the co-design team to create additional activities that leveraged open educational resources and expert interviews to call out specific, systemic factors that contribute to inequitable COVID-19 outcomes for communities of color. We used the subsequent workshops to identify the open education resources related to our learning goals, share them with the unit group, and discuss them together. For example, this exploration led to the identification of an expert video (Gwinnett NAACP, 2020) featuring a public health expert that discussed which factors impact COVID-19 outcomes for communities of color (higher rates of chronic disease due to segregation and environmental factors, less protections against COVID-19 like access to masks or paid leave from work) and which factors do not impact outcomes (genetic differences between people). The RPP team felt that this video appropriately addressed our challenges because it clearly stated what factors were and what were not factors, and it became a key project driver that supported addressing the design tension. The clear and direct way the video communicated ideas was embedded to support students in discovering the correct factors and disregarding the incorrect, often deficit-framed factors.

This OER and others were integrated into an activity that occurred at the end of the COVID-19 unit after students explored COVID-19 data and identified trends, patterns, or other noticings about COVID-19 data (See Figure 11 for where this activity fit in the overall unit narrative). The goal of this activity was to help students distinguish factors that help to explain why they saw certain demographic and outcome trends in the data. The distinguishing activity was designed to support students in sorting ideas about why they saw certain demographic and outcome trends in the COVID-19 data in ways that pushed them beyond health, individual choice, or deficit-based factors.

Figure 11
Overview of Revision Two of the COVID-19 Unit

Lesson 1: Data Collection and Variables	- Elicit student's ideas about the stories they want to tell about COVID-19 - Distinguish how to determine if a source or set of data is credible and use criteria to determine the validity of a data set	- Discover how D4BL uses data to tell stories about how the Black community is impacted by COVID-19 - Reflect on how challenges with data reliability and completeness impact the stories you can tell using data
Lesson 2: COVID-19 trends overtime	- Elicit student's predictions about the changes in COVID-19 outcomes overtime - Distinguish how predictions and actual outcomes were similar or different	- Discover the characteristics of informative graph. Graph data to Discover how COVID-19 outcomes changes overtime - Reflect on learnin by helping a peer choose the right data visualization for their research question and data
Lesson 3: COVID-19 impacts on communities	- Elicit student's questions about the differences in COVID-19 outcomes by demographics due to age, vaccination, economic, and pre-existing health factors. - Use findings from the data to distinguish how different factors impact COVID-19 outcomes for different demographic groups	- Graph data to Discover differences in COVID-19 outcomes by demographics due to exposure, vaccination, economic, and pre-existing health factors. - Connect ideas to answer students' questions about COVID-19 outcomes.
Lesson 4: How do we explain the trends we see in the data?	- Reflect on what questions students can answer based on the ideas they have discovered so far in the unit - Distinguish between factors that lead to inequitable impacts for communities of color using a sorting activity	- Discover specific factors that contribute to inequitable impacts of COVID-19 for communities of color by watching an expert video and reviewing local case studies - Expanded activity that prompts students to work together and connect ideas to propose and execute a community building or public health action

Students began the activity by summarizing what they noticed from the data and how their investigation helped to explain why some communities were more impacted by COVID-19 than others. Students then watched a video clip from the expert interview (Figure 12). Following the video, students engaged with a sorting activity that supported them in distinguishing between the correct and incorrect factors stated in the video.

Figure 12
Screenshot of the Expert Video and Sorting Activities Added to the COVID-19 Unit



Which factors did Dr. Jones identify as contributing to inequitable impacts of COVID-19 on Black communities and other communities of color?

- Increased exposure to COVID-19 due to being frontline workers and jobs where you cannot work from home - Less protections against COVID-19 (ex: access to masks, paid leave from work, etc.)	- Genetic differences between people - Higher rates of chronic diseases due to segregation and environmental factors (ex: pollution)	- Individual lifestyle choices like: food preferences, amount of exercise, time spent outdoors - Less access to health care
Is a factor	Is not a factor	
SAVE	SUBMIT	

The two case studies in previous versions of the unit were reframed as examples of the topics discussed in the expert video. Following the video and sorting activities, students explored the case studies to explore how the factors discussed by the expert directly impact COVID-19 outcomes in their community. Both leverage OERs or local news articles and are related to access to medical care or resources that help stop the spread of COVID-19, including vaccines and medical facilities. These activities supported students to distinguish how factors such as access to medical care and resources impact communities close to them, providing explicit, concrete examples of the factors described by the expert. In creating these activities (or tangible “as created situations”), the co-design team sought to make macro-scale systems of oppression clear and explicit to students, while also providing them concrete examples through which they could explore the systems in action.

Student Learning Outcomes Revision Two Implementation

We used a pre/posttest design to measure student learning of the most recent implementation (Revision Two) that resulted from the iterative co-design process described above. These findings are another “as created situation” that resulted from the work of the co-design team. Positive gains between pre and post-test would indicate that Revision Two of each unit supported students to integrate their science and justice ideas to explain the two SJSI. Mean pretest and posttest scores for the COVID-19 *Impacts* item and the Henrietta Lacks *Impacts* item are shown in Tables 17 and 18. A paired t-test was used to measure statistically significant changes between pretest and posttest scores. Across both units, students in both Forrest and Valley high schools showed gains in KI between pre- and posttest, and most gains were statistically significant (all except Valley High School’s gains for the COVID-19 *Impacts* item).

Table 17

*Results for the COVID-19 Impacts Item in Revision Two. * Indicate Statistically Significant Results, With P-values Below 0.05.*

School	Pretest Average	SD	Posttest Average	SD	Difference	Significance
Forrest	2.36	0.65	2.85	1.01	+0.49	0.0006*
Valley	2.67	0.28	2.81	0.95	+0.14	0.28

Table 18

*Results for the Henrietta Lacks Impacts Item in Revision Two. * Indicate Statistically Significant Results, With P-values Below 0.05.*

School	Pretest Average	SD	Posttest Average	SD	Difference	Significance
Forrest	2.06	0.57	2.30	0.75	0.25	0.014*
Valley	2.44	0.70	2.66	0.69	0.21	0.022*

For the COVID-19 unit, both schools increased in KI. Forrest increased from a KI of 2.36 to 2.85, and this increase was statistically significant (P-value below 0.05, see Table 17). Valley increased from a KI of 2.67 to 2.81. This increase was not statistically significant (See Table 17). Both schools converged on a similar KI at posttest (2.85 at Forrest and 2.81 at Valley), indicating that the unit supports similar levels of Knowledge Integration among students regardless of school site or starting KI score among the two schools. These results indicate that, across the two schools, students were able to improve in their ability to express one accurate idea about the disparate impact of COVID-19 on communities. However, average scores were not above a three, indicating that, on average, students were unsupported to link multiple ideas together. These suggest that though students made progress, they still need more support connecting science and justice ideas about COVID-19's impact to achieve a 4 or 5 on the KI scale.

Similar trends occurred in students' pre-/post-gains for the Henrietta Lacks *Impacts* item. On average, students at Forest increased in KI from 2.06 at pretest to 2.30 at posttest. This increase was statistically significant (P-value below 0.05, see Table 18). On average, students at Valley increased KI from 2.44 to 2.66. This increase was also statistically significant (P-value below 0.05, see Table 18). However, the average posttest KI scores for both schools remained below three on the KI rubrics, indicating that, on average, students did not express one clear idea related to how individuals might receive inequitable care or treatment from medical professionals.

Revision Two of each unit supported students across the two schools to make KI gains. Though these gains were significant, students still need more support to increase their average KI scores above a three for both of the units. This indicates that there is still more work to be done to refine each of these units and address the design tensions discussed above, as well as support teachers to enact customizations and teaching moves to support students' integrated understanding of SJSI.

Discussion and Conclusion

Findings Across Units

Though the co-design team made progress in supporting students to integrate justice ideas, thereby making progress on addressing the tension, more work is needed to improve the units to support students to integrate ideas about racialized systems that contribute to inequitable access to high-quality healthcare, medical resources, and the ability to make decisions about their health. Increased classroom conversations about these ideas and improvements in students' responses to the *Impacts* assessment item show promising progress. However, many students pointed to justice-ideas that occurred on the micro-scale when answering the *Impacts* question, such as person-to-person interactions ("if there was racist doctor or nurse, they might treat their white patients better than their other patients of different races." HeLa *Impacts* response) or consequences related to individual choices ("I chose differently because people do things differently some people wear masks Some people don't." Covid *Impacts* response). This suggests that the unit activities need further refinement. Students needed more support to understand and integrate specific macro-scale ideas, including institutional biases in medicine, the impact of segregation on medical care, doctor-patient matching (Hela ideas), and racialized factors and policies that contribute to healthcare access and the distribution of health resources (COVID-19), as these ideas were less present in students' responses. Our RPP participants continue to refine the units to address this challenge by continuing to modify activities, integrating new OERs, and implementing more robust teacher customizations that center justice ideas. Findings align with challenges previously identified in the

literature in supporting students' justice-centered STEM learning, suggesting this is a persistent design tension for the broader field, not just our RPP (Philip et al., 2018; Rubel et al., 2016; Visintainer, 2023). Our “as created situations” presented progress, but no clear solutions. Our RPP continues to iterate on our designs and collaborate with others in the field to address this challenging design and pedagogical dilemma.

Both units made progress in providing opportunities for students to explore ideas about race and justice. This resulted in as created situations, in this case, activity designs within the curricular units that centered on supporting students to distinguish justice ideas in Revision Two. The OER and sorting activity in the final lesson in the COVID-19 unit makes justice ideas explicit to students and provides them opportunities to distinguish between factors in ways that investigating the data sets could not support. Additions to the HeLa unit, including the increased emphasis on segregation and stop-and-prompt (Revision One) and the additional activity on patterns in patient treatment and doctor-patient matching, created opportunities for students to discover that though medical racism and bias may look different today than they did for Henrietta, it still occurs.

While these changes show promise, there is clearly a gap in supporting students to integrate these ideas from the unit into their repertoire, and in supporting students to link multiple science and justice ideas together in their explanations. Continued work is needed in this area.

There are several avenues our RPP is pursuing. One promising avenue is the use of automated, KI-aligned AI guidance to elicit a wider variety of student ideas and support students to distinguish between ideas. KI-aligned AI guidance has shown promise in supporting student learning in science (Gerard et al., 2025; Li et al., 2024), and scholars are beginning to explore how it can be used to elicit and help students distinguish between a wider variety of students' ideas about SJSI (Bradford et al., 2023b). Though not included in this study, colleagues and I have collaborated to turn the impact rubrics described above into idea rubrics that can inform AI guidance, and are currently pilot testing new KI prompts for these two items.

Another avenue is working with teachers to integrate multiple justice-centered science units into instruction. While students can make some progress in integrating ideas during one-week or two-week-long units, sustained engagement with justice ideas can support more robust Knowledge Integration. This has been shown in longitudinal studies focused on integration of science (Liu et al., 2015) and graphing ideas (Boda et al., 2021). Two other RPP researchers and I are working with Beatriz to document the impact of four justice-centered science units (of which *COVID-19* and *Henrietta Lacks* are two) on her students' learning. This research is ongoing.

Impact of Teacher Feedback During Co-Design

The expertise of our partner teachers was key in refining aspects of justice-centered instruction in both of the units. Gregory, an expert in the unit due to his experience with the pilot, provided key feedback after each version that helped to center race more concretely in the unit. His customization in Revision One, which led to a classroom conversation that centered on continued injustice experienced by people of color today, inspired changes to the unit for Revision Two. Elaine and Lacey's conversation about facilitating class discussions inspired the stop-and-prompt step, which guided teachers on when to hold discussions to support students in distinguishing ideas about race and segregation. This prompt was taken up by the majority of the teachers.

Elaine and I hypothesized that providing students with data sets containing more variables aligned to their interests and justice factors would support students in integrating justice ideas into

their understanding of the impact of COVID-19. However, our hypothesis was not correct. Though there is some evidence that students discussed demographic factors in conversation, results of the *Impacts* assessment revealed that students were still not linking multiple science justice ideas in Revision One. Elaine's impact on the COVID-19 unit was also key in pushing it forward. She was one of the first teachers to speak to students' challenges with distinguishing ideas about race, and this motivated her to work on the tension in the COVID-19 unit. Her role in unit redesign is further explored in both study two (specifically her impact on the data sets and data inquiry activities) and study three (how her summer research internship supported her co-design and professional identity development).

Specific RPP structures were key to unit refinement. Opportunities to examine student work with KI rubrics, both in post-implementation meetings and the workshop, helped teachers identify the ideas students had and the potential origins of those ideas (e.g., Jaime's comment about students pulling ideas about COVID-19 from what was "big in the media"). Teachers' insights about student learning were important sources of data for both unit refinement and responding to student learning during future instruction. (Linn & Eylon, 2011; Rosebery et al., 2016) Teachers were also supported in identifying the specific ideas students still needed to add to their repertoire (ideas about race and ideas about access to healthcare). Teachers' insights helped shape more in-depth analyses of student work, prompting me to examine the specific justice ideas students did or did not have. These insights informed more targeted interventions as we refined both units to better support students' justice-centered learning. Previous research highlights how examining student work using KI rubrics impacts teachers' ability to customize instruction and implement KI-aligned teaching interventions (Bichler et al., 2021; Bradford et al., 2021; Gerard et al., 2010). We build on this work by showing how similar activities can also help broader co-design teams improve the design of the KI-aligned curricular units themselves.

Unit prototype discussions were the site of a majority of teachers' work on unit refinement (aside from Elaine's summer internship, which supported her intensive work on the COVID-19 unit). Unit prototypes served as anchoring resources during these sessions, supporting teachers to give specific, actionable feedback on unit design. This work highlights the continued importance of anchor resources to facilitate co-design among participants, particularly participants with different perspectives (Jayathirtha et al., 2025; Matuk et al., 2023; Severance et al., 2016).

The curricular units, which are available for free on the WISE platform, themselves are Open Educational Resources (OERs, Creative Commons). However, the integration of other OERs, including videos, articles, and data sets focused on justice factors, into the units was important for unit refinement. For the *COVID-19* unit, OERs such as data sets, resources from D4BL, maps (such as the one suggested by Beatriz in Revision One), and expert videos (added into the final lesson in Revision Two) helped to center justice ideas within unit content and helped facilitate discussions about justice ideas in classrooms. OERs in the HeLa unit, such as videos about Henrietta's story and graphs documenting patient treatment today, helped students discover both historical and contemporary justice ideas. Similar to their role in supporting science learning (citations), OERs are key resources that support the integration of justice ideas in science content and provide students with a variety of interactive avenues (videos, interactive maps, data investigations) to engage with justice content (Gerard et al., 2022b; Porcello & Hsi, 2013). Teachers served important roles in collecting these resources, either providing them independently (like Beatriz) or helping to curate collections during workshop activities. We continue to privilege the ideas and contributions of our educators, as many of the resources they share with us have been critical to improving instruction (Gerard et al., 2022b).

Finally, teachers' involvement in the co-design of justice-centered curriculum impacted their teaching. Those most involved in unit design (Gregory, Elaine, and Beatriz) showed an increase in holding justice-centered conversations or implementing justice-centered customizations in their classrooms over time. Gregory, who initially held class discussions on ideas related to consent when he implemented the pilot of the *Henrietta Lacks* unit, added customizations focused on supporting students to connect Henrietta Lacks story to persistent issues of injustice today in Revision one. Beatriz, who did not engage in any customizations related to justice ideas the first time she used either unit, integrated customizations that called out justice ideas when she implemented revision one of the *Henrietta Lacks* unit. Finally, Elaine held justice-centered class discussions throughout both units, refining them between the pilot and revision one. Co-design conversations helped them identify gaps in students' justice ideas that needed further support, which likely helped to inspire the need for increased conversations. Teachers were also able to discuss dilemmas during RPP activities. For example, as Elaine and Lacey suggested the need to hold a class discussion about segregation and Henrietta's story, they wrestled with how best to facilitate the discussion in ways that helped students distinguish ideas, including how they might use specific resources to help structure the conversation. Fostering spaces for teachers to grapple with tough pedagogical questions related to justice-centered STEM instruction is key to supporting their continued development and confidence in implementing transformative STEM learning experiences that center social justice (Bradford et al., 2023a; Kinskey, 2025; Morales-Doyle et al., 2019; Scott & Philip, 2022)

Future Work

The work to refine each of these curricular units continues as these units continue to be implemented and refined by the RPP. For example, the COVID-19 unit is being updated to reflect the shifting landscape of the pandemic and long-term impacts of the pandemic on communities, particularly marginalized communities that continue to lack adequate access to healthcare. New research seeks to leverage the promising AI dialogues described above to support students in distinguishing justice ideas (Bradford et al., 2023b; Gerard et al., 2025; Li et al., 2024). As our teachers become more confident in enacting justice-centered STEM instruction, they have increasingly customized the curricular units (see study three for more information on their trajectories). We continue to learn from these customizations and integrate teachers' developing best practices and supportive activities into the online, web-based units. Finally, these two units are part of a suite of justice-centered STEM units informed by KI (Bradford et al., 2023a; Wiley et al., 2023) that includes units focused on environmental racism and food justice. Comparisons across units are needed to examine if the tensions hold outside of public-health-related SJSI, and lessons learned from the refinement of each of these units can help inform the refinement of the others.

Chapter 4: Centering Students' Experiences Towards Making Complex Data Sets and Data Science Concepts Accessible

Introduction

This chapter responds to a need to design robust, justice-centered data science education that supports students' development of data science skills and their broader understanding of the cultural and socio-political contexts of data (Lee et al., 2021b, Louie, 2022). These learning opportunities are challenging to design, as they must support students to integrate their ideas about data, justice, and other content disciplines (Vakil & Higgs, 2019) and require students to make connections between their prior knowledge, findings from data, and the context that the data sits within (Wilkerson & Laina, 2018; Wilkerson & Polman, 2020). One potential avenue for supporting students to work with data is to connect data and data science concepts to real-life issues and experiences familiar to students. This strategy aligns with the KI design principle, making science accessible through relevant examples (Linn & Hsi, 2000). However, as demonstrated by the findings in this chapter, identifying the right real-life connections to make data science more accessible to students can be challenging for those designing curricula.

This chapter discusses how the RPP team refined two justice-centered science units focused on public health issues to make data sets and data science concepts, such as data privacy and how data is used in medical research, accessible to students. I discuss how a major design tension arose in trying to do this work (Tatar, 2007): Balancing making SJSI accessible and integrating complex, publicly available data and data science topics unfamiliar to students. I discuss how the team collaborated and leveraged teacher expertise to refine the units in ways that made Social Justice Science Issues and data more accessible to eighth and ninth-grade students. I also discuss decisions that the RPP made regarding dropping certain data sets or data science concepts in order to prioritize making SJSI accessible, and what data contributed to making these decisions. This study builds on initial work that I have reported elsewhere (Billings et al., 2023) and previous literature that discusses how students use their personal experiences to reason about data (Lee et al., 2021a; Van Wart et al., 2019; Wilkerson & Laina, 2018). In this chapter, I ask:

1. How did the co-design team refine the units in ways that centered on making data and data science concepts accessible to learners?
2. How did changes to the unit support students to create investigable questions of publicly available COVID-19 data?
3. What continued tensions exist in supporting students to work with data when learning about complex SJSI?

Background

Making Science and SJSI Accessible

A key tenet of Knowledge Integration (KI) is making complex science topics accessible to young learners by rooting science learning in examples relevant to students' lives (Linn & Hsi, 2000). Using real-life examples provides opportunities for students to bring their personal knowledge, observations from everyday life, and community expertise into science class (Linn & Hsi, 2000; Donnelly et al., 2015). This validates their perspectives and ideas, supporting interest and motivation in science and learning that is connected to the ideas they bring into the classroom

(Bang et al., 2007; Roseberry et al., 2010). While students have many prior ideas to pull from, their ideas are often fragmented, and their understanding is often missing key mechanistic ideas (diSessa, 2018). Content in science courses can help fill these gaps, provided educational interventions support students to integrate these ideas with their prior understanding (Linn & Eylon, 2011).

Prior research points to several designs that leverage real-life examples of science phenomena to support students' Knowledge Integration (Linn & Hsi, 2000; McElhaney et al., 2015; Ryoo & Bedell, 2017). For example, students have a variety of experiences that educators can build on to support students' learning about thermal dynamics, such as holding hot and cold beverages or having to wait for hot soup to cool down (Donnelly et al., 2015). These experiences provide students with every day, intuitive ideas that they can integrate with ideas about thermodynamics they discover from science class, including concepts of thermal equilibrium and heat transfer.

Research has highlighted specific strategies for making science phenomena more accessible. Using Dynamic visualizations or graphs to depict complex science concepts can help scaffold students' understanding of cause and effect relationships or components of complex systems (Donnelly-Hermosillo et al., 2023; McElhaney et al., 2015). These visualizations have been shown to support Knowledge Integration for diverse groups of learners, including English Language Learners who may be less supported to engage in science using text-based lessons or assessments (Boda et al., 2021; Ryoo & Bedell, 2017). Centering indigenous ways of knowing (Bang et al., 2007), social justice (Bradford et al., 2023a; Calabrese Barton & Tan, 2020; Morales-Doyle, 2017), students' communities (Upahyay et al., 2020), and everyday knowledge from students' home environments (Bricker & Bell, 2014) can help to make science content accessible for students and validate their varied funds of knowledge.

In this chapter, I focus on how the RPP navigated tensions in making complex justice and data science content within two justice-centered science units accessible to students. While we know that connecting academic content knowledge to real-life examples and students' lived experiences can promote Knowledge Integration, more work is needed to understand how design teams identify and leverage the right examples that are relevant and motivating to students. Additionally, we surface the complexities of identifying the right real-life contexts given the complex, interdisciplinary nature of SJSI.

Supporting Students to Reason about Data and Data Science Practices

Data, graphs, and other data visualizations are widely used to communicate information in the news, science, and health contexts. Students interact with data in their everyday lives. For example, students likely encountered graphs depicting COVID-19 case rates in the media or online during the COVID-19 pandemic. Students and their families might have used trends in COVID-19 outcomes to make personal decisions about masking, social distancing, or vaccination. However, students often see data or graphs in isolation in schooling contexts (such as math classes), where they are removed from the rich contexts in which everyday data is usually embedded. This can prevent students from understanding the relevance of data science learning in school to their everyday contexts. Learning about graphing in isolated contexts can also lead students to see graphs as static images, rather than dynamic visualization of real-life phenomena (Clement, 1985).

When data and graphs are integrated into other coursework or real-life contexts, students can use their ideas about science or their personal experience to reason about the data (Boda et al.,

2021; Matuk et al., 2019; Wilkerson & Polman, 2020). Just as using real-world examples can help make science content accessible and support students to integrate their science ideas, connecting data to real-world contexts can support students to reason about different variables, interpret data visualizations, and draw meaningful conclusions from data (Lee et al., 2021a; Van Wart et al., 2019; Wilkerson & Laina, 2018).

The SJSI in each unit centers aspects of data science. The *COVID-19* unit calls on students to reason about complex, publicly available datasets related to the COVID-19 pandemic to come to conclusions about COVID-19's impact on marginalized communities. Students must engage in skills related to writing investigable questions, identifying variables within publicly available data sets to answer their questions, and constructing graphs. The *Henrietta Lacks* unit asks students to reason about concepts related to data privacy, including ethical practices regarding obtaining medical data and how to make personal decisions related to sharing data. These topics can be challenging for students, as they require students to integrate their ideas about data, justice, and science content (Vakil & Higgs, 2019) and bring up questions about the cultural and sociopolitical contexts of data (Lee et al., 2021b; Philip et al., 2013). They require students to make connections between their prior knowledge, findings from data, and the context that the data sits within (Wilkerson & Laina, 2018; Wilkerson & Polman, 2020).

Researchers have explored how students engage in data practices through a justice-oriented lens in math classrooms (Louie et al., 2022; Rubel et al., 2016) and after-school learning communities (Vakil et al., 2020). These designs have shown that robust data science learning can happen alongside meaningful investigations into localized justice issues. For example, Rubel et al. (2016) report on a spatial justice-oriented math curriculum that centers the lottery as a social justice phenomenon to teach students about math concepts like statistics and probability. Results from this study suggest that students felt that the lottery phenomenon was engaging to them because it was a phenomenon they were familiar with outside of a school context. The authors also reported that the unit supported students' math and data science learning by connecting concepts to a local issue (the lottery) and allowing students to examine data at multiple scales (personal, neighborhood, city). Louie et al. (2022) used income inequality as a social justice phenomenon to support students' data science learning in a high school math class. The learning module supported students in developing data science practices, a socio-political awareness around issues of income inequality, and student agency. These designs show that social justice issues are promising, relevant subject matter for data science learning and student empowerment.

Prior research supports the idea that making science accessible by connecting data to real-world contexts can help students to reason about data sets. This aligns with KI's focus on making science accessible to students (Linn & Hsi, 2000), and this design principle can be extended to supporting students to reason about data and data science topics. Previous research on KI has highlighted how the framework can be used to support students to integrate ideas about graphs with their science understanding (Boda et al., 2021; Matuk et al., 2019). I have built on this work in pilot studies focused on the refinement of the Data Explorer and data sets (Billings et al., 2023) in early iterations of the COVID-19 unit. In this chapter, I extend this work by examining how the RPP team refined the units to make public-health data and complex data science topics more accessible to eighth and ninth-grade learners.

Methods for Analyzing Student Work

Chapter 2 outlines the data sources and analysis of co-design data. However, a unique analysis of student data related to the COVID-19 unit was conducted as part of understanding student learning and engagement while working with the publicly available COVID-19 data sets. This analysis is outlined below.

Data Sources

The WISE platform logged students' responses and graphs related to their data investigations, including the questions they wrote for their investigations. These questions were collected throughout co-design as a way to measure how the unit was supporting students to work with the data. For the Pilot and Revision One, students' questions are discussed in the context of the co-design narrative of each unit, but not analyzed in depth. In Revision Two, we collected student-generated questions from the focal lesson for two of the teachers who used all three versions of the COVID-19 unit, Elaine and Beatriz (Table 19). Any students who did not complete the data investigations were removed from the question analysis (N=53), resulting in 138 responses (out of the total of 191 students).

Table 19

Participating Classrooms Used in the Investigation Question Analysis

School	Teacher	Grade Level	N R2
Bayview (year 1-2) Forrest (year 3)	Elaine	9	75
Valley	Beatriz	9	63
Total			138

Data Analysis

Students' questions were first categorized as "answerable" or "non-answerable" based on the students' chosen data set. Elaine (one of our partner teachers) and I each coded the questions independently, then met to discuss any questions about which we had disagreement and resolve those differences. We used an open coding approach to categorize non-answerable questions into the reasons they could not be answered. We first coded roughly 20 percent (28 questions) together, then coded the remaining questions independently. We then met to go over each question and discuss any disagreements in the coded categories. This resulted in four major categories of unanswerable questions, which are discussed in the COVID-19 section of the results.

Results

In the two sections below, I outline how the tension was revealed and addressed in the co-design of each of the units. I discuss RPP structures that support participants to identify gaps in student understanding and work towards improving the unit to support students' learning using

examples and data that students could connect to their experiences and communities. This proved especially challenging for the RPP. In the Henrietta Lacks unit, designers navigated tensions around adjusting activities to align with students' experiences with health professionals and preserving content around data privacy and sharing medical data, which was removed from students' experiences. Ultimately, the team, led by teachers' insights on their students, decided to center more common medical decisions unrelated to data privacy to make justice content more accessible for students. For the COVID-19 unit, the team balanced aligning datasets with student interests, providing choice, appropriate scaffolding of data investigations, and curating data sets of the appropriate size and scope. We started too small in the pilot, expanded datasets in ways that made them challenging to work with in revision one, and trended towards a solution somewhere in between for revision two. However, there is more work to be done to refine the data sets and activities moving forward. Though progress has been made in both units, these findings point to real challenges in making complex data sets and data science concepts accessible to students to support their learning.

Henrietta Lacks Unit

Pilot design

The pilot design of the Henrietta Lacks unit centered Henrietta's story in the broader scope of data practices used in scientific research, positioning her story as an example of unethical scientific research and a violation of patients' rights and data privacy. In an attempt to make science accessible to students and validate their prior knowledge, the justice-centered lessons began by eliciting students' ideas about what the word ethically means to them, and about times in their lives when they have engaged with different permission forms, such as social media permissions, or forms they and their parents or guardians had to sign for school. In centering consent or permission forms that students might have previously encountered, the design team hoped to make the concept of informed consent for sharing data (which was not obtained from Henrietta) more accessible to students. This activity then launched into Henrietta's story, which focused on how doctors did not get her consent to use her cells for medical research, and how this was an unethical violation of her rights as a patient and a breach of her privacy. The rest of the justice-centered unit focuses on Henrietta, her family, and how her cells have been used in research. The lesson ended with an activity that positioned students as scientists who must make a decision about which cells to use for research, given both scientific and ethical implications.

Pilot Implementation Findings

During the pilot implementation, students expressed concern for how Henrietta and her family were treated, but felt that Henrietta's story, including the violation of her bodily autonomy and privacy, was something that occurred in the past and was not connected to issues in medical research today or students' lives. While introducing the idea of consent through permission forms connected to students' prior experience, it did not support students in connecting the implications of Henrietta's story to contemporary issues of data privacy and or students' decision-making around sharing data and consent. An overview of these findings can be found in Table 20. Field notes that captured conversations between students and Gregory during pilot implementation first illuminated the need for additional connections between Henrietta and modern experiences with medical professionals. For example, as two students discussed her case, one said to the other "It's good that cures were found [with her cells] I guess, but I feel bad for her" (observation field notes,

5/18/2022). Another pair made a similar comment, though also said that “doctors don’t do that anymore, that’s common sense” (Observation field notes, 5/18/2022). These conversations made it apparent that while students understood that what happened to Henrietta was wrong, they felt that issues of unethical research practices were a thing of the past and no longer a relevant social justice issue. This finding from the field notes was echoed during Gregory’s post-implementation interview. “I think some of them felt a little bit like it sort of was resolved. Like wasn’t as open-ended... because the family is now part of the research’s decision-making” (*HeLa* pilot post-interview, 6/6/2022).

Table 20

Summary of Findings From Pilot Implementation of the Henrietta Lacks Unit and Resulting Revisions to Revision One

Data Source (participants)	Summary of findings	Planned Revisions
Online web-based unit	Though step 3.1 was designed to elicit students’ ideas about what ethically means to them and step 3.3 connected the concept of consent to forms students see in their everyday lives (social media permissions, field trip forms), students were unable to connect Henrietta’s story to the examples from their everyday lives.	The Eric case study was added. The case focuses on a young person with Cystic Fibrosis who makes decisions about sharing health data and participating in medical research to contrast Henrietta’s story with that of a modern young person. Students help Eric make a decision about whether to participate in research. Workshops helped refine the language of the Eric case study to better align with what students might ask or discuss in conversations with medical professionals.
Observations from unit implementation (Lead researcher, Gregory, Gregory’s students)	Students expressed that they felt sorry for Henrietta, but that her story was resolved, and students were unable to distinguish the implications of Henrietta’s story to issues of data privacy and medical racism today.	
Teacher Interview (Lead Researcher and Gregory)	Gregory agreed with findings from observations, mentioning that it was challenging to support students to see the implications of Henrietta’s story to issues of data privacy and medical racism today.	
Workshop (2 researchers, 6 teachers)	During unit prototype discussions, RPP participants reviewed initial changes to the unit, including the new Eric Case study. Teachers felt that it was a step in the right direction to make Henrietta’s story more accessible, as it reflected experiences they were familiar with. Gregory highlighted how centering those impacted (Henrietta’s family) helped engage students and make her story more accessible to them.	A family decision-making activity was added to build on students’ interest in Henrietta’s family and mirror the decision-making activity in the Eric case study.

These initial findings from unit implementation suggest that students did not find Henrietta’s story relevant to their lives, making her story less accessible as an SJSI through which to interrogate data privacy and issues of medical racism. This is unsurprising, as the U.S has made

major changes to policy to address research ethics, and Henrietta's family has successfully advocated to be a part of decision-making regarding her cells. Including detailed permission forms might have also reinforced this idea, as they present a stark difference to the very basic and general permission form signed by Henrietta. The pilot design did not support students in seeing the relevance of Henrietta's story to their everyday lives as patients who interact with medical professionals, and how making decisions about sharing medical data still applies today. Changes needed to be made to make the connections between her story and students' experiences with medical professionals more explicit.

Refinement and Revision One Design

Gregory's initial feedback resulted in a prototype of a new activity: the Eric case study. This case centered on how a young person with cystic fibrosis, Eric, navigated decision-making related to his health, sharing health data, and participating in research. The case reflects how patients are involved in research today and models decisions a young person might make regarding their own health and the sharing of medical data. Additionally, the team hoped this new activity could serve as a contrast to Henrietta's case, supporting students to distinguish ideas.

This prototype activity was shared with teachers at the following two workshops, which were key sites of refinement to ensure that the case study reflected students' experiences with medical professionals and could make Henrietta's story more accessible by bridging the gap between students' experiences and her treatment. Prototype discussions allowed small groups of two to three teachers to provide feedback on the prototype and suggest additional activities or areas for improvement. Teachers felt that the Eric case study was a step forward in connecting unit concepts to their students' lives.

All the questions [in activity], I think they're perfect and for my students in middle school, totally applicable to them. At that age, they start to... the parent isn't always in the room at the doctor and stuff. I think those are really good for them to think about." (Winter 2023 Workshop, 1/21/2023)

They had additional suggestions to refine the activity to better support students' identification with Eric's case. Multiple teachers (including Gregory, who provided the initial feedback on the prototype) emphasized the need for students to connect their experiences to Henrietta's and suggested that additional questions prompting students to reflect on their own experiences might need to be integrated with the Eric Case Study to emphasize the relevance of the unit to their daily lives. This feedback solidified Eric's case study as a focal activity in the unit and resulted in some refinements to the new case study that prompted students to consider their own experience alongside Eric's.

Gregory also shared the importance of continuing to emphasize the story of Henrietta's family, especially the continued work of the family members. He shared how the story was engaging to his students, and it "was a good way to get engaged in the story and debate around privacy and consent, specifically through what happened with Henrietta Lacks" (Summer workshop field notes, 6/14/2022). This prompted revisions that further integrated their work into the narrative of the unit, which was also aligned to parallel Eric's case study.

The resulting Revision One design used two parallel case studies, Eric's case and Henrietta's case, to help students make accessible ideas about how patients are included (Eric) or have not been included (Henrietta) in decision-making about sharing health data and the factors

that have impacted how patients have been treated by medical professionals (See Figure 13 for one of the activities in Eric's case). Students encounter the Eric case study first, which centered on questions related to data sharing and consent for research from the patient perspective in the present day. These ideas were key to understanding Henrietta's story and developing empathy with her perspective. Students first met Eric and the various stakeholders involved in his health, then distinguished the different types of data that each of the stakeholders had to help Eric manage his Cystic fibrosis. Students distinguished what data is appropriate for Eric to share with his doctor to help him manage his cystic fibrosis, reflecting decisions students might make about sharing health data at their own doctor's appointments. The final half of the case study focused on helping Eric decide whether he should participate in a research study. Students helped Eric and his parents examine the overview of the study, discovering what types of data Eric would be asked to share and how his privacy would be protected. Students then sorted different reasons why Eric may or may not want to participate before advising him on whether he should participate or not (Figure 15). By including a case that aligned more with students' experiences, we hoped to make ideas around sharing medical data and consent for research more accessible.

After Eric's case, students learn about Henrietta and her family's fight for recognition and compensation. Students complete an activity parallel to the final section of the Eric case study: students help Henrietta's family (who are now part of making decisions about how her cells are used for research) decide if her cells should be used for a particular research study. They examine the study overview, examine the implications of the work, and sort through why the family may agree or deny the use of her cells. The parallel formats of the Eric and Henrietta cases serve to help scaffold students to distinguish the similarities in how a young person and Henrietta's family have to think about sharing medical data, making the implications of Henrietta's case more accessible to students.

Figure 13

An Activity From the Revision One Version of The Eric Case Study Focused on Making Decisions About Sharing Data

What data can each person share?

Stakeholders work together to make sure Eric is healthy. To do this, they must share information!

Stakeholders share information about Cystic Fibrosis and Eric's health.

Match the stakeholder with the information they have that they could share with others.

Goals		
Information about Cystic Fibrosis research studies or clinical trials Eric can participate.	Information about Eric's current symptoms and how his symptoms have changed recently.	Information about what medicine and equipment are at the school to support Eric's health.
Information about how to diagnose and treat Eric's cystic fibrosis.	Information about how Eric's health is affecting how he is doing in school.	Information about the family's medical history.
		Information about how Cystic Fibrosis affects the body.

Revision One Implementation and Findings

Teachers' enactment of the units further supported students to connect with Eric's case and distinguish differences between his experience and Henrietta's (An overview can be found in Table 21). Gregory and Elaine made customizations that focused on making Eric and Henrietta's cases accessible and relevant to their students' lives by facilitating discussions with students about what

consent looked like in their daily lives. These discussions elicit students' initial ideas about consent and help connect their initial ideas to Eric and Henrietta's cases. Elaine in particular elicited students' ideas about how opportunities to provide consent might differ based on justice factors (see Table 22 for an example from Elaine's class). Gregory's and Beatriz's "stop and talk" activities included additional opportunities to connect Henrietta's to their lives in the present day by prompting students to consider how racial and medical injustices like those experienced by Henrietta continue to occur today, though none of the ideas mentioned by students connected directly to issues of data privacy (See Table 23 for an example from Gregory's class). Though taking different approaches, each customization centered on students' prior knowledge about present-day experiences and issues of social justice, leveraging this knowledge to make Henrietta's case and concepts related to research ethics and medical ethics more accessible. However, there were missed opportunities to center the data privacy aspect within the discussions.

Table 21

Summary of Findings From the Revision One Implementation of the Henrietta Lacks unit and Resulting Revisions to Revision Two

Data Source (participants)	Summary of findings	Planned Revisions
Online web-based unit	Changes to the unit focused on making Henrietta's story more accessible by (a) using Eric's case to connect to students' experiences with medical professionals (Steps 4.1-4.6) and (b) increasing activities focused on Henrietta's family, which helped engage student interest in the pilot. Parallel decision-making activities were used to connect the two cases (Step 5.10). Emphasis on data privacy remained, but emphasis on research ethics was reduced as the positionality of researchers was challenging to relate to students' lived experiences.	The focus of Eric's case study shifted from making decisions about sharing medical data to working with medical professionals to meet specific health goals. This better aligns with students' experiences with medical professionals, helping make unit content more accessible (Figure 4). Helping Eric decide to participate in research was still kept, but the wording was adjusted to align with the new framing (Figure 5).
Observations from unit implementation (Lead researcher, Gregory, Elaine, Beatriz, and their students)	Gregory and Elaine implemented customizations that (a) encouraged students to build empathy with Henrietta and her family and (b) elicited students' ideas about what consent means to them. Gregory and Beatriz implemented customizations focused on connecting Henrietta's story with modern examples of injustice today. However, these issues were disconnected from data privacy or making decisions about sharing data.	Parallel research decision-making activity focusing on Henrietta's family was kept as is. A final sorting activity was added after Henrietta's case to prompt students to distinguish differences in how Henrietta and Eric were
Teacher Interview (Lead Researcher and Gregory, Elaine, and Beatriz)	All three teachers viewed the two cases positively and felt that they helped students make connections. However, teachers felt that the emphasis on data privacy	

and research ethics was still challenging for designers and educators to make accessible to students, as many students had few experiences with making decisions related to sharing medical data.

treated by medical professionals.

Workshop (lead researcher and Gregory)

While Gregory viewed both cases positively, he emphasized the continued need for opportunities to compare the cases and distinguish ideas.

Table 22

Transcript From Revision One Implementation of the Henrietta Lacks Unit in Elaine's Classroom. Revision One Observation Field notes, 3/7/2022

Turn	Participant	Transcript
1	Elaine	How you think consent has changed from the 20 th century to now.
2	Student 1	First, there was no consent back then, which is a big issue because you trust your doctor with information. Now we sign forms, they want to make sure they have consent from people.
3	Elaine	Let's build on that, let's think about today.
4	Student 2	We talked about the same thing...what else should I talk about?
5	Elaine	Well what about socio-economic status, how does that impact people's medical care?
6	Student 3	People with low income didn't have much say, but people with high income can go somewhere else if they don't like how they're treated.
7	Elaine	Great, one more group.
	Student 3	I think the amount of money you make really does make a difference. Like, we have Medicare, and we don't get a lot at all. If you're rich you get more, like can afford medication, have more appointments.

Table 23

Transcript From Revision One Implementation of the COVID-19 Unit in Gregory's Classroom. Students are Discussing the Question, "How are these same patterns of unequal care/treatment of people of color repeated today?" Revision One Observation Field notes, 5/22/2023

Turn	Participant	Transcript
1	Gregory	What other forms do we see today? Other forms of discrimination.
2	S1	(Quietly) racist things.
3	Gregory	Yeah, racist things. So what other forms of bias and racism do we see?
4	S2	Class, like biased based on class.
5	Gregory	Ok biased based on class, what else?
6	S3	There is definitely some bias in education based on wealth lines. Kids who can afford computers and internet at home have a head start, people who don't have to worry about food have an easier time focusing on school. And it's easier to focus on school when you don't have issues at home. And higher education and private schools, those places are definitely closed off based on wealth lines.
7	Gregory	I like how you're talking about wealth. What else?
	S4	Assumptions. People make assumptions based on gender or ethnicity. These people are smart, these people will like this subject. Even though they aren't really true, people go along with those assumptions and treat people based on them.

During post-implementation interviews, teachers expressed that students were engaged during the Eric case study and that it helped students empathize with Henrietta and consider their own experiences.

"I liked that it was trying to connect what medical consent meant back then and Henrietta Lacks' case, and an actual like case for a young person in the present time. I think that made better connections for students as they were thinking about why or what consent and medical ethics look like for them." (Elaine, HeLa Revision One post-interview, 3/27/23)

However, teachers felt that the focus on data privacy and research consent still felt somewhat removed from students' everyday experiences with healthcare professionals, as this is something that most students have never experienced. "I think they probably never thought about the fact that scientists might use your, you know, health data from research institutions or core research institution purposes." (Beatriz, HeLa Revision One post-interview, 3/22/23). While teachers appreciated the increased awareness, they felt that students struggled to understand how decisions about data and data sharing were directly relevant to their regular doctor's visits. This could be part of why teachers did not center these ideas in their facilitation.

Refinement and Revision Two Design

This prompted the design team to consider an alternative framing of Eric's case study, which dropped much of the focus on data privacy. Instead of focusing on data privacy and deciding whether to share data, we shifted the case study to focus on how patients like Eric can advocate for their personal health goals at the doctor's, how stakeholders can support young patients to use data about their health to reach their goals, and model productive and respectful conversations between medical professionals and patients. Though data sharing practices and privacy were no longer central to the narrative, they were still a key aspect of how Eric can address his goals. This framing felt more realistic for the types of conversations students would be having with medical professionals, and the design team hypothesized that this adjustment in framing would better support students to connect the storylines in the unit to their common experiences in the doctor's office.

We presented the updated prototype during a one-on-one meeting with Gregory. He felt that the new framing was appropriate and provided additional feedback focused on supporting students to compare the Eric and Henrietta cases to their own experiences. "We need more comparisons, like how does your own situation or different situations affect people's access or lack of access to healthcare?" (Gregory, summer 2023 workshop, 6/16/2026). In response to this feedback, we added a step that asked students to explicitly compare Eric and Henrietta's cases and distinguish concrete differences in how they were treated by medical professionals (see below for more details on this additional step).

While Revision One made strides in connecting a historical case study (Henrietta Lacks) to students' lives in the present, additional adjustments were needed to the Eric case study to reflect common experiences of students in medical settings. Though data privacy was no longer the central focus, data practices were still included in how Eric's case modeled how a team of stakeholders can use data to help a young person address their health goals. Teachers' feedback during post-interviews helped to inform changes to the prototype, which Teacher 1 was instrumental in refining during the workshop.

In the Eric case study in Revision Two, students are tasked with helping Eric make decisions about his health. Students follow a sequence of activities that support students to understand Eric's goals regarding his medical care and ways that different stakeholders (Eric, his parents, the doctor, the school nurse, his teacher, and his soccer coach) can help him reach his goals for his medical care. After learning about Eric's goals and different stakeholders, students read a transcript of a conversation between Eric and his doctor about Eric's goals, distinguishing how Eric advocated for himself and how the doctor respected and supported Eric (Figure 14). The research portion of the activity remained the same, though small changes in framing and language were made to align with the altered storyline (Figure 15). It was eventually revealed that Eric ultimately did not decide to participate in the study for now to focus on his health goals, but would be interested in participating in the future.

Figure 14

New Eric Case Study Activity in Revision Two Focused on Patient Advocacy and Communication with Medical Professionals



"I really want to play soccer this year, but I'm worried about making my Cystic Fibrosis worse. Can I ask you some questions?"

"That's an awesome goal Eric, and sounds fun! Ask away, I'm here to help."

"I think I'll have to run a lot during practice... Is there any way that my Cystic Fibrosis might cause a problem during soccer practice?"

"That's a good question. You're doing well, but I suggest we do some fitness tests with a physical therapist to see where your fitness is currently at. That will help us figure out specific concerns and realistic goals for soccer and running."

"That makes sense. Would it be good for the soccer coach to know about the results?"

"If you're comfortable with that, then yes. Then they can help you if you're ever worried about your health during practice."

"Ok! Hey Dad, can we make an appointment to do the tests?"

Figure 15

In this Activity, Students Distinguish Reasons why Eric Might or Might Not Want to Participate in Research and Share His Medical Data with People Outside His Support System.

Sort the following statements into the possible reasons why Eric DOES want to participate in research, possible reasons why Eric DOES NOT want to participate in research, and statements that do not impact his decision.

Eric could help discover new ways to manage Cystic Fibrosis Eric must keep careful written track of his physical activity	Eric must share health data with researchers he has never met Eric could help other kids with Cystic Fibrosis The study might distract Eric from his soccer goals	Eric cannot predict how the research will be shared with others The research might not be successful
Possible reasons why Eric DOES want to participate	Possible reasons why Eric DOES NOT want to participate	Does not impact Eric's decision
SAVE		

Finally, a short sorting activity was added after Henrietta's case to prompt students to distinguish between how medical professionals treated Eric and Henrietta. Students sorted details from the cases, like "The patient was respected as an important decision-maker in their health" or "the patient's medical information or material was taken without their consent." Students could sort details into buckets labelled "Eric", "Henrietta", or "both". In doing so, students distinguish differences between Eric's case, which is more familiar to their experience, and Henrietta's, which is new and exemplifies violations of consent and medical racism.

In summary, the RPP team added the Eric case study to make Henrietta's case, which was removed from students' time and life experience, more accessible to them. Activities were designed to support students in distinguishing between the two cases. However, teachers felt that content related to issues of data privacy and sharing medical data was hard for students to identify with, as it was unlikely that most had made decisions related to sharing medical data. This prompted a shift in framing for revision two that decreased the emphasis on data science practices and research in order to make justice ideas related to Henrietta's story more accessible to students. For this unit, the "as created situations" were not just the activities that were added and refined within the unit (e.g. the Eric Case study) but also the specific content that was adjusted or dropped in order to make the SJSI more accessible to students.

COVID-19 Unit

Pilot Design

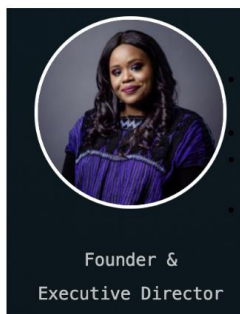
The pilot design of the COVID-19 unit positioned students as data storytellers who can use data to uncover and tell stories about the impact of COVID-19 on their community. This concept was modelled using a real-life example, an organization called Data 4 Black Lives (Figure 16). At the time (2020 and 2021), this organization was collecting, analyzing, and visualizing data about the impact of COVID-19 on Black communities in the United States. Providing a concrete example of how an organization used Data Storytelling in a justice context made the concept of using data in a justice-oriented way more accessible to students by modelling what they could do with COVID-19 data in the unit.

Figure 15

Pilot Activity Centered On Data4BlackLives and Its Founder, Yeshimabet Milner.

Intendend Purpose of Data

Many different organizations determine **why**, **for whom**, and **how** for themselves. Here is an example of one way Yeshimabeit and Data for Black Lives (DFBL) determined their **why**, **for whom**, and **how**.



COVID-19 Data should **inform the implementation of available and accessible testing sites and tests** that meet the health needs of **Black communities**.

COVID-19 data should **inform transparent, accountable, and community-informed protocols for contact tracing** and other public health concerns.

After exploring Data4BlackLives in the first few steps of the unit, students discovered different variables used to understand the impact of COVID-19 and challenges and limitations in collecting and analyzing COVID-19 data at the time. Students then used the Data Explorer to engage in two investigations of using publicly available COVID-19 data. The first investigation was a structured and narrow investigation that focused on trends in COVID-19 in their local area over time. The second was a more open-ended investigation focused on using COVID-19 data and demographic data (age, race/ethnicity) to uncover trends in how demographic groups were impacted by the pandemic. Available data was primarily organized by county and state, showing the percentage of total COVID-19 cases by race/ethnicity. Students could choose between comparing four different large counties within their state or comparing four different states, including the one they lived in (Table 24). After identifying patterns in county or state data, students participated in a jigsaw activity to explore possible explanations for the different patterns observed in the data. These final activities are discussed in more detail in Chapter 3.

Table 24

Summary of Data Sets Used in Each Version of The COVID-19 Unit

Iteration	Data Set	Localization	Variable examples
Pilot	Case by race/ethnicity and county	Yes (counties within state)	-Case percent per race/ethnicity -Population percent per race/ethnicity
	Case by race/ethnicity and state	Yes (state)	-Case percent per race/ethnicity -Population percent per race/ethnicity
Revision One	Economic/job loss over time by demographic	No (national dataset)	-Time in months from May 2020 to April 2021 -Demographics (male/female, race/ethnicity) -Employment Status (remote work, unable to work with pay, unable to work with no pay)
	Essential workers and risk by demographic	No (national dataset)	-Demographics (including gender, race/ethnicity, education) -Job sectors with “essential status” (ex, food service, health)
	Pre-existing conditions and case rates by county	Yes (counties within state)	-County -Four pre-existing medical conditions -Percent in poverty -COVID-19 cases and deaths -Percent without health insurance
	Vaccinations by county	Yes (counties within state)	-County -COVID-19 vaccination/booster rates -Percent in poverty -Percent without health insurance -County demographics (race/ethnicity, age)
Revision Two	County Demographics and COVID Outcomes	Yes (counties within state)	-Demographic (race/ethnicity, gender) -percent of population -percent fully vaccinated -Cases per 100k, % of cases -Deaths per 100k, % of deaths

Age and COVID outcomes in CA	Yes (state)	-Age group -percent of population -percent fully vaccinated -Cases per 100k, % of cases -Deaths per 100k, % of deaths
Risk factors across counties	Yes (counties within state)	-County -percent fully vaccinated -Cases and deaths per 100k -Percent in poverty -Percent without health insurance -Percent over 65
State demographic and COVID outcomes in CA	Yes (state)	-Demographic (race/ethnicity, gender) -percent of population -percent fully vaccinated -Cases per 100k, % of cases -Deaths per 100k, % of deaths

Pilot Implementation and Findings

Observation field notes indicated that many students attempted to center themselves in the data. This was often reflected in the data sets that the variables students chose to explore. For example, many students chose counties or the state (California) that they lived in (Beatriz and Elaine's students) or knew people who lived in ("I got family in LA" observation field notes, Elaine's class, 8/26/2021). Conversations between Gregory's students suggested that some of his students were centering themselves as they reviewed the data by comparing COVID-19 outcomes for Black people where they lived to other states (Table 25). In this example, students compared across states, but they did not discuss why they saw these differences.

Table 25

Transcript From the Pilot Implementation of the COVID-19 Unit in Gregory's Classroom. During the Discussion, Students Compare the Percent of COVID-19 Cases by Demographic Groups (In This Case, African American) In the State They Live In (California) To Other States. Pilot Observation Field notes, 9/15/2021.

Turn	Participant	Transcript
1	Student 1	Let's look at California. California has only 5%.
2	Student 2	Oh that's bad.
3	Student 1	Yeah, oh Texas has more than us, that's super sad.... Louisiana is where there is 32%, that's the most, oh Mississippi has 37% I'm just going to look through, that's really interesting, this is actually super interesting.

Elaine was the only teacher among the three who centered students' experiences while using the unit. After students learned about D4BL, she asked students to verbally share their ideas about the different stories they wanted to tell about COVID-19 in their communities. Students mentioned ideas such as telling "stories about vaccines" and "a story about everyone in my community" (Observation field notes, 8/16/2021). While this prompt was already included in the

unit, her discussion provided students with additional opportunities to share experiences from the pandemic, making the purpose of the unit and use of data to understand the COVID-19 pandemic more accessible. An overview of these findings and others from the pilot implementation can be found in Table 26.

Table 26

Summary of Findings From Pilot Implementation of the COVID-19 Unit and Resulting Revisions to Revision One

Data Source (participants)	Summary of findings	Planned Revisions
Online web-based unit	Steps 1.1-1.3 highlight an example of how a real-life organization uses data to uncover injustice, making concepts of data storytelling and using data for social justice accessible to students. Data sets focus on ethnographic variables available at the time (age, race/ethnicity) and case, death, and hospitalization rates). Data sets were limited in supporting students to investigate questions that were of interest to them or mattered to their communities.	D4BL connection remained. Data Sets and Data Explorer: Data sets were expanded to include additional variables related to underlying factors that contribute to inequitable COVID-19 outcomes (exposure, healthcare access and affordability, job loss, and pre-existing conditions).
Observations from unit implementation (Lead researcher, Teachers Gregory, Elaine, Beatriz) Implemented but not observed: Jaime	Observations indicate that some students centered themselves within the data sets in various ways, including using language that centered themselves while interpreting the data (Gregory) or choosing certain data sets or variables because they are familiar with them or live in them (Elaine, Beatriz). Elaine is the only teacher who uses an activity or discussion to elicit students' ideas from their experiences. While students were working on their data investigations all three teachers circulated to support students with the technical aspects of graphing (e.g. what should go on the X and Y axis, choosing the appropriate type of graph.	Data explorer: No major changes to the capabilities of the data explorer In the final activity, students explore several youth-led initiatives during the pandemic focused on fighting misinformation, increasing vaccine access, and disability rights. Students use these examples as jumping-off points for brainstorming how they might take action to support their communities.
Students' Data Investigations (Gregory, Jaime, Elaine, Beatriz)	59.7% (Total N =234) of the student questions could be answered by the data in the unit, however, few were complex and many could be answered with yes or no responses.	

Teacher Interview (Lead Researcher and Teachers, Gregory, Jaime, Elaine)	Teachers felt that including a real-life example of how an organization uses data made concepts more accessible for students. Teachers reported that students were less engaged during the data exploration activities. Teachers attributed this to different causes, including the simplicity of the questions students could ask given the data (Jaime), and challenges in connecting variables to students' prior knowledge or experiences (Gregory).
Workshop (2 researchers, Gregory, Elaine, and an additional teacher who ended up not using the unit)	This tension was not discussed during the workshop.
Teacher Research Internship (1 researcher, Elaine)	Elaine and the researcher curated data sets based on newly published data and student interest. The team hypothesized that by connecting to students' interests and the stories students wanted to tell about their communities, students could center themselves and their communities in the data. Elaine added an activity focused on youth-led action during the COVID-19 pandemic to empower students to consider how they might support their communities.

Student work revealed that while many students were able to create questions that were answerable by the provided data sets, few were complex, and many could be answered with yes or no explanations. 59.7% (Total N =234) of the student questions could be answered by the data in the unit, and 40.3% could not be answered using the data or were not questions (incomplete sentence, a statement about data instead of a question, etc.). Questions that could be answered by the data sets could be sorted into two categories: identifying specific data points (What's the amount of COVID cases for Latinx in California?) or comparing variables (Do white people in California have more COVID cases per percent population than Asian people in California?). Those that could not be answered by the data were often why questions, such as “Why are there so many cases for Hispanic/Latino people in [example] county?”

Teachers agreed that the Data4BlackLives example was supportive in helping students discover how data science can be used towards justice-centered ends. “[Data4BlackLives] was super valuable, especially because it's showing that this collaboration is happening in a real-world context” (Elaine, COVID-19 Pilot post-implementation interview, 9/16/21). However, the data sets themselves were not motivating or scaffolded enough to support robust learning and engagement in data science practices. All three teachers noted that students struggled with the open-ended investigations. For example, Gregory noted that students seemed “frustrated with not being able to show their learning the way that they wanted to” (Gregory, COVID-19 pilot interview, 10/1/2021) during the data investigations. Jaime and Elaine attributed this to the limited

data sets and felt that they did not provide enough opportunities for students to create complex questions about the impact of COVID-19, resulting in students' simple, relatively easy-to-answer questions. "Some of the questions that they came up with... You know, weren't that interesting. Like what happens to hospitalizations as the number of COVID cases goes up? I mean, it's kinda like duh" (Jaime, COVID-19 pilot post-implementation interview, 10/1/21). They suggested that using more complex data might result in students creating deeper questions that result in more than surface-level observations about COVID-19 cases across two different variables. Gregory had a different hypothesis, stating that his students had limited knowledge about differences between California counties, which made it challenging for them to reason about what they were seeing in the data.

I do feel like their knowledge of national politics is much more informed than California county politics. If they did county right, they were comparing Santa Clara to something up north. I'm not sure they know that much about the politics of California and how that affected COVID. (Gregory, Pilot post-implementation interview, 10/1/2021)

Teachers explained students' lack of engagement and challenges in working with the data to inaccessible data sets, either because relationships were simple and unmotivating (Elaine and Jaime) or because variables were not relevant to students' lived experiences and prior knowledge. This made reasoning about the data inaccessible to many students, suggesting the need to refine the data sets.

Refinement and Revision One Design

Elaine, Gregory, and another teacher (who did not end up using the unit in the fall) reviewed a unit prototype during the summer 2022 workshop. Their discussions focused on student work related to the *Impacts* question (discussed in chapter three) and not students' investigations. However, Elaine shared slides she made to accompany the unit during a peer consultancy session, which contained several scaffolds for her English Language Learners. While not aligned with making the content accessible through real-life examples or relevancy, these slides used specific scaffolds (such as Spanish translation or sentence starters) to make content accessible to a specific population of students who needed additional support. These slides were not integrated into the unit, but were shared with other teachers.

Refinements to the unit focused on revising the curated data to better align with students' interests regarding the impact of COVID-19 and making adjustments to the data explorer to better support students in working with the data. This work was supported by Elaine, who was participating as a research intern with the RPP in the summer of 2022. We had a unique opportunity to expand the topics of the different data sets, as our work coincided with the availability of more data. Major government websites (CDC, county websites, etc.) became more robust in their data reporting. Variables about vaccination, booster rates, pre-existing conditions, and other equity measures were added to county, state, and national websites. These additional variables allowed us to create more interesting datasets for students to investigate (Table 20) that aligned with some of the interests identified in Elaine's summer internship.

To identify specific topics to narrow our curation of the data sets, Elaine analyzed students' answers to a question in the pilot version of the unit, "What story would you like to tell about COVID-19?" With the research team's support, Elaine created a codebook of topics and

categorized the topics students were interested in telling a story about. She identified 16 story categories, including topics such as the impact of personal decisions (like masking) on others (110 responses, 31%), COVID-19 impacts on health (74, 21%), impacts on school/education (67, 19%), and the number of cases/infection rates (53, 15%). Twelve responses (3%) were personal stories, such as stories about sick family members. The sixteen categories were compared to existing topics or data sets found within the pilot. Four categories of student ideas were found to already exist in the unit: Number of cases, the impact of personal decisions, death/hospitalization rates, and COVID infection based on race. We used the remaining topics not included in the unit to identify five new datasets to add to the unit. These topics were chosen based on the number of responses that included the category, availability of public data sets, and whether the data sets could be cleaned to work in the WISE platform. We identified four datasets to use in the lesson (Table 19) and one additional dataset on COVID-19 misinformation to use in another portion of the unit. In curating a broader set of variables students could explore with these data sets, we hoped to make the data more accessible to students by connecting to the stories they were interested in telling.

Several scaffolds were integrated into the lesson to support students in making sense of the data sets. When first introduced to the data sets, students worked in groups to create informational posters about one of the four data sets. These posters included an overview of the topic of the data set, the meaning of the different variables, relationships between variables that could be explored, and draft questions. Students could then review the various posters made by their classmates to gather background information on each data set before choosing a specific dataset to explore for their investigation. Once they chose a dataset, students completed a short activity that prompted them to revise an imaginary student's question based on the criteria provided to them. Students created (or chose from the various posters about their data set) and revised their own investigation question before finally moving to the data tool to investigate their question using their chosen data set.

Finally, Elaine was motivated to add a new activity to the units unrelated to the datasets that focused on taking action. In this activity, students read examples of different youth-led actions in the pandemic, both locally and globally, including actions focused on disability rights, fighting COVID-19 misinformation, and increasing access to vaccines. After reading about the examples, students brainstormed ideas for how they could support their community coming out of the pandemic. These real-life examples, which focused on youth action, made the concept of youth and community-led action accessible to students.

Revision One Implementation and Findings

Implementation revealed the different ways that teachers supported students' investigations (An overview can be found in Table 27). During the new poster activity, Elaine had students create posters in groups using poster paper and markers. Beatriz and Rachel, partner teachers at the same school site, had students create posters online using Google Slides. All three teachers facilitated brief gallery walks after students completed their posters to promote collaboration and sharing of information about the datasets between students. Teachers circulated during the data investigations to answer student questions, clarify variables, or provide feedback on their investigation questions. For example, Elaine circulated while students were completing the posters to support different groups, and spent much of her time pushing students to create more complex questions. For example, one group wrote the question “Did the number of people working go down?” on their poster for the economic/job loss data set. Elaine asked them to “be a little more specific... It's not just the number of people, right? You're looking at a specific group of people. How did the number of people working decrease overall compared to one specific demographic? Because this, [their

original question], I can just Google” (Observation field notes, 9/6/2022). Students took several minutes to revise their question by adding a comparison between groups: “How did the number of working women go down compared to men during COVID?”

Table 27

Summary of Findings From The Revision One Implementation of the COVID-19 Unit and Resulting Revisions to Revision Two

Data Source (participants)	Data/Examples Summary of findings	Planned Revisions
Online web-based unit	While the expanded data sets provided students with more choice aligned with student interest and included several new economic, health, and exposure factors related to COVID-19 outcomes, students struggled to make sense of the complex variables, create investigable questions, and identify trends within the data.	D4BL connection remained. Data Sets: The scope of data sets was narrowed while preserving opportunities for student choice and interest.
Observations from unit implementation (Lead researcher, Elaine, Beatriz, and Rachel) Used by no observations: Lacey	Elaine enacted two customizations that connected unit content to students' communities by building on her pilot customizations and the empowerment activity she added to the unit over the summer. Beatriz and Rachel did not implement customizations or supports related to making content accessible through real-life connections. All three teachers implemented the new poster activity. Elaine used written posters, while Beatriz and Rachel used online tools. All three teachers circulated to support students' investigations. Supports focused on data science practices (such as refining investigation questions) and graphing. Teachers shared feedback during implementation, highlighting continued challenges with supporting students to reason about the data.	New scaffolded exploration activity that prompted students to distinguish between different variables within the data set. Data Explorer: Changes allow students to compare certain variables and show trend lines for their data. The final empowerment activity remained
Student work (Elaine, Beatriz, and Rachel)	36% (Total N =133) of the student questions could be answered by the data in the unit. Students were less supported in reasoning about the variables and creating answerable questions from the new, expanded data sets.	
Teacher Interview (Lead Researcher Elaine, Beatriz, and Rachel)	Teachers felt that the expanded data sets were too large in scope. They reported that students had challenges working with multiple variables and making sense of certain variables. Data sets and activities needed refinement to narrow scope and scaffold student investigations.	

Discussions between the teachers and the lead researcher during implementation created opportunities for teachers to provide initial feedback on changes to the datasets, data explorer, and new activities. Though the poster activity prompted students to stop and work with their peers to break down the data sets, teachers noticed that students still needed more support in understanding the variables or creating answerable questions that moved beyond yes or no answers. For example, Rachel pulled me aside to mention some concerns about the variables in the economic/job loss data set, stating that “I’m not sure that they’re seeing the connection between these variables and the impact of COVID-19. They are seeing this as separate” (Observation field notes, 10/7/2022). She also noted that students were having trouble understanding measures such as *percent of population* and added an in-the-moment customization that walked students through how this type of measure is calculated. Elaine and Beatriz shared similar feedback regarding unit scaffolding and challenges in supporting students to work with the data.

Findings from student work aligned with teachers’ initial feedback. Students were unsupported by the unit activities to create answerable questions, and the broader, larger data sets were challenging for students to work with. While students’ questions were related to the topics discussed in the datasets, a smaller percentage of their questions (36%, N=133) were answerable with the datasets provided as compared to the pilot. Questions that could be answered using the data compared two or more specific data points. For example, “Which county has more vaccinations in California, Alameda, Santa Clara, or San Mateo?” or “How many women and men teleworked?” Questions that could not be answered using the data were either too vague, such as “How many cases have there been in the U.S?”, or asked why trends in the data existed, or combined variables in the data in ways that could not be examined using the tools available in the unit. For example, one student asked, “How many people got vaccinated while being in poverty?” These findings suggest that the changes to the data sets made them too challenging for students to work with. This could have occurred for a variety of reasons. As Rachel stated above, certain variables might have been unfamiliar to students or difficult for them to connect directly to COVID-19 outcomes. Additionally, the size and scope of these new data sets were much larger than the pilot data sets (See Table 19). This likely made them more challenging for students to work with.

Teachers’ feedback during post-implementation interviews aligned with their initial thoughts that were shared during implementation. Rachel repeated her feedback about the economic/job loss data set shared during implementation and discussed how to support students to understand the differences and ability to compare specific measurements, such as the percent of cases versus cases per 100,000 people. While she felt her customization was somewhat supportive, she suggested adding a specific activity to the unit to support students in distinguishing between the two ways of measuring COVID-19 outcomes.

What would a matching activity look like where they have to identify like the problem in the data with like a picture of that data set...this one is a percent and you can't compare them because it's percent and then this other one is numbers.”
(Rachel, Revision One post-implementation interview, 2/13/2023)

Rachel also mentioned that the data sets themselves seemed to be too big in scope and needed to be narrowed down to provide her students more opportunities for success

I think, just more simplified raw datasets and just sticking with, like, comparing these two variables. So they can really go deeper with it. You know, they have trouble with multiple variables just in general... I think it just might have been a little too much, at least for my students. (Rachel, Revision One post-implementation interview, 2/13/2023)

Beatriz agreed with her colleague about the size of the datasets, but suggested a slower approach to build up to larger datasets. “They had so many options. Maybe more of a stepwise thing, these variables, then add another variable onto the graph. Students want to go 100 different directions, so a progression might help.” (Beatriz, Revision One post-implementation interview, 11/2/2022). Elaine, who had curated the datasets and worked on the Data Explorer over the summer, had similar reflections. While she felt that the broader scope of topics was engaging to her students, she felt that “We went too big, I think, we need to find the right size of data sets and relevancy of variables” (Elaine, Revision One post-implementation interview, 9/6/2022).

Finally, Rachel had additional feedback related to supporting students to make connections between the data and their experience, given the more historical nature of the pandemic at the time of Revision One. She suggested adding additional prompts to ask students, “How were you affected by the pandemic?” to “get that buy-in right away” into unit content (Rachel, Revision One post-implementation interview, 2/13/2022). She followed this by adding prompts at the end that asked students to compare their experiences to what they saw in their data investigations. “It would be nice to circle back at the end, as you looked at this data. What are your thoughts now?” Rachel’s feedback focused on connecting to students’ experiences and using their experiences to help them reflect on what they found in the data.

Data from the implementation of Revision One revealed major areas for refinement. First is managing the scope and size of the data sets to be more appropriate for ninth-grade students, as students struggled to make sense of the large, complex data sets. In the first iteration, the scope and size of the data sets were too limited, which led to students creating superficial questions. Student questions were more complex in the second iteration, but over half (64%) could not be answered using the data provided. These results underscore the importance of curating data that is appropriate for the learners. While redesigning the activities over the summer, researchers (and Elaine, who continued as a research intern for a second summer) determined which of the added variables from Elaine’s changes the prior summer were most relevant to students within these existing data sets and limited the scope of the data to support their investigations in revision two.

The second area for improvement is refining the scaffolds to support students in understanding the different variables and refining their investigation questions. Rachel highlighted challenges in students’ ability to make connections between certain variables and the COVID-19 pandemic, and Elaine’s discussions with students provide insights into some of the ways students can be prompted to engage in revision. She prompted students to consider whether their question could be answered with a simple yes or no. Offering this criterion and others for students to check their questions with before conducting their investigation can scaffold the revision process. Though our revision activity asked students if they could answer their questions with the data provided, it did not contain the specific questions that Elaine used with her students. Her implementation and feedback served as a model for refining the unit activities.

Revision Two Design and Student Work

Major changes were made to the unit, Data Explorer, and scaffolding activities to respond to the challenges highlighted in our findings from revision one. First, data sets were adjusted to limit the size and scope, while maintaining some of the topics and ability for choice (Table 24). Students were able to choose between four main datasets, and if they chose a county dataset, they could pick a specific county to focus on. In limiting the scope of the data sets, the team sought to still include opportunities for choice so that students could investigate variables and questions that felt meaningful or interesting to them. Options related to job loss or economic outcomes were removed, and the topic was integrated into a different aspect of the unit.

Adjustments were also made to the structure of the unit and activities to better scaffold students in working with data. Rachel's suggestion about adding some personal reflection was added to the beginning and end of the unit. Students were also able to preview dataset topics at the beginning of the unit, and were prompted to consider which dataset would be most interesting to tell a story about, given the story they wanted to tell about their communities. We made adjustments to the data exploration activity that, while similar to the poster activity, provided more structure for defining the variables, comparing different ways of measuring outcomes, and distinguishing between the ability to compare specific variables (Figure 18). Students then created draft questions, completed a question critique activity, and revised their questions before choosing and graphing their variables. Changes were made to the Data Explorer tool (Figure 19) that allowed students to better compare certain variables and create regression lines. Elaine's empowerment activity remained in the unit.

Figure 18

Scaffolded Data Exploration Activity Added To Revision Two.

Explain what each of the variables in the data set means in your own words.

% of population:
% fully vaccinated:
Cases per 100,000:
% of cases in county:
Deaths per 100,000:
% of deaths in county:

SAVE

Which variables are shown as percents (%) and which are shown as a number per 100,000 people?

Choices

People who are vaccinated

Deaths

Population within the county

Cases

Percent

Number per 100,000

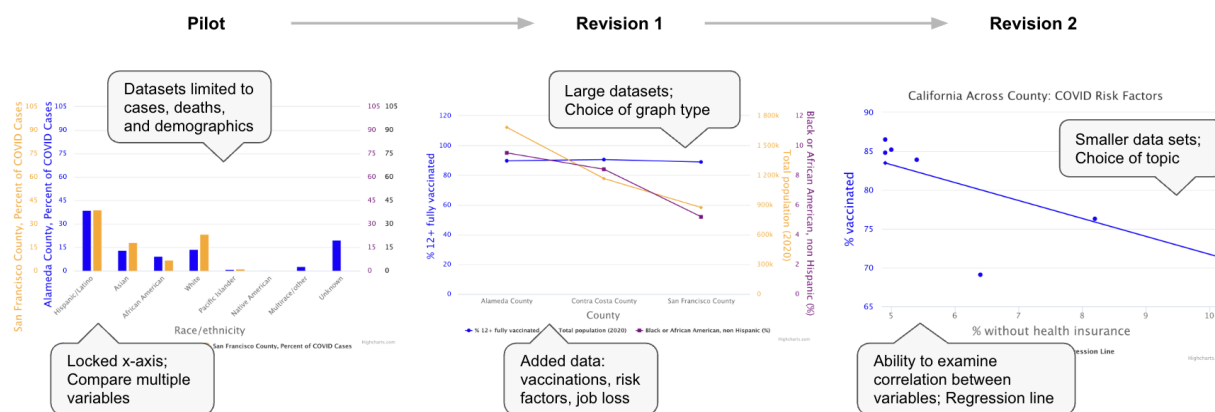
Both

SAVE SUBMIT

This data set as race/ethnicity demographic variables (example: Black/African American) and gender demographic variables (male or female). Can you compare a race/ethnicity variable to a gender variable? Why or why not?

SAVE

Figure 19
Refinement of the Data Explorer Across the Three Versions



In revision two, students had more success in creating answerable questions. 59% (N= 138) of students' questions were answerable, an improvement from revision one and similar to the pilot. This suggests that the changes to the unit for revision two to both the data sets and activities were more supportive of student learning than revision one. Unanswerable questions fell into four categories, incomplete, unrelated to specific variables within the dataset but relevant to COVID-19's impact, and why questions (Why did older people (60 and up) die more for their population compared to other ages), or relevant to variables but unable to answer given the data set (How has the amount of COVID-19 deaths changed since people began to get vaccinated compared to before the vaccines were made?).

Adjusting the data sets and activities to make variables more accessible to students and support them in using their experiences to make sense of the data was challenging for the co-design team. While students had some success reasoning about the variables and creating investigable questions in the pilot, the limited data sets and lack of appropriate scaffolding limited many students' ability to successfully complete the investigations. Elaine centered on making the data sets more accessible to students in revision one by aligning topics with what students were interested in, but this resulted in data sets that were too large in size and scope, and the inclusion of variables that were challenging for students to connect with COVID-19 outcomes. However, Elaine's empowerment activity served as an example for how the team could use real-life examples and center students' communities to make taking action accessible. In revision two, the team narrowed the scope of the data sets and refined the scaffolds to support students' data investigations, while trying to maintain relevance to students' lives and interests. As a result, students were moderately more successful in creating investigable questions relevant to the data sets. While progress has been made, the RPP team continues to work to refine the data sets and units.

Discussion and Conclusion

Emerging Design Tension When Making Data Science Accessible

This study highlights a challenging design tension (Tatar, 2007) experienced by the RPP: balancing the use of appropriate real-world examples and connecting to students' experiences to

support them in making sense of data and centering complex data science topics or skills in unit content. This work required repeated conversations about unit design, students' perspectives, and goals related to students' data science learning. Participants made choices about what content or activities to privilege or remove to try to address these goals. The “as created situations” that emerged as the RPP worked to address the design tension included the activities added to each unit (e.g., the Eric case study) the resulting data sets or OERs used in the unit (e.g., the publicly available data sets in the COVID-19 unit), content that was dropped (e.g., data privacy concepts in the *Henrietta Lacks* unit), and teacher-created customizations that focused on connecting concepts to students' communities (e.g., Elaine's empowerment activity). There was not one clean solution for either unit, and these designs continued to be iterated on by the RPP.

The pilot version of the HeLa unit heavily emphasized concepts related to data privacy, including making decisions about whether to share medical data and how researchers make decisions about what data (including physical data such as cells) to use for research. This framing, while it centered complex data privacy topics, was removed from students' everyday lives and limited their engagement. Adding and refining the Eric case study better reflected students' experiences and made Henrietta's story more accessible to students, but de-emphasized data privacy concepts. It may be that Henrietta's story, while an appropriate SJSI for discussing ideas about medical racism and inequities in access to quality medical care for people of color, may not, in fact, be the appropriate SJSI to support students to interrogate questions and ideas related to data privacy. It is also possible that the design team simply has not found the right way to integrate those concepts yet. Prior research has provided examples of how these concepts can be integrated into computer science and data science courses in ways that center justice issues (Baumer et al., 2022; Pangrazio & Selwyn, 2019; Vakil, 2018; Vakil et al., 2020). Conversations about Artificial Intelligence have opened up further opportunities for interrogating critical data science concepts and data privacy (Morales-Navarro et al., 2024). However, these learning experiences often occur outside of the K-12 school day or in undergraduate education. More work is needed to identify how to support students to learn about data privacy and critical data science concepts within the limitations of the K-12 curriculum.

In the COVID-19 unit, the team balanced aligning the data sets with students' interests with curating data sets of the appropriate size and scope to support students to successfully work with the data. Our data sets in the first iteration were too narrow, resulting in less complex questions and limitations in the types of questions students could ask. In revision one, “we went too big” (Elaine), and while the data sets included more topics aligned with students' interests, they became unwieldy, including variables that students were unsupported to successfully reason about, and ultimately, students were less successful in creating investigable questions. As Elaine put it in her post interview, “We need to find the right size of data sets and relevancy of variables.” Revision two made progress in getting to a happy medium, though the RPP is continuing to work on curating appropriate data sets (which have new challenges related to the removal of several data sets from government websites). As we continue to iterate on the unit and Data Explorer, we continue to seek to find the right balance in size and scope of data sets (Kjelvik & Schultheis, 2019) and look to the literature on the design of data analysis tools that support student learning as we continue to refine the Data Explorer (Konold, 2007; McNamara, 2019; Pimentel et al., 2022).

This work also extends our understanding of the KI design principle by illustrating how challenging it can be to make complex SJSI and data science topics accessible for students. There is no one-size-fits-all approach, as students have a variety of experiences and ideas related to those experiences that they can draw from when reasoning about SJSI or centering themselves in the

data (Linn & Eylon, 2011; Wilkerson & Laina, 2018). In the COVID-19 unit, students drew on their experiences and familiar locations to make choices about variables and reason about the data sets. We sought to build on this when choosing new topics, but discovered that the types of data students were interested in were not necessarily intuitive to reason about. For example, students were interested in telling stories about the economic impact of the pandemic, including job loss. When this data set was integrated into the unit, students struggled to see the connection between job loss and COVID-19. In the Henrietta Lacks unit, we initially tried to make concepts of data privacy and consent accessible by using consent forms students might be familiar with from social media. However, given that they were removed from the medical context, this example was unsupportive in making Henrietta's story accessible. While the literature on KI provides ample evidence that making science content accessible is supportive for learning (Linn & Hsi, 2000; McElhaney et al., 2014; Ryoo & Bedell, 2017), design teams must work to figure out the right real-life examples given specific SJSI.

Contributions of Teacher Expertise

Teacher expertise and involvement in making design decisions were key in the refinement of both units to make the unit content more accessible. Gregory initially highlighted that students felt that Henrietta's case was removed from their experience and was a major driver in integrating the Eric case study into the overall unit narrative. Teachers' feedback at workshops ensured that the types of questions included in the case study reflected their experiences and helped to refine the activity to better support students to contrast Eric and Henrietta's cases. Teachers' familiarity with their students' everyday experiences, including what they might go through when speaking with medical professionals, was an asset used to refine the language of the unit. These refinements highlight the importance of including teachers as experts during co-design (Matuk et al., 2016). They know their students, and this expertise is key in making science and justice content accessible. Partnerships that provide the space for teachers to share their ideas honestly and openly (Philip et al., 2022) and make their design decisions visible (Bichler et al., 2021; Bradford et al., 2021) are important in facilitating co-design.

Elaine led the refinement of the COVID-19 data sets and Data Explorer alongside me and a computer scientist in the RPP. She conducted the bulk of the analysis to identify topics of interest to students, and together we used this information to curate new data sets. Her continued reflection on the design, rooted in both her experience teaching the unit and as a designer over the summer, helped to further refine the data sets and Data Explorer in revision two. Elaine saw herself as a designer and felt ownership over the work during her reflections, using "we" when describing the continued changes that were needed. Involving Elaine in research and deep design work not only pushed designs forward but also created meaningful learning experiences for her. Her case illustrates how providing teachers with opportunities to participate in the research invites opportunities for learning and expanding professional identities (Jurasaitė-Harbison & Rex, 2005; Kowalczyk-Wałędziak & Ion, 2025; Taylor, 2017). This is explored in more detail in study three.

Future work

I am extending this work in several ways. First, I only analyzed a small portion of students' work within the units related to their data science learning, and a more extensive analysis of their work is needed to make their ideas visible (Ritchhart & Perkins, 2008) and identify continued areas of growth for the unit. I have started an extended analysis of students' data investigations, including their graphs and written graph captions, with Elaine. This analysis is still ongoing. In the HeLa unit, there are several items related to data science practices, including making sense of

graphical representations of patient outcomes and map data. While the emphasis on data privacy has been removed, there are opportunities to still examine how the unit supported students to reason about data.

Continued work is needed to refine the Data Explorer. At this time, refinements have been driven by teacher input and classroom observations. However, more in-depth user studies are needed to examine students' work with the tool more closely. How are they sorting the data as they explore the variables? The tool allows students to easily create graphs. Are they trying multiple visualizations and experimenting, or choosing specific variables and only creating a graph once? User studies where we collect data via screen recordings and have students talk through how they work with the tool are needed to continue to refine it.

Finally, our teachers made several customizations to support students' data science learning, only some of which are discussed here. I am interested in exploring these customizations more deeply to identify specific practices that support students to work with data, as these findings can support continued refinement of the unit and identify best practices we can support other teachers in developing.

Chapter 5: Teachers' Co-design Trajectories in an RPP Focused on Justice-Centered Science Instruction¹

Introduction

This chapter explores how a Research Practice Partnership (RPP) shaped the trajectories of three life science teachers as they engaged in co-design and customized two social justice science units. As stated in chapter two, this RPP is a long-term relationship among classroom teachers, learning scientists, discipline experts, and computer scientists who jointly seek to improve teaching practice, curricula, and pedagogy (Coburn & Penuel, 2016). Previous research has documented the impact of products of RPP and how these products improve teacher practice and student learning outcomes (Gerard et al., 2010; Matuk et al., 2016). Like other RPPs across the world, this RPP is the site for creating transformative educational interventions (Bang et al., 2007; Gerard et al., 2010; Kang & Nation, 2023; Matuk et al., 2016; Penuel et al., 2007; Vakil et al., 2022). In recent years, there have been calls to better understand the mechanisms within RPPs that support collaboration among participants and empower non-researcher partners, including school administrators, teachers, community members, and students to be leaders within partnerships (Goldman et al., 2022). While several authors have recently explored these dynamics and structures that democratize research in RPPs, more work is needed to understand the diversity of practitioners' experiences and how systems, relationships, and structures within RPPs can empower teacher agency, given the unique experiences and professional goals of practitioner participants.

As outlined in chapter two, this RPP merges Knowledge Integration (KI) pedagogy (Hoadley, 2017; Linn & Eylon, 2011) and Justice-Centered Science Pedagogy (JCSP, Morales-Doyle, 2017), to leverage educational technology to implement justice-centered science instruction. The partnership includes a wide variety of participants, including teachers, researchers, computer scientists, and subject matter experts, and supports participants to engage in co-design towards creating and refining the justice-centered science units. This specific chapter focuses on the experiences and learning trajectories of three focal teachers involved in the RPP: Elaine, Gregory, and Beatriz. Previous research has highlighted how co-design can validate teachers' perspectives and leverage their expertise to create solutions to educational problems (Lee et al., 2024; Penuel et al., 2025; Sjolund et al., 2023). We report on how the three teachers participated in co-design with learning scientists in the context of the RPP. We explore how each teacher — varying in RPP experience, school context, and background — customized justice-centered science units and how RPP structures supported their development. We investigate the following research questions:

1. What are the trajectories of the three teachers? How does the co-design structure support each teacher?
2. How does the RPP Workshop support the participating teachers' progress in co-design?

¹ An initial analysis of Gregory's case was presented at the International Society of the Learning Sciences Annual meeting in June of 2024 and co-authored with Marcia C. Linn. This chapter was submitted to a special issue of *Information and Learning Sciences* in March of 2026 and co-authored with Marcia C. Linn. The word limit for the manuscript was 8000 words, including tables. For a detailed breakdown of labor, see appendix, Table 30.

Rationale

RPP Background

RPPs create innovative STEM curricula and education technology (Kang & Nation, 2022; Penuel et al., 2007), refine teaching practices (Billings et al., 2025; Kang, 2022), support teacher learning (Penuel et al., 2022), and elaborate on justice perspectives (Calabrese Barton & Tan, 2020; Vakil et al., 2022). Our RPP produces standards-aligned, web-based science units that have been adapted by teachers globally (Bichler et al., 2022; Matuk et al., 2016). It creates education technologies, including interactive computer models (Gerard & Linn, 2025), AI guidance (Gerard et al., 2025), and collaboration tools (Matuk & Linn, 2023). It supports teacher learning (Gerard et al., 2022b) and explores social justice perspectives in science education (Bradford et al., 2023a). The RPP has impacted uptake of KI across the field (Kali, 2006; Krajcik & Mun, 2014) and has leveraged KI to support teachers in customizing curriculum (Wiley et al., 2019).

Teachers as Co-designers of Justice-Centered STEM Instruction

This RPP emphasizes creating justice-centered STEM instruction that focuses on Social Justice Science Issues (SJSI) that are relevant to students and their communities. Doing so validates students' personal and community knowledge (Morales-Doyle, 2017) and aligns with the KI principle of making science accessible through real-life examples (Linn & Eylon, 2011). However, though researchers can have initial ideas about what SJSI are motivating and meaningful for students, we are not experts on the perspectives of students and their communities. Educators, students, and their families are the experts. While this RPP does not directly involve students and their families, we rely on the expertise of our teachers to co-create meaningful learning experiences for our student participants.

The important contributions of teachers to the design of justice-centered STEM curriculum and enactment of equity-oriented teaching practices are well documented (Bradford et al., 2023a; Calabrese-Barton & Tan, 2020; Kang & Nation, 2022; Morales-Doyle, 2017; Upadhyay et al., 2019). Morales-Doyle's research, which proposes justice-centered science pedagogy, occurred while he taught high school chemistry, and his findings are the result of the design, implementation, and refinement of a justice-centered chemistry unit in his own classroom (Morales-Doyle, 2017). His positionality as an educator allowed him to identify SJSI relevant to his students and create opportunities for them to collaborate with local scientists and educate members of their communities. Upadhyay et al. (2019) document how a teacher leveraged his understanding of his students' indigenous cultural practices to inform science instruction that included local social justice issues and opportunities for students to integrate their indigenous practices into science instruction. This supported his students to feel that their culture held value, while also supporting them to develop sociopolitical consciousness. This classroom is one of several examples that demonstrate how crucial teachers' expertise is for designing meaningful justice-centered science instruction for students.

Respect for RPP Participants

Successful co-design requires that each participant respect the expertise and perspectives of other participants, often by overcoming established power relationships. Researchers may act as authorities in RPPs, and teachers may be positioned as enactors of curriculum, rather than co-designers and co-researchers. Activity structures that position researchers as authoritative can

imply that teachers' knowledge is less valuable than researchers', stifling teachers' voices and agency in the partnership. Structures can disrupt these typical dynamics to position teachers and researchers as respecting each other's perspectives (Kyza & Agesilaou, 2022). With this chapter, I hope to contribute to a growing movement within co-design research to examine how specific structures and activities can disrupt these typical dynamics to position teachers and researchers as respecting each other's perspectives and increasing teacher agency in co-design (Penuel et al., 2023; Severance et al., 2016; Severance & Krajcik, 2018).

Deliberate designs that invite practitioners to contribute have proven successful in eliciting teachers' ideas about curriculum design and refinement and promoting teacher agency within partnerships. In chapter four, I discussed how a prototype of the Eric Case study served as an anchor resource to scaffold teachers' feedback on the new activity. Teachers were able to share how the activity made Henrietta's case more accessible by allowing students to connect to a contrasting case similar to their experiences with medical professionals. They were also able to provide concrete feedback on adjusting the wording of the activity to make certain questions easier for students to understand. This was built on existing work from the literature that demonstrated promise in eliciting teachers' feedback with functional prototypes, unit descriptions, and other artifacts. For example, when practitioners shaped the design of a teacher dashboard, they added features that made it more useful (Matuk et al., 2016). Functional prototypes and student work helped to elicit teachers' feedback and highlight the most useful features for teachers. Using tools such as standards-aligned storylines (Severance et al., 2016) and unit descriptions (Jayathirtha et al., 2025) can make design decisions and pedagogy visible, supporting teachers to share feedback during co-design. Finally, positioning practitioners as co-leaders within partnerships (Kyza & Agesilaou, 2022; Philip et al., 2022) who can shape participation structures with RPPs themselves can help to position teachers as leaders and structure co-design in ways that attend to the complexities of teachers' given school and district contexts.

KI Pedagogy and Justice-Centered Science Instruction

RPP activities have informed KI Pedagogy, and KI guides members of the RPP as they design units, customizations, and classroom teaching strategies. KI pedagogy emerged during longitudinal and cross-sectional studies of students' reasoning that showed that students bring multiple, disconnected ideas about science and justice phenomena into classroom learning (diSessa, 1993; Inhelder & Piaget, 1958). For example, when learning about the impact of COVID-19, students draw on a variety of ideas based on their experiences with the disease, what they witnessed in their everyday lives, and their prior understanding of infectious diseases. Students use these ideas to make sense of COVID-19 data and understand the pandemic's impact on a broader scale (Calabrese Barton et al., 2021; Sedawi & Calabrese Barton, 2024). KI pedagogy emphasizes that initial ideas are important building blocks that students can integrate with newly discovered ideas to support a robust understanding of phenomena (Linn & Eylon, 2011).

Research on KI has revealed four instructional strategies that support students in building on their prior ideas and integrating their ideas: *eliciting* student ideas, *discovering* new ideas, *distinguishing* among ideas, and finally *sorting connections* between ideas. Research has also surfaced four design principles (Kali, 2006): (1) making science accessible to each learner with relevant examples (Linn & Hsi, 2000), (2) making student thinking visible using explanation activities that require linking ideas with evidence (Ritchhart & Perkins, 2008) (3) helping students collaborate (Matuk & Linn, 2023) and (4) promoting autonomy by guiding reasoning (Davis, 2003). Chapter one outlines these instructional strategies and design principles in more detail, and

discusses how the instructional strategies were merged with the key components of Justice Centered Science Pedagogy (JCSP, Morales-Doyle, 2017). Chapter four discusses how the RPP attended to a design tension related to the KI design principle, making science accessible with relevant examples.

During RPP activities, teachers refine their understanding of KI and JCSP that underlie curriculum design. Various activities made these frameworks explicit to participants, allowing RPP participants to use them as a common language to communicate ideas about student learning outcomes, unit refinement, or teaching pedagogy. (Bichler et al., 2021; Bradford et al., 2021; Gerard et al., 2022b). Specific resources, such as unit visualizers and prototypes, made the four instructional strategies explicit and visible to participants. These resources have been refined through previous research and have been shown to support participants in discussing how unit activities engage students in different KI-aligned instructional strategies (Bradford et al., 2021). KI rubrics make explicit how students can integrate science and justice ideas to progress in KI, and teachers use these rubrics to examine student work and reflect on student learning (Gerard et al., 2010). Positioning activities build a collective understanding about what it means to integrate science and social justice in science teaching using SJS. For example, a positioning activity used in one of the first RPP workshops, all RPPs examined data related to an SJSI and shared their ideas about the data in an online Padlet discussion board. This online discussion board *elicited* ideas from all participants and displayed them in a way that allowed teachers to collaborate and learn from each other's ideas (Gerard et al., 2022b). As teachers moved through the rest of the positioning activity, they engaged in each KI instructional strategy. As we examine teachers' customization trajectories, we focus our analysis on how their progress aligns with these pedagogical frameworks.

Methods

Participants

Elaine identifies as a Black woman and has been teaching 9th-grade biology in the same district for five years before joining the RPP. The first author recruited her to join the RPP. Elaine has been part of several educator communities focused on social justice. She was motivated to join the RPP because she felt it would expose her to new ideas that could help improve her practice. Elaine participated in a summer research internship that supported (and compensated) her to work with the RPP in a research capacity for two summers. This additional opportunity and corresponding artifacts are included in the analysis.

Gregory identifies as a white man. He joined the RPP 13 years ago, when he started teaching middle school life science. He has implemented over twenty units during his time with the RPP. Gregory initiated discussions of social justice in the RPP after independently investigating issues of social justice. He feels that discussions of social justice and race are “important to teach in all classrooms” (reflective interview, 11/7/2023)

Beatriz identifies as a Latina. Beatriz earned a Ph.D. in public health before becoming a biology teacher. She feels that public health and access to healthcare are a “through line” with which to center social justice in science. She has over twenty years of teaching experience, mostly at her current school. Beatriz joined the RPP along with her colleagues at the school. When the RPP incorporated social justice five years ago, Beatriz was motivated to regularly participate.

The original manuscript that became this chapter was written for a special issue of *Information and Learning Sciences* in partnership with my advisor, Marcia C. Linn. The first

author, myself, identifies as a white woman. I am a former science teacher who centered my science curricula around local phenomena or justice issues. I joined the RPP when I became a Ph.D. candidate in the fall of 2020 and have worked closely with all three teachers. I combine the perspective of a teacher and a learning scientist in the RPP.

The second author, Marcia C. Linn, identifies as a white woman. She initiated the RPP, leads funding for the RPP, and coordinates refinement of KI pedagogy. She serves as a mentor to the members, visiting classrooms and meeting with each participant. She teaches classes that review technological innovations and grapple with interpretations of findings from RPP activities.

The three co-design partnerships involved the first author of the paper (as researcher) and each of the teachers. The second author supported co-design during workshops, data collection, and data analysis throughout the partnership.

Data Sources

The RPP supports participants with weekly meetings, workshops, and co-design partnerships (Table 28). Learning scientists, classroom teachers, computer scientists, and discipline experts meet weekly to coordinate logistics, report on work in progress, and collaborate on designs. Elaine joined during her summer internship. RPP workshops involve all participants in reviewing student work, customizing units, aligning teaching practices with units, and refining technologies and KI pedagogy. Co-design partnerships take many forms. In this paper, we report on three teacher-learning scientist collaborations focused on two units (*COVID-19* and *HeLa*). Figure 20 provides a high-level summary of the timeline of RPP structures over the course of the study and the different structures each teacher participated in.

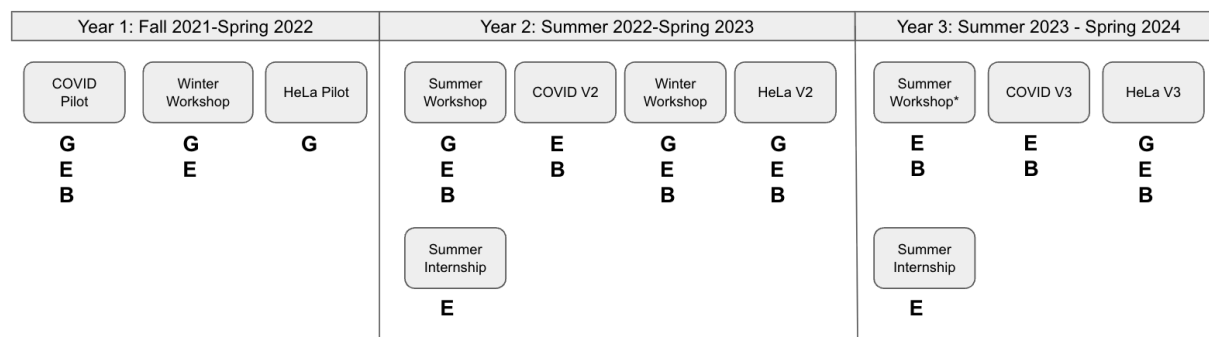
Table 28
Overview of the Three RPP Structures

RPP structure	Participants	Activities	Open Educational Resources (OERs), RPP products	Data Sources Used in Analysis
Weekly Research Group	Researchers (faculty, visiting scholars, graduate and undergraduate students)	Coordination of RPP activities	Web-based, customizable curriculum units	Curriculum designs and customizations
		Work in progress reports	KI-aligned curriculum visualizer	Data analyses, interpretations (Elaine only)
		Workshop planning	KI Assessments	
	Classroom teachers, summer interns	Consultancies on educational technology, research designs, proposals, and report drafts	Student work and related data analyses	Publication drafts (Elaine only)
	Computer scientists	Technology updates	Research reports and literature reviews	

Workshops featuring all participants (teachers, learning scientists, computer scientists)	Learning scientists	Analyze logged student work	Analyses of logged student work	Workshop activity transcripts, learning scientist field notes
	Classroom Teachers	Customize unit in response to student work and reflections	Customized unit with updated technologies	Logged teacher work, reflections
	Computer scientists	Refine classroom practice	Classroom practices aligned with unit	Customized units
				Collaborative documents
Co-design partnership featuring teacher and learning scientist interactions	Lead learning scientist	Plan implementation: Reflect on needs; revise unit, classroom practices	Implemented Web-based unit	Planning meeting transcripts, email communication
	Lead classroom teacher	Enact and observe	Logged student work, including pretests, posttests	Enactment field notes
	RPP collaborators	Discuss observations between class periods	Classroom activities aligned with unit	Memos on between-class conversations
		Reflect on practice and student learning, plan next steps	Reflective interview questions	Analyses of pretest, posttest progress
				Reflective interview transcripts

Figure 20

Timeline of Teachers' Participation in the RPP Structures. G = Gregory, E = Elaine, B = Beatriz.



*Summer 2023 workshop did not feature the COVID-19 or HeLa unit

Data Analysis

We employ a cross-case analysis of the three partnerships (Yin, 1998). We sequenced data from each partnership to create timelines documenting activities for the two units (Beatriz also co-

designed two other units not included here). The first author used an open coding approach to review Gregory's timeline and identify co-design episodes. For each episode on Gregory's timeline, the first author created an analytic memo describing the RPP structure, participants, and co-design resources (OERS and RPP products) in the episode. Actions of the co-design teacher were coded within each episode (informed by the KI principles and elements of JCSP), creating an emergent code-book, which was then reviewed by the second author. See Table 32 in the appendix for the codebook and examples. The first author and the second author reviewed Gregory's coded episodes to clarify the episodes and codes. The first author followed the same procedure for the remaining teachers, refining the codebook as needed; the second author's review resulted in grouping codes into larger categories. These distinctions helped to organize the results and create coherent narratives for the co-design partnerships. After coding was complete, the first and second authors created short analytic memos summarizing each teacher's progress and involvement in co-design over three years, and identified three illustrative episodes to include in each memo. These memos were then used for the reflective interviews (discussed below).

We quantified the number of episodes for each code and compared across teachers to identify any major differences in how the teachers engaged in co-design (Table 32). The frequencies helped identify specific RPP and co-design activities and resources that aligned with the codes and helped characterize the role of activities and resources in co-design.

We designed a 45-minute reflective teacher interview. The interview asked teachers questions about their involvement in co-design (How would you describe your role in the partnership? What are the highlights of your collaboration with the learning scientist?), interpretation of findings from the analytic memos, and their interpretations of the illustrative episodes to gain insight into their perspective on the co-design and development of their professional practice. These interviews were audio-recorded and transcribed. See Table 31 in the appendix for the interview protocol.

Results

Research Question 1

Teachers had unique co-design trajectories that reflected their prior experience and how the structures in the RPP empowered them to contribute. Gregory's extensive experience in the RPP empowered him to engage deeply in co-design. He initiated the design of the *Hela* unit and refined it with researchers. He reflected on student learning in ways that centered on KI and unit redesign. Elaine's summer internship empowered her to collaborate with researchers. She used her collaborations as opportunities to reflect on her students' learning and classroom teaching. Beatriz followed the typical trajectory of a new member of the RPP, first using the units as designed and then aligning the units with her classroom practices. A conversation about her role in the RPP empowered her to customize the curriculum. Relationship building within the co-design partnerships allowed each teacher to improve their practice and take advantage of KI/SJSP pedagogy. This section draws on the frequency of episodes assigned specific teacher-action codes, examples, and co-design activities shown in Appendix Table 32.

Co-design Partnership with Gregory

Gregory's prior experience with the RPP and expertise in KI supported him in taking a designerly perspective for both units. In year one, Gregory offered feedback on the design of the *COVID-19* unit, including last-minute adjustments to ensure clarity and support students' engagement.

Between class periods, Gregory made comments about engagement and usability to the researcher. He independently customized the unit based on the classroom practices he used in his teaching. For example, Gregory implemented daily openers that elicited students' ideas about science content or created opportunities for students to distinguish between science and justice ideas. During the post-implementation interview, Gregory used what he observed during class and in student work to highlight areas where students disengaged from learning (graphing activities) and how providing additional scaffolding to support students to generate hypotheses and prediction graphs could address his concerns. During the subsequent workshop, he reiterated the need for added scaffolding to help students distinguish among the variables in the available datasets.

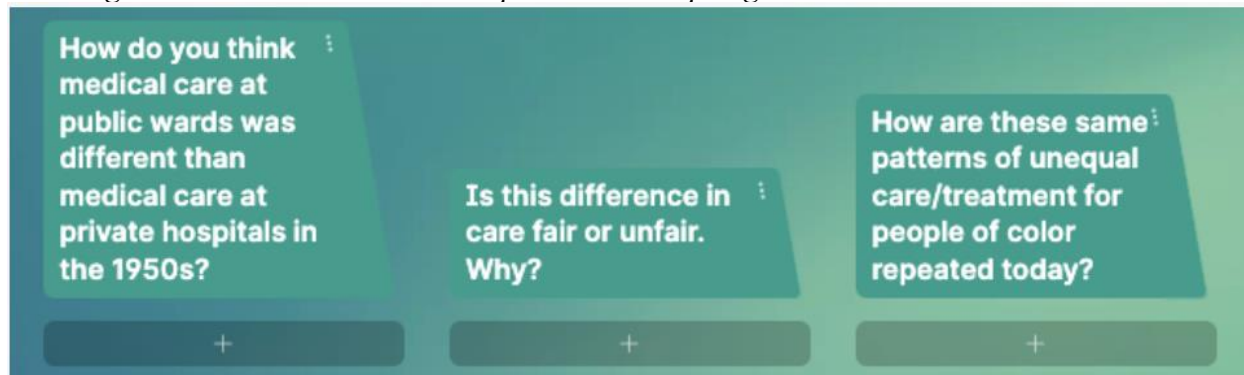
Gregory proposed Henrietta Lacks' story to the RPP and took a leadership role in design, supported by his long-standing relationship with the RPP. Gregory felt that Henrietta Lacks' story brought in "a lens of social justice and racism into the science classroom," (Reflective interview, 11/7/2023), aligning the unit with JCSP's emphasis on authentic connections between social justice in science content. Gregory piloted the unit at the end of year one. He noted that the pilot was successful in many ways and reported that students were "making the [justice] links. Like, oh, she's Black. I heard kids say that" (*HeLa* pilot post-interview, 6/6/2022). He also identified areas for improvement that he addressed during workshops, saying, "I think some of them [students] felt like it sort of was resolved...because the family is now part of choosing how the money is being spent or having decision-making in the research" (*HeLa* pilot post-interview, 6/6/2022).

Gregory was positioned as a leader for the *HeLa* unit during the subsequent workshop. He shared valuable insights aligned with KI pedagogy. For example, he identified strengths of the unit that made science accessible. He noted that the video featuring Henrietta's living family engaged students and remarked, "They perked up here a little more and asked more questions and clarifications." (Workshop field notes, 6/14/2022) In addition, he encouraged new teachers to make the story accessible by spending time discussing the video, supplying additional information he gathered from reading the book about Henrietta Lacks (Skloot, 2010).

In the winter 2023 workshop, Gregory provided specific examples of how the unit could be improved to better align with KI. Gregory noticed that students saw Henrietta's story as removed from their own experiences. He suggested reframing the unit to elicit students' ideas about their experiences with health professionals and adding an activity where students explored scenarios where someone might ask for or need their health information. These scenarios raised questions about sharing health information with health professionals, friends, or others. These improvements provided students with a reference point to distinguish between their experiences and Henrietta Lacks' story.

Despite his leadership role, Gregory emphasized his positionality as a learner, particularly given the RPP's justice-centered focus and his identity. "I've really appreciated teachers at different schools and different demographics, and different identities of teachers... seeing their perspectives because I don't have that experience [as a White man]" (Reflective interview, 11/7/2023).

Gregory worked closely with researchers to co-design a major customization in year two. He initiated the customization during the pre-implementation meeting, reiterating the need to support students to connect Henrietta's story to justice issues today. Gregory suggested using a Padlet to scaffold student learning, as it would elicit students' written ideas to teacher-generated questions, and allow students to discover new ideas from their peers (Figure 21). We spent the rest of the meeting designing the Padlet prompts and accompanying activity.

Figure 21*Co-designed Padlet Customization, Implemented in Spring 2023*

We iterated on facilitation during implementation. In his first period, Gregory projected Padlet, read each post, and invited responses from students. Afterwards, he approached his co-designer about the activity, expressing that there was more teacher than student voice. We discussed how to facilitate the discussion to increase student voice and provide students more time to think about their peers' ideas. In the next two periods, Gregory prompted students to first discuss whether they agreed with the posts with their table partners, then facilitated the class discussion. This resulted in a more engaging discussion, with students sharing alternative perspectives about medical racism, unequal access to education, and police violence against Black communities.

Gregory found it especially exciting when students interacted with the materials in unexpected ways or shared ideas that the team had not anticipated. "Planning something a certain way, and when the kids do it, I didn't think it would happen like this. Talking with the learning scientist about it, where do we go from here?" (Reflective interview, 11/7/2023). Gregory viewed in-the-moment collaboration as an exciting opportunity to think about students' ideas and co-design activities.

While Gregory initiated the customization during a formal pre-implementation meeting, implementation RPP structures, such as conversations between class periods, served as an important space for Gregory to voice his ideas and collaborate with researchers. We refined the activity and Gregory's teaching practices to include more opportunities for students to learn from one another and discover alternative perspectives (KI). Gregory reflected on the success of the customization in the post-interview, "It felt like a more natural way to get out some of the things they might be thinking or feeling about what happened [to Henrietta]" (*HeLa* Revision one post-interview, 6/16/2023). Gregory continued to co-design this activity in partnership with the first author in year three.

Gregory felt empowered in his role as a major contributor to design, bringing a practical perspective that balanced the theoretical contributions of researchers. He believed that teachers' ideas moved the designs of units forward and felt comfortable "pushing back a little bit" if he felt that the design did not meet the needs of his students. Gregory's longstanding involvement in the partnership empowered him to feel that his perspective held similar value to those of the researchers. His case highlights how building strong relationships that center and uplift teachers' perspectives can transform power relationships within a partnership.

Co-design Partnership with Elaine

Elaine was a frequent customizer of instructional materials. She prioritized connecting content to her school's community and scaffolding instruction for her English Language Learners (ELLs). She initially made a few changes to the web-based design, instead independently creating a slide deck for each step in the *COVID-19* unit (Figure 22). She used and refined the slides in years two and three, and created similar slides for the *HeLa* unit. Elaine used her slides to walk students through each unit step and often paused for group or whole-class conversations about students' ideas. Implementation differed from year to year, or even period to period, adjusting pacing or based on students' needs. Elaine shared these customizations with other teachers during the following workshop and suggested ways for incorporating scaffolds within her slides into the online unit. Elaine did not communicate any feedback on the unit to researchers before or during implementation. During her post-implementation interview, she examined student work from the *COVID-19* data investigations and helped inform initial ideas about re-ordering certain steps and redesigning the Data Explorer to better support students to work with data.

Figure 22

Examples of the Language Scaffolds that Elaine Embedded Into Her Slides. These Slides Are From Year Three (Fall 2023) of the COVID-19 Unit

Complete Sections 1.4 - 1.6

Example sentence stems:

- I think _____ and _____ would be most important to study [in understanding COVID-19] because _____.
- I have used _____ because _____.
- I learned _____. This was [helpful / not helpful] for me because _____.

After completing 1.6, click **SAVE**
Do Not move to 1.7

1000

Vaccine Distribution

DISCUSS
Community power is built when individuals feel they have a voice in their spaces - What helps build voice? What prevents it?

CONVERSAR
El poder de la comunidad se construye cuando las personas sienten que tienen una voz en sus espacios. ¿Qué ayuda a construir una voz? ¿Qué lo impide?

STOP

Elaine's summer internship provided her with opportunities to work on the design. During her first summer, Elaine focused on redesigning the *COVID-19* unit and Data Explorer with the first author. She curated new data sets for the unit that aligned with student interests by analyzing students' answers to a question embedded within the unit (*What stories do you want to tell about COVID-19?*) and identified data sets aligned with the most common topics. She presented her analysis of student work and drafts of redesigns during research group meetings, allowing her to get feedback from the broader research staff. Her redesign centered on making data accessible to students by increasing the relevance of the data sets (KI) and signified increased ownership over design.

Elaine felt empowered to be more collaborative with researchers in year two, though she continued to do most of her customizing independently. Elaine provided feedback during implementation related to the wording or usability of specific steps to support student engagement. Elaine made additional customizations to the *COVID-19* unit by creating opportunities for students to engage in community or individual action and connect with local organizations. "The volunteer work that I had students do... I was looking for ways that students can authentically engage in their community, fresh out of the pandemic" (Reflective Interview, 6/6/2025). Students integrated ideas from the unit to create informational posters about vaccines, facilitate community listening sessions on the pandemic's impact, or volunteer at vaccination events. By linking content to

students' communities, Elaine's activities made science content more accessible (KI) and positioned students as transformative intellectuals within their school community (JCSP).

Elaine's feedback after using the unit aligned with her focus on the Data Explorer during the summer, highlighting how her research experience shaped her work during the year. "We went too big, I think, we need to find the right size of data sets and relevancy of variables" (*COVID-19* Revision one post-interview, 9/6/22). Elaine centered herself as one of the designers by using "we," indicating a shift in her professional role from practitioner to designer. Elaine also highlighted limitations in students' understanding of justice ideas that indicated a need for refinement. "The connection between race and economy and other social issues is so hard to grasp because there's so much history that is connected with race. It went over a bunch of people's heads" (*COVID-19* Revision one post-interview, 9/6/2022).

Elaine continued to focus on justice ideas while reviewing the *HeLa* unit during a unit prototyping session in the winter 2023 workshop. She and another teacher (not included in this study) discussed how they might scaffold a class discussion related to segregation and medical racism, which they believed was crucial for helping students distinguish ideas. "Henrietta could not consent to a lot of things because of the times that she was living in. This is different from being under 18 and needing parents' consent for certain things" (Workshop field notes, 1/21/2023). This prompted the addition of a stop-and-talk prompt to cue teachers to hold a class discussion to support students in distinguishing their ideas after discovering justice ideas within the unit. After using the *HeLa* unit, Elaine continued to emphasize the need to support students to reason about justice topics (the role of segregation in Henrietta's ability to access care). "Students wrote about some justice ideas, such as consent or bodily autonomy, but we're still missing the race factor. Why does it matter that Henrietta was a Black woman?" (*HeLa* Revision one post-interview, 3/37/23) She did not have specific suggestions during the interview for how to improve the unit.

Elaine extended her design work during her second internship. She refined the Data Explorer and accompanying scaffolds and did additional design work related to another grant focused on AI applications to educational problems. She also worked to disseminate findings, which supported reflection on teaching and design. Writing and presenting a conference paper about the refinement of the Data Explorer (Billings et al., 2023) helped Elaine see limitations in her redesign that made it challenging for students to successfully create investigable questions. A journal article (Billings et al., 2025) focused on KI-aligned, justice-centered teaching practices, which supported Elaine to reflect on her practice in ways that aligned with the RPP frameworks. "[The paper] helped me learn stuff about my teaching. I didn't know there was a way to name the practices I was using" (Reflective interview, 6/6/2025). The summer internship provided structured, compensated time to deepen her reflections and communicate ideas to a broader audience, increasing her confidence and collaboration with researchers. While she valued working on unit design, she "loved collaborating beyond the units and reflecting on my teaching practice and sharing that in ways that others can implement" (Reflective interview, 6/6/2025). This suggests that providing teachers with opportunities to engage in research can impact their overall co-design trajectory and professional confidence.

Elaine continued to collaborate with learning scientists before and during implementation. During a *COVID-19* unit pre-implementation meeting, Elaine examined student work from the previous year and noted that students needed help with creating investigation questions and identifying which variables can help them answer those questions. "They're having a lot of trouble understanding the variables and trying to make a question out of it...they submitted graphs they could make just because they could, not because they were related to their questions" (*COVID-19*

Revision two pre-interview, 8/31/2023). Elaine and the first author co-created initial plans for a customization design to support students in discovering common characteristics of effective investigation questions, which Elaine expanded upon independently. While implementing the *COVID-19* unit, Elaine pulled the first author aside to discuss whether students should watch a video highlighting specific justice ideas in pairs or as a class to help them distinguish ideas. Following the conversation, she led the class to watch the video and held a short discussion about key ideas.

Post-implementation interviews provided further opportunities to reflect on design and facilitation. For *COVID-19*, Elaine discussed the improvement of the unit as compared to previous years. “Students felt more confident working with the data. They didn’t get stuck like before, but there was still enough choice [of datasets]” (*COVID-19* Revision two post-interview, 11/3/2023). Elaine’s feedback in *HeLa* was focused on both the successes (improvement in activities focused on segregation) and continued improvements (helping students make sense of contemporary data related to medical racism).

Co-design Partnership with Beatriz

Beatriz, a new member of the RPP, implemented the *COVID-19* unit as designed by the RPP in year one. In year two, Beatriz reflected on her experience in year one and (with help from the RPP) added two customizations to the *COVID-19* unit: a vocabulary list and a map documenting *COVID-19* outcomes in the U.S by race. She also contextualized unit content during two lectures, one focused on inequitable access to healthcare and the other on distinguishing between the uses of specific types of graphs. For *HeLa*, Beatriz contextualized Henrietta’s story as one example of many instances of medical racism throughout U.S history.

During her post-interview for the *COVID-19* unit, Beatriz identified students’ struggles to create graphs and complete data investigations. Beatriz suggested improving the Data Explorer and graphing activities by creating a longer “progression with more steps” (*COVID-19* Revision one post-interview, 11/2/2022) where students add variables as they go, or by limiting the number of variables in the data sets. For *HeLa*, she suggested ways to improve the usability of the tools in the unit. For example, she suggested some changes to instructions for an activity that asked students to label a model using a drawing tool to clarify the purposes of specific icons in the tool.

Beatriz provided critical feedback during the winter 2023 workshop that supported the refinement of the *HeLa* unit. She emphasized the need to support students to understand research practices so they could make informed decisions about participating in medical research. She drew on her public health background to contribute ideas about why participants are needed in medical trials. “If I don’t have enough people to get data from, you can’t really understand what’s going on. With a lot of people participating, you can see patterns and answer questions” (Workshop field notes, 1/21/2023). Her contribution resulted in additions to the unit focused on discovering ideas related to having enough participants to draw conclusions from data.

In year three, Beatriz refined her *COVID-19* vocabulary list with the first author. As we discussed the customization, Beatriz asked if it would “mess up your data” for the research if she added activities. This was surprising, since we had explained that the RPP was intended to support teachers as experts in their classrooms. We used this conversation to explicitly empower Beatriz to integrate her teaching practices and explain how her customizations would advance the RPP’s work. Beatriz was appreciative of researchers’ enthusiasm to learn from customizations. “I like the receptive nature of their learning scientists to include things to help with student learning... People

are willing to welcome me to customize and improve access to information for students” (Reflective interview, 5/30/2025).

As a result, Beatriz reviewed her student work and created classroom activities to address gaps in students’ KI. For *COVID-19*, Beatriz noticed that students had trouble aligning the variables they selected with their questions, remarking, “That’s the critical problem here, the data they chose doesn’t match the question” (*COVID-19* Revision two pre-interview, 9/19/23). Beatriz planned a class activity to support students in linking *COVID-19* questions to the specific variables. Students linked questions to variables on a worksheet, followed by a class discussion about their ideas. She used the same structure for *HeLa*, with a worksheet connecting segregation to healthcare access for Black patients. The worksheets focused on eliciting student ideas, and the class discussion enabled students to distinguish among their ideas.

Beatriz focused on student work during the third year post-interviews. For *COVID-19*, she closely reviewed students’ questions and graphs, relating improvements in students’ investigations to her customization and unit improvements. For *HeLa*, Beatriz reported on what she heard during class discussions. “It was clear by their responses [to the discussion] that they realized that this bias and segregation were happening.” She noticed that these justice ideas were not necessarily showing up in written work, saying, “It’s interesting because some students say no, the race of the patient or the race of the doctor shouldn’t matter” (*HeLa* Revision two post-interview, 4/15/24). Her reflection highlights that, though the unit contained activities designed to support students in discovering justice ideas, those ideas were not being integrated into students’ answers. In the *HeLa* post-interview, consistent with the KI pedagogy that emphasizes building on promising student ideas, Beatriz focused on the specific justice ideas students were adding.

Beatriz felt that the RPP’s focus on justice-centered STEM teaching was aligned with goals for her own teaching. This motivated her to take a more active role in the RPP and use multiple units. “I think there is a certain importance in using science in support of society. That really speaks to me and these units” (Reflective interview, 5/30/2025). Beatriz attended a wide variety of sessions focused on different units and had touch points with several researchers throughout the year. Regular engagement in a variety of RPP activities across unit contexts likely supported her development. When asked about how the RPP has helped her improve her practice, Beatriz mentioned that the KI framework helped her learn “more about how students learn and... holistically or more broadly understand what students know” (Reflective interview, 5/30/2025).

The three distinct trajectories and levels of empowerment reflected the RPP experience and structures. Gregory’s leadership in design refinement reflected his long-term participation. Elaine’s research focus reflected her summer internship experience. Beatriz’s co-design relationship eventually empowered her to communicate her deep analysis of student work to suggest KI-aligned customizations.

Research Question 2

Workshops provided structured opportunities for teachers to take leadership roles, share their expertise, expand their insights into KI, and use KI rubrics to review their student work to inform design suggestions. Elaine felt empowered to share her expertise in developing multiple scaffolds for ELLs in the winter 2022 workshop. She offered her slides as a resource that other teachers could use in their classrooms. In the summer 2022 workshop, Gregory shared his expertise as the developer of the *HeLa* unit by leading a customization session for the other teachers. His

knowledge of the unit and ability to frame his experience in the shared language of KI positioned him as the unit expert.

At each workshop, teachers reviewed their student work and used the KI rubric to score selected responses. The researchers gained insights into teachers' interpretation of KI, often engaging in discussions about how to respect each student's ideas while also encouraging them to develop more sophisticated responses. Teachers supported each other by illustrating how they elicited student ideas or figured out why students generated surprising responses.

Teachers shared their feedback on the curricular units and developed solutions in collaboration with researchers and other teachers. Teachers could use unit prototypes to identify specific areas for improvement. For example, Teachers' feedback on the *HeLa* unit during the winter 2023 workshop illustrates the value of teachers' perspectives. Gregory reported on his ideas for making the unit more accessible to his students by leveraging students' experiences with medical professionals, utilizing KI language to share his ideas. Elaine reported on her dilemma concerning connecting the unit to social justice issues. She and another member of the RPP discussed ways to build on what existed in the unit to elicit additional social justice ideas. Finally, Beatriz drew on her background in public health to propose additional activities to support students in making sense of research practices. By contrasting their distinct approaches to a weakness of the *HeLa* unit, the teachers affirmed each other's concerns and opened up new opportunities for refining the unit. The discussion supported teachers to acknowledge each other's expertise and resulted in multiple suggestions for improving the unit design.

Discussion

The three distinct trajectories illustrate how the RPP supported each participating teacher's unique experience. The co-design process created a meaningful experience for both highly experienced (Gregory) and novice (Elaine and Beatriz) teacher-designers. Gregory felt empowered to lead the design of the *HeLa* unit and closely collaborate with researchers. Elaine and Beatriz grew in their ability to engage in co-design. Elaine identified ways to make the content accessible for her students, based on her understanding of their needs. She independently customized the curriculum and shared her customizations with other teachers. During the summer research internship, she benefited from collaboration with researchers. Beatriz tested the units as designed and benefited from structured reflection activities during co-design to examine student work. During co-design activities with researchers, she customized the units and the classroom activities by building on KI pedagogy.

RPP activities and resources supported teachers to participate in co-design while providing enough flexibility to support unique trajectories reflecting teachers' goals, interests, and student needs. Unit prototyping sessions illustrate how structured activities that utilize concrete resources provide enough scaffolding for teachers to share detailed, though different, insights. Each teacher provided different feedback on the *HeLa* unit related to making content accessible (Gregory) and supporting students to distinguish between justice (Elaine) or science ideas (Beatriz). As in other RPPs, the anchor resource (unit prototypes) supported specificity while giving teachers flexibility to share feedback aligned with their expertise (Jayathirtha et al., 2025; Matuk et al., 2023; Severance et al., 2016).

Co-design partnerships supported the refinement of unit design and the development of teachers' KI or justice-aligned teaching practices. Gregory felt empowered to lead design work alongside researchers, resulting in the refinement of units and customizations. He embodied KI as

he rapidly refined his customizations with the first author between classes, focusing on making students' ideas visible and helping students learn from one another's ideas. Previous research has documented how co-design occurs in RPP activities that happen outside of the classroom (Bradford et al., 2021; Tan & Lee, 2023). The co-design work that occurs as the researcher and teacher jointly observe instruction is reminiscent of lesson study conversations (Jansen et al., 2021; Vermunt et al., 2019). Gregory's case illustrates the importance of informal spaces for rapid refinement and teacher involvement in co-design, which deserves future study (Billings & Linn, 2024).

Elaine and Beatriz were supported to develop their co-design capabilities in ways that aligned with their professional goals and indicated increasing alignment with KI. Structured collaboration with researchers during pre and post-implementation meetings supported Beatriz to expand her teaching and design in ways that aligned with the KI framework. An explicit conversation empowering her to contribute to the RPP enabled her to take a more active role in customizing, illustrating the need to explicitly empower each RPP participant.

Elaine engaged in independent design work and embodied aspects of KI through her complex customizations. Opportunities outside the classroom to collaborate with researchers, including one-on-one meetings and her summer internship, supported her co-design trajectory during implementation. Her participation in research shifted power dynamics in ways that prompted Elaine to take ownership of refining the Data Explorer and see herself as a designer. Elaine's participation in writing supported her in using the KI and JCSP as tools to reflect on and name her teaching practices. Elaine's case illustrates how providing teachers with opportunities to participate in the research invites opportunities for learning and expanding professional identities (Jurasaitė-Harbison & Rex, 2005; Kowalczyk-Wałędziak & Ion, 2025; Taylor, 2017).

The RPP workshops empowered teachers to take leadership roles, supported researchers and teachers to jointly build an understanding of KI and justice-centered pedagogy, and explored dilemmas that arose in their classes. As the HeLa example illustrates, this could lead to multiple customized solutions to common concerns, rather than a single ideal approach. The workshop supported shifting of RPP power dynamics, informed by expertise around the dilemma rather than hierarchical structures (Goldman et al., 2022). Future work seeks to examine the impacts of teachers' contributions on their colleagues' learning within the RPP.

As the workshop examples highlight, relationship building and mutual respect empower teachers during co-design (Matuk et al., 2016). Gregory felt empowered to customize, provide feedback, and lead during RPP activities based on his history with the RPP. Elaine's shift in her professional identity to that of a designer was also facilitated by the relationships she built with researchers, especially during her internship. Elaine reported an increase in confidence in her practice and ability to present her insights to adults. In Elaine's words, her favorite aspect of the partnership was her internship work, and "the people, obviously," that she got to work with. Beatriz's case highlights the importance of providing space for participants to explicitly discuss roles and negotiate power (Philip et al., 2022).

This work reveals many ways to improve our RPP. The most important thing is ensuring that each member feels empowered to contribute. Our findings contribute to the field's growing understanding of how roles and relationships within design partnerships are established, negotiated, and maintained in ways that empower educators (Cheuk & Morales-Doyle, 2022; Kyza & Agesilaou, 2022; Sjölund et al., 2023).

Conclusion and Limitations

Our teachers' experiences in the RPP highlight the varied trajectories that occur in RPPs. They felt empowered to “push back a little” (Gregory), “customize and improve access to information for students” (Beatriz), and use the KI framework to “name the practices I was using in the classroom” (Elaine). All three have remained active in the RPP, and we continue to track their trajectories to deepen our understanding of our RPP's impact.

Our work has several limitations that point to avenues for further research. First, race and identity likely play a major role in these teachers' involvement in co-design, though this study does not conduct a race or gendered analysis. This is an area for future work. Second, our data is limited to data collected during RPP activities. Participants engaged in additional planning and reflection independently, and we present an incomplete account of their full stories and development. Third, our analysis focuses on only three teachers within the RPP. Other participants, including both practitioners and learning scientists, likely have different experiences. Future work will examine a wider variety of participant perspectives to improve collaboration for all. Finally, this study focuses on the experiences and learning of our teachers, but does not examine the impact of their learning and unit refinement on student outcomes. Previous research has identified some of these impacts (Billings et al., 2023; Billings et al., 2025), but more work is needed to uncover the full impact of teachers' practices and unit designs on student learning.

Chapter 6: Discussion and Conclusion

Summary

This dissertation documents the multi-year work of an RPP focused on designing justice-centered science curricula. My goal in writing this dissertation was to explore how co-design occurred within the RPP and how participants with different backgrounds and expertise were supported to refine the unit in partnership with one another. These three studies are guided by two overarching research questions: *What design tensions arose during the process of co-designing justice-centered science curricula, and how did the RPP integrate the expertise of participants to address these tensions? How did the RPP support the development of teachers' co-design capacities?* Taken together, these studies document how RPP participants came together to design justice-centered science curricula and wrestled with challenges as they iterated on designs. While our team made progress in supporting students to integrate science and justice ideas and engage with data rooted in personally relevant Social Justice Science Issues, open questions remain about supporting students to integrate complex, systemic justice ideas and engage with complex data and data science topics related to SJSI. These challenges align with others identified in the literature, adding to our broader understanding of how to design educational interventions that integrate social justice into STEM teaching and learning (Philip et al., 2018; Rubel et al., 2016; Visintainer, 2023). Findings have implications for expanding our understanding of KI to justice-centered contexts. This dissertation demonstrates how merging KI and JCSP can inform the design of justice-centered science curriculum. KI Rubrics that measured students' ability to integrate science and justice ideas supported the RPP to reflect on student learning and refine curriculum. This extends our understanding of how KI rubrics (that traditionally measure students' ability to integrate only science ideas) can be used to measure student learning and inform responsive instruction. Though focused on one RPP, this dissertation contributes to the field's broader understanding of how co-design occurs between researchers and practitioners within an RPP and the structures and resources within an RPP that help to facilitate collaboration. Findings highlight how certain structures can empower teacher leadership and democratize education research more broadly (Kyza & Agesilaou, 2022; Philip et al., 2022).

Chapter 3 Summary and Implications

We iteratively refined two justice-centered science units to support students in linking science and justice ideas to explain two public health-focused social justice science issues. Data from pilot versions of the two units revealed limitations in students' ability to reason about ideas related to race and missed opportunities within the units to center racial oppression. Co-design centered on addressing these issues in revision one, and continued to refine adjustments in revision two. Teachers' open and honest reflection about their practice was especially evident in this tension, including their perceived limitations in their practice and desire to improve their ability to discuss race in the classroom. Students' responses to the *Impacts* assessment item in the final versions of each unit showed statistically significant improvements from pretest to posttest, but on average, students still need more support to link multiple justice and science ideas together to explain the two SJSI.

In the *HeLa* unit, the pilot version of the unit did not contain enough opportunities for students to distinguish how racial policies like segregation impacted Henrietta's treatment, and only one student referenced race in their answer to the *Impacts* question. Revisions focused on

reducing the focus on science ideas related to research and expanding opportunities for students to explore and discuss the role of segregation in limiting the availability and quality of care Henrietta had access to. During workshops, the team collaborated to create new activities within the unit, as well as a prompt that prompted teachers to hold a class discussion focused on justice ideas. Teachers held discussions about justice ideas while implementing the first revision, but not all teachers focused on race, suggesting they need more support in holding these types of conversations in class. Though there was evidence of students discussing complex justice ideas during class, few did so in their answers to the *Impacts* question. These findings and teachers' continued feedback prompted additional refinements for revision two, focused on supporting students to distinguish between contrasting case studies and identify ways medical racism persists today. These changes were led by me and a lead teacher, Gregory.

In the *COVID-19* unit, data from pilot implementation revealed that students needed more support in moving beyond individual actions and health factors to integrate ideas about the limitations of health systems and access by race. Limitations in available data allowed students to identify differences in COVID-19 impacts by demographic groups, but students were unsupported by the unit and teachers' facilitation to discover why these differences exist. Elaine and I led Initial changes focused on updating the data sets within the unit to include variables that could help students explain differences in COVID-19 outcomes by race and other demographic variables, such as socioeconomic status, jobs, or other factors, and access to or affordability of healthcare. Other activities that were unsupportive were removed. Revision One saw an increase in the number of classroom conversations related to race and factors that contributed to inequitable outcomes of COVID-19 by race, and many students chose to center race in their data investigations. However, like the pilot, there were no statistically significant changes in students' ability to integrate their ideas. Teachers' feedback focused on making justice ideas more explicit to students, and a resource gathering session at a following workshop supported the team to identify OERs that could be integrated into the unit to provide clear examples of justice factors. In Revision Two, OERs were coupled with distinguishing activities to support students in distinguishing which factors do and do not impact inequitable COVID-19 outcomes by race.

While many students pointed to justice ideas that occurred on the micro-scale when answering the *Impacts* question, they needed more support to understand and integrate specific macro-scale justice ideas into their understanding of SJSI. This aligns with challenges previously identified in the literature in supporting students' justice-centered STEM learning (citations). While we did not find a clear solution, certain promising avenues emerged, including leveraging existing OERs focused on racial justice ideas and creating opportunities for teachers to hold class discussions focused on justice ideas. Continued work is needed to support students in distinguishing justice ideas related to race, and future studies hope to integrate the use of educational technology, such as automated, KI-aligned AI guidance, that has shown promise in supporting students' integrated understanding of science phenomena. Teacher expertise was key in refining both units, and several RPP structures elicited their ideas about student learning and unit improvements. KI rubrics helped teachers analyze student work and identify justice ideas students had or were missing in their explanations. Unit prototype discussions that used anchor resources supporting teachers to give specific, actionable feedback on the unit, which was key in improving the units to support students to integrate science and justice ideas.

Chapter 4 Summary and Implications

This chapter discusses how the RPP team refined two justice-centered science units focused on public health issues to make data sets and data science concepts, such as data privacy and how data is used in medical research, accessible to students through real-life examples and contexts. This proved to be an especially challenging design tension for the RPP to address. In the Henrietta Lacks unit, designers navigated tensions around adjusting activities to align with students' experiences with health professionals and preserving content around data privacy and sharing medical data. This content eventually was reframed, as it was removed from students' experiences. For the COVID-19 unit, the team balanced aligning datasets with student interests, providing choice, appropriate scaffolding of data investigations, and curating data sets of the appropriate size and scope. Though progress has been made in both units, these findings point to real challenges in making complex data sets and data science concepts accessible to students to support their learning.

The pilot version of the Henrietta Lacks unit centered Henrietta's story in the broader scope of scientific research practices, positioning her inequitable and harmful treatment as an example of unethical scientific research and a violation of a patient's data privacy. However, this framing was inaccessible to students, and pilot findings suggested that they viewed Henrietta's story as removed from their everyday experience and racial justice issues today. Refinements resulted in the integration of the Eric case study, which centered on how a young person with cystic fibrosis navigated decision-making related to his health, sharing health data, and participating in research. Teacher input helped to design the case to reflect students' experiences with medical professionals. The parallel formats of the Eric and Henrietta cases serve to help scaffold students to distinguish their ideas and make Henrietta's case more accessible. While these changes resulted in improvements that were viewed positively by teachers, teachers still felt that the emphasis on data privacy was hard for students to grasp. This prompted the design team to consider an alternative framing of Eric's case study that focused on how patients like Eric can advocate for their personal health goals with their doctors and use data to make decisions about their health. This is more closely aligned with the types of decisions students might make.

The pilot of the *COVID-19* unit centered on a real-life organization, D4BL, and used publicly available data sets that reflected COVID-19 outcomes in communities students lived in or were connected to. Pilot findings suggested that many students centered themselves in the data. While many students were able to create questions that were answerable by the provided data sets, limitations in available data resulted in few complex questions, and many could be answered with yes or no explanations. Teachers felt that major changes needed to be made to support students in reasoning about the data. Refinements to the unit focused on revising the curated data to better align with students' interests regarding the impact of COVID-19 and making adjustments to the Data Explorer activities to better support students in working with the data. This work was led by a partner teacher, who aligned new data variables with students' interests and added an activity focused on taking action. Though activities prompted students to stop and work with their peers to break down the data sets, teachers noticed that students still needed more support in understanding the variables or creating answerable questions that moved beyond yes or no answers. Additionally, the increased size and scope of the data sets were challenging for students to work with, resulting in less successful questions as compared to the pilot. Major changes were made to Revision Two. First, data sets were adjusted to limit the size and scope, while maintaining some of the topics and ability for choice. Adjustments were also made to the structure of the unit and activities to better scaffold students in working with data. Students had more success in creating answerable

questions. While progress has been made, the RPP team continues to work to refine the data sets and units.

This study highlights a challenging design tension (Tatar, 2007) experienced by the RPP: balancing the use of appropriate real-world examples and connecting to students' experiences to support them in making sense of data and centering complex data science topics or skills in unit content. These findings point to the challenges with integrating data science into K-12 content classes, and suggest that more work is needed to identify how to support students in learning about data privacy and critical data science concepts within the limitations of the K-12 curriculum. This work highlights how there is no one-size-fits-all approach to identifying the most effective real-world examples to support students' knowledge integration, and that more work is needed to identify the right real-life examples given specific SJSI. Teacher expertise and involvement in making design decisions were key in the refinement of both units to make the unit content more accessible. Partnership activities that provided space for teachers to share their ideas honestly and openly (Philip et al., 2022), make their design decisions visible (Bichler et al., 2021; Bradford et al., 2021), and compensate them for research work were important in facilitating co-design.

Chapter 5 Summary and Implications

This chapter explores how a Research Practice Partnership (RPP) shaped the trajectories of three life science teachers as they engaged in co-design and customized two social justice science units. We discuss how specific structures and resources within the RPP supported their co-design trajectories and leadership within the partnership. Teachers had different trajectories, impacted by their backgrounds, personal goals, and interests in justice-centered science instruction. Findings suggest that the RPP provided meaningful opportunities for growth and ownership over co-design for both experienced (Gregory) and novice (Elaine and Beatriz) co-designers. Close working relationships between teachers and researchers and flexibility within the RPP supported teachers to engage in co-design in different ways, increased curriculum customization, and positioned teachers as experts. Workshops and summer research internships provided space for teachers to take on leadership and research roles in co-design.

Gregory's extensive experience in the RPP empowered him to engage deeply in co-design. He initiated the design of the *Hela* unit and refined it with researchers, and he reflected on student learning in ways that centered on KI and unit redesign. Gregory was a close collaborator with researchers throughout the workshops, planning, and implementation, which was exemplified in how he and I collaborated to design and rapidly refine the Padlet customization. Elaine immediately customized units to meet the needs of her diverse learners and connect content to students' lives and communities. Originally, she did much of this work on her own. Elaine's summer internship empowered her to collaborate with researchers and supported her to feel ownership over the *COVID-19* unit. She used her collaborations as opportunities to reflect on her students' learning and classroom teaching. Beatriz followed the typical trajectory of a new member of the RPP, first using the units as designed and then aligning the units with her classroom practices. A conversation about her role in the RPP empowered her to customize the curriculum and highlighted the need for creating spaces during co-design for participants to discuss and negotiate roles.

Workshops provided structured opportunities for teachers to engage in a variety of activities related to co-design. Gregory felt supported to take on a leadership role as an expert on the *HeLa* unit, and both he and Elaine felt supported to share their expertise with other educators. Opportunities to review student work with KI rubrics provided researchers with insights into

teachers' interpretations of KI, and educators were able to discuss student learning with one another. Unit prototypes served as important anchor resources that scaffolded discussions of feedback, while also providing enough flexibility for teachers to share feedback informed by different foci and perspectives. The unit prototype discussions supported teachers to acknowledge each other's expertise and resulted in multiple suggestions for improving the unit design.

Taken together, these three cases highlight how RPP activities and resources supported teachers to participate in co-design while providing enough flexibility to support unique trajectories reflecting teachers' goals, interests, and student needs. Unit prototyping sessions illustrate how structured activities that utilize concrete resources provide enough scaffolding for teachers to share detailed, though different, insights. Co-design partnerships between individual teachers and researchers supported teachers' progressions and their implementation of KI or justice-aligned teaching practices. These partnerships revealed how specific structures within the RPP, including informal spaces such as passing periods, were key in involving teachers deeply in co-design work. This work reveals many ways to improve our RPP. The most important thing is ensuring that each member feels empowered to contribute. Findings contribute to the field's growing understanding of how roles and relationships within design partnerships are established, negotiated, and maintained in ways that empower educators.

Crosscutting Implications

This discussion utilizes the three studies to illuminate how participants with different professional backgrounds can be supported to co-design justice-centered science curriculum together, and how co-design can support the learning and agency of practitioner participants. The first two studies focus on how co-design supported the refinement of the curriculum and how the RPP team addressed two major Design Tensions (Tatar, 2007) that arose: tensions in supporting students to link science and justice ideas and tensions in making data science concepts in both units accessible. The third study illustrates how working on these challenging Design Tensions with colleagues can support teacher growth and leadership within co-design, given supportive RPP structures, and intentionally build relationships that emphasize teachers' contributions to co-design. Taken together, these studies reveal the important impact of teachers in co-design and how RPPs can be structured to uplift and leverage their contributions when designing justice-centered STEM curriculum.

The Value of Merging KI and JCSP

This dissertation extends our understanding of Knowledge Integration by elaborating on how, when merged with Justice-Centered Science Pedagogy, it can be used to create supporting justice-centered STEM instruction for 6-12 students. The refinement of each unit helped to solidify our understanding and application of the merged frameworks and illuminate challenges applying KI instructional practices and design principles to the design of justice-centered science units.

Each unit provides concrete examples of each of the merged instructional strategies discussed in the first chapter of this dissertation. In the Henrietta Lacks unit, the Eric Case Study was used to *elicit* students' ideas and experiences about their own experiences with medical professionals, rooting learning in experiences similar to those students might have with medical professionals in their everyday lives. The unit also facilitates the *discovery* of ideas related to medical racism and the injustices still experienced by Henrietta's family today, using Open Educational Resources that center the voices of her living family members and their continued

work to fight for recognition and compensation. In the COVID-19 unit, an OER (the expert video) was used to clarify which factors contribute to inequitable COVID-19 outcomes for Black communities, and which factors do not. After watching the video, students use a sorting activity to *distinguish* between the different factors the expert discussed. Elaine's customizations to the COVID-19 unit embody the final instructional strategy. Elaine connected students to community and school-based organizations to support them in enacting COVID-19 action projects. Students connected their personal experiences and what they learned from the data to inform action projects. These illustrative examples help to clarify what a merged KI-JCSP framework looks like and how it informs the design of the curriculum.

This work also highlights the power of Knowledge Integration rubrics as a tool to measure student learning and support reflection when refining justice-centered STEM curriculum. Traditionally, KI assessments measure students' ability to integrate ideas about science (Liu et al., 2008), and are valid across science disciplines in items where students must connect ideas and evidence (Boda et al., 2021; Lai et al., 2016; Liu et al., 2008). New research has examined the validity of these assessments in measuring students' integrated science and justice understanding, with promising results (Billings et al., 2026; Bradford et al., 2024). In study one, KI rubrics were important for illuminating challenges in students' ability to integrate justice ideas, which was key in identifying ways to improve each of the units. However, students needed additional support to distinguish between their ideas.

While our designs made progress in supporting student learning, persistent challenges emerged that point to the need for continued work to refine the framework and how we apply it to design. Study two points to how the design principle of making science accessible through real-world examples (Linn & Hsi, 2000) can be challenging to implement, though prior research has solidified this principle as supportive of student learning. In the *Henrietta Lacks* unit, the team wrestled with integrating complex, critical data science topics, such as data privacy and research ethics, in ways that made these concepts accessible for students. Ultimately, we were unable to find the right entry point, though the Eric Case study provided support in making Henrietta's story more accessible for our learners. While prior research has provided examples of how these concepts can be integrated into computer science and data science courses in ways that center justice issues (Baumer et al., 2022; Pangrazio & Selwyn, 2019; Vakil, 2018; Vakil et al., 2020), more work is needed to identify how to make these complex topics accessible within the limitations of the K-12 curriculum. This is important to ensure that all students have access to data science instruction, regardless of whether they take data science electives or enroll in college-level data science courses.

In the *COVID-19* unit, the team balanced aligning the data sets with students' interests with curating data sets of the appropriate size and scope to support students to successfully work with the data. This work illustrates that there is no one-size-fits-all approach to making data accessible to students, as students have a variety of ideas related to those experiences that they can draw from when reasoning about SJSI or centering themselves in the data (citations). Continued work is needed from the co-design team to identify the right examples and avenues for making data and SJSI accessible for 6-12 learners. This is an ever-changing task, at least given the context of the COVID-19 pandemic. As the height of the pandemic becomes a more historical SJSI, rather than a contemporary one, students may have fewer personally relevant ideas about the pandemic with which to reason about the data.

The Design Tensions Framework for Exploring the Complexities of Co-design

In chapters three and four, the Design Tensions framework (Tatar, 2007) was used to help make sense of how the co-design team refined the units. The framework helped to illuminate how conversations were related, identifying the emerging tensions discussed in this dissertation. In chapter three, participants navigated persistent challenges in supporting students to integrate complex justice ideas. This process involved leveraging both our values, the KI and JCSP frameworks, and project drivers, specifically OERs that focused on social justice ideas, to refine activities in both of the units to better support students to integrate justice ideas. Our work required repeated conversations about how to center justice ideas, such as segregation (*Henrietta Lacks*) and inequitable access to healthcare (*COVID-19*), in the curriculum. This led to more explicit activities that used OERS, such as the expert video in the *COVID-19 unit* that named the specific justice ideas and provided opportunities for students to distinguish between ideas.

Chapter four documents how the RPP navigated balancing making SJSI accessible and integrating complex, publicly available data and data science topics unfamiliar to students. Repeated changes in the *Henrietta Lacks* unit to provide students with opportunities to connect their experiences with Henrietta's story resulted in a reduction of the emphasis on data science concepts. This presents a complex "as created situation" that documents the intended (creating a case study that aligns with students' experiences with medical professionals) and more unintended but needed (reducing context related to data privacy that was less meaningful for students) adjustments to address the tension. In the *COVID-19 unit*, the team repeatedly negotiated the curation of data sets, balancing attending to students' interests in ways that aligned with KI (a project value) and curating data from publicly available data sets of manageable size and scope (a project driver). In both studies, these choices were not made during one conversation or in one moment of decision-making. They were repeatedly negotiated and iterated over the course of three years. This dissertation elaborates on the applications of the Design Tensions framework, validating it as a way to examine the co-design of justice-centered STEM curriculum, in addition to math and science curriculum (Johnson et al., 2016; Penuel et al., 2022; Penuel et al., 2025)

Next steps for this aspect of the work are to dive more deeply into the RPP participants involved in decision-making. This dissertation documents the conversations and feedback that led to specific design decisions and discusses who is involved in many of those discussions. For example, study two documents on Elaine's involvement, and it is clear she was a major contributor to refining the *COVID-19 unit* in ways that made data more accessible. Study three illustrates Gregory's leadership in the initiation and refinement of the *Henrietta Lacks* unit. However, these studies do not systematically examine who contributes to specific design changes and how often. Are changes being led by researchers with teacher input, or are teachers leading conversations and researchers acting as thought and implementation partners? Examining the contributions of individual participants to navigating the design tensions will further elaborate on how tensions are navigated within RPPs, as well as provide more detailed insight into the role of RPP participants in co-design (Kavanagh et al., 2022; Tan & Lee, 2023). This will not only support the refinement of structures within our RPP to continue to empower teachers' contributions, but also can illuminate challenges or best practices in supporting collaboration in RPPs for the field.

RPP Structures that Facilitate Co-design

While many studies have shown the success of educational interventions and products created using co-design, more work is needed to understand how structures and tools within RPPs support co-design, teachers' involvement, and their learning. I contribute to this gap with this

dissertation. Taken together, these studies highlight the specific ways in which tools and structures within the RPP facilitated co-design and teacher learning.

Tools utilized in this RPP, including unit prototypes and KI rubrics, facilitated discussions between participants about supporting student learning and adjustments to unit design aligned with the KI framework. As discussed above, opportunities to examine student work using KI rubrics allowed teachers to identify the justice ideas students had, and others they were missing, including justice ideas related to race and racial projects (Omi & Winant, 2014). This helped inform the refinements to the unit, resulting in an increased focus on segregation and the stop-and-prompt step in the *Henrietta Lacks* unit and the inclusion of the expert video and distinguishing activity in the *COVID-19* unit. These changes were documented in chapter three. In chapter four, extended opportunities for Elaine to examine student work, including both students' data investigations and their answers to the embedded question "What story would you like to tell about COVID-19?," supported her to align data set topics with student interests in Revision One, and reflect on student learning in ways that informed continued refinement of the data sets for Revision Two. Understanding students' thinking is key to responsive instruction (Kang, 2022; Luna, 2018; Rosebery et al., 2016), and this work emphasizes the role of student work in understanding students' thinking in ways that can inform curricular design and refinement in RPPs.

Unit prototypes were a key resource throughout co-design, providing teachers with an anchor resource with which they could root specific feedback in. This was especially true for the *Henrietta Lacks* unit. In chapter five, I discussed how each teacher provided specific, though different, feedback on the *Henrietta Lacks* unit prototype that spoke to their varying foci and expertise. Gregory focused on making her story accessible, Elaine on the role of segregation, and Beatriz on science ideas. This suggests that anchor resources can provide both structure and enough flexibility to empower teachers to share a wide variety of feedback that can help refine curriculum and instruction in a variety of ways. This builds on our understanding of anchor resources as a tool for scaffolding co-design with practitioner participants (Jayathirtha et al., 2025; Matuk et al., 2023; Severance et al., 2016).

Chapter five showed how several RPP activities were also shown to be especially supportive of collaboration between participants, facilitating co-design. For an expert co-design partner like Gregory, informal spaces like passing periods facilitated collaboration between him and the researcher in ways that supported rapid refinement of an educational intervention. These informal spaces are under-explored as sites of co-design work. They are often short and occur spontaneously, making it challenging to systematically collect and analyze data on what occurs in these spaces. For this dissertation, I summarized our conversations in analytic memos at the end of each day of observations and analyzed my summaries. Future research can explore how to better document these informal conversations and systematically analyze the ways that they contribute to co-design.

Finally, Workshops created spaces for educators to share resources and insights: Gregory shared his experience using the *Henrietta Lacks* unit, and Elaine shared her customization artifacts with other teachers. Meetings between teachers and researchers provided opportunities to discuss problems of practice and iterate on unit design and were open enough for new teachers like Beatriz to ask questions about her role in the work. Continued work is needed to create open, welcoming spaces where teachers feel empowered to share their expertise, ask questions, and identify roles within partnerships that feel meaningful to them.

RRP Structures that Support Teacher Learning and Agency

This dissertation also contributes to our understanding of how RPPs can support teacher learning, aligning with a growing area of the field (Gerard et al., 2010; Penuel et al., 2022). All three chapters demonstrated how opportunities for teachers to review student work during RPP workshops or post-implementation interviews supported teachers in reflecting on student learning. Pre-interviews before implementing revision two of the *COVID-19* unit supported Beatriz and Elaine to review students' data investigations from the previous year and use what they discovered from student work to plan responsible customizations to support students in working with data. Reviewing the *Impacts* data from the *Henrietta Lacks* unit helped teachers identify gaps in students' understanding of justice ideas, particularly ideas about segregation or how Henrietta's story related to current issues of injustice. This prompted teachers to hold class discussions that centered on race and enact customizations focused on justice ideas. Our findings align with the prior research that speaks to the power of using student work as an anchoring resource for informing the customization of curriculum and for facilitating teacher reflection and responsive instruction (Bichler et al., 2021; Bradford et al., 2021; Roseberry et al., 2016).

Chapter five focused on the experiences of three of our partner teachers, Elaine, Gregory, and Beatriz. This chapter highlights the ways that the RPP supported their learning and agency, though aspects of their learning and leadership also emerge in chapters three and four. Gregory, an expert in KI and co-design within the context of our RPP, was supported to leverage his knowledge and take on leadership roles. RPP workshops created space for him to lead prototyping sessions, validating his classroom expertise and teacher perspective. Gregory also grew in his ability to enact justice-centered instruction. While using the *Henrietta Lacks* unit, he progressed from having no conversations about race to enacting a thorough Padlet customization and class discussion that centered on contemporary racial justice issues. Elaine felt empowered to engage in research, and the compensated research internship provided her with the space and time to do so. This opportunity supported her to practice and implement KI pedagogy in curricular design and reflect on her teaching using the KI framework. It also helped shift her professional identity, as seen by her use of "we" when reflecting on the design of the *COVID-19* unit (Kyza & Agesilaou, 2022). Finally, Beatriz was supported to grow in her ability to customize instruction. She shifted from using units largely as is to integrate KI-aligned customizations focused on both science and justice ideas. An important part of her growth was an honest, open discussion about RPP roles. This empowered her to align curriculum with her instruction and points to the importance of transparently discussing and negotiating roles with all RPP participants (Philip et al., 2022).

As we continue this work, we seek to continue to implement and refine structures that support teacher learning aligned with KI and JCSP and agency to take on leadership roles that feel meaningful to them within the partnership. Our RPP is beneficial to the learning of both experienced (Gregory) and novice (Elaine and Beatriz) co-design partners.

Limitations

This dissertation has several limitations. The first is regarding measuring student learning as they engage in justice-centered science instruction. For this dissertation, student work is analyzed and integrated into the larger analysis of the work of the co-design team. While I discuss some findings related to student learning from Revision Two of both units and how the results point to the success and limitations of the unit designs, more work is needed to analyze student work (including embedded assessments within the WISE platform, teacher-generated activities, and students' class

discussions) more deeply. Doing so would provide a more robust understanding of how students make sense of SJSI than is currently documented by this dissertation. Additionally, outcomes measured here only measure student learning while engaging in one justice-centered science unit. The justice ideas, specifically ideas related to systemic oppression and racial projects (Omi & Winant, 2014), are challenging for even adults to make sense of. Engaging in multiple units would likely support a more integrated understanding of justice ideas. Though students in both Elaine and Beatriz's classrooms used multiple units throughout the school year, this dissertation does not measure the impact of multiple opportunities to engage in justice-centered science instruction on their learning.

Teacher customizations were also discussed in the context of the larger narrative of the co-design of the justice-centered science units and three teachers' experiences within the RPP. A deeper analysis of these customizations, including the discussions that occur during them, is needed to understand the nuances of how teachers facilitate discussions about SJSI. While I discuss changes in the number of discussions and general progress in implementing KI-aligned teaching practices, a more thorough analysis of classroom transcripts is needed to uncover how science teachers discuss race and how these ideas are taken up by their students in conversation with one another (Philip et al., 2018). These analyses are ongoing work.

This dissertation focuses on the contributions of practitioners within one specific RPP. I only discuss the contributions and activities of practitioners who were more heavily involved in the RPP (attended workshops, interviews, etc.) and do not discuss the activities of those who implemented the units in their classrooms but were not involved in broader co-design activities. As a result, this dissertation does not document the experiences, learning, and contributions of these educators. In focusing on the experiences of teacher participants (and myself, in partnership with these participants), this dissertation is also limited in discussing the contributions of other RPP participants of other professional backgrounds (researchers, computer scientists). Finally, while what we learned can cut across and inform other RPPs, the findings in this dissertation cannot be removed from the unique contexts of the RPP's history and participants' identities. Findings cannot speak to the practices of all RPPs or the experiences of all educators who are involved in RPPs across the globe.

Next Steps

There are several directions for future research that other members of the RPP and I are currently pursuing. First, future research seeks to examine co-design data from the other three justice-centered science units produced in this RPP to see if the two emerging tensions are relevant across all the units or if additional tensions arise. If so, are there nuanced differences between how the tensions emerge for each unit, and do differences in the focus of SJSI (environmental justice issues rather than public health ones) result in differences in how participants refine units? More work is needed to identify other tensions that cut across units, as these can inform best practices or design principles for creating justice-centered STEM curriculum that can be shared with the field.

Next steps also involve examining student learning more closely and tracking students' ability to integrate science and justice ideas after engaging in multiple social-justice science units. Beatriz uses four units, and I am currently working with her and two other researchers within the RPP to validate an instrument to measure students' ability to integrate ideas to explain SJSI, regardless of the specific focus of the SJSI, to track students' learning over time.

As stated in chapter three, automated AI guidance informed by Knowledge Integration has shown promise in supporting students to integrate science ideas (Gerard et al., 2025; Li et al., 2024). Future research seeks to integrate technology informed by KI rubrics, such as automated guidance, to help students distinguish justice and science ideas. These KI-informed educational tools can likely be helpful here as well. Another RPP researcher has done this with an SJSI focused on climate change (Bradford et al., 2023a), and pilot studies are underway for AI guidance for COVID-19 and Henrietta Lacks *Impacts* assessment items.

As teachers continue to use these units, they repeatedly refine their customizations. Future work seeks to investigate teachers' customizations in more detail and track teachers' progress in centering justice ideas in their class discussions and customizations (Billings, 2025) over time to measure the impact the RPP has on their ability to center justice and race in science instruction.

Alongside these initiatives, the RPP continues to iterate on these two units and refine the curricula. For example, the COVID-19 data sets and data investigations have gone through another round of iterative refinement in partnership with data science undergraduate students at UC Berkeley. Their expertise has been vital in cleaning complex new data sets that were previously challenging for me and Elaine to modify for use in the unit. Future research continues to assess the impact of unit refinement on students' learning.

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Appendices

Supplemental Tables and Figures for Chapter 2

Table 29

Post-Interview Protocols

Post-Interview	Questions
COVID-19 Pilot post-interview	How did students engage with this unit? What parts of the unit were most or least engaging, and how could you tell? Were there any comments or questions that students asked that you wanted more support as a teacher in discussing? How did the unit align with your own teaching practice, reinforce your own practice, or lead you to practice differently? Now that you've taught an ARISE unit, what have you learned about teaching an anti-racist science curriculum? After teachers open student work in the WISE teacher tools: How did students bring in their own knowledge and experiences about COVID? Where did it come from? What were students' initial ideas about COVID and COVID data? Where were they starting from, from an initial perspective? Do you think the unit shifted or reinforced students' initial ideas/understanding? Do you think students were linking issues of equity to the data? If yes, what are some examples? If no, where do you think they are getting stuck? Do you think students were linking issues of race to the data? If yes, what are some examples? If not, where do you think they are getting stuck? Based on your experience teaching the unit, what customizations or changes would you make if you were to teach it again? What support for your students' thinking could be added? How could the unit better support your students' thinking? Graphing?
COVID-19 Revision One post-interview	What worked well in the unit? What needed adjustments or additional scaffolding? How did you customize the unit for your students? After the teacher opens student work in the WISE teacher tools: How did students use the data explorer? What was challenging for them? - Follow-up: How did you feel about the size of the data sets for your students?

-
- Follow up: What improvements might help students engage with the data better?
 -

What data did students choose to investigate? What additional data did they want to complete their investigations?

What additional data do you think students might be interested in exploring?

What other data science topics would you be interested in discussing with your students?

Ex: qualitative data investigations? Data privacy?

Henrietta Lacks Pilot post-interview

Overall, how do you think students engaged with this unit?

After the teacher opens student work in the WISE teacher tools:
When asked (during the pre-interview) how you anticipated how students might link science and social justice, you mentioned that you thought they would make strong connections between the ethics of using cells in research, as well as why/how cells are used (vaccines). Do you think students made these connections? How do you know?

How might we make this connection more obvious in future iterations of this unit?

What concepts or ideas did students struggle with during this unit? How do you think they might be better supported?

What other suggestions do you have for improving this unit?

Henrietta Lacks Revision
One post-interview

What did you like about the changes you noticed in the unit?

How do you think the flow/transition from the genetics to the HeLa portion went? (Cystic Fibrosis/Eric introduction, Eric case study, Henrietta Lacks case study, Lesson 6)

What ways could the unit be improved?

After the teacher opens student work in the WISE teacher tools:
What genetics ideas did you notice students write/discuss?

What ideas related to privacy, consent, and Henrietta Lacks did you notice students write/discuss?

How do you think students connected their science (genetics) ideas and their ideas about privacy, consent, and Henrietta Lacks?

How did students' ideas change over the course of the unit?

-Bring up pre/post if possible.

Plot Lesson Sequence	Lesson Driving Question		Lesson Objective		Revision 1 Lesson Sequence (fall 2022)			Revision 2 Lesson Sequence (fall 2023)								
	Driving Question		Lesson Objective		Driving Question		Objective	Driving Question		Objective						
Lesson 1 - Data Collection and Variables	What data do we collect about COVID-19? What are the challenges in collecting COVID-19 data?		Students can construct a data story about COVID-19 in their community. Students can identify challenges in collecting and analyzing data about COVID-19.		Lesson 1 - Data Collection and Variables	What data do we collect about COVID-19? What are the challenges in collecting COVID-19 data?		Students can identify challenges in collecting and analyzing data about COVID-19. Students can evaluate the validity of COVID-19 data and information sources.	Lesson 1	What data do we collect about COVID-19? What are the challenges in collecting COVID-19 data?		Students can identify challenges in collecting and analyzing data about COVID-19. Students can evaluate the validity of COVID-19 data and information sources.				
	KI STEP		Activity Description			KI STEP				KI STEP						
	1.1 Meet a Scientist	Elicit	Introduce D4BL. Elicit ideas about story they want to tell about covid in their community.	Kept		1.3 Meet a Scientist	Elicit	Introduce D4BL. Elicit ideas about story they want to tell about covid in their community.		1.2 What stories can you tell with this data?	elicit	Students indicate data they might be interested in. Ideas about what story they could tell with that data are elicited.				
		Elicit		Moved to the end of L1, re-position as reflection			Elicit				elicit					
	1.2 Your ideas how why for whom	Elicit	introduce D4BL, intended purpose of data. Elicit ideas about intended purposes of COVID data	Kept		1.4 COVID-19 variables	Elicit	Elicit ideas about important variables to measure, easy of measuring. Elicit ideas about where students go to find covid information and which sources they think are reliable.		1.3 COVID-19 variables	Elicit	Elicit ideas about important variables to measure, easy of measuring. Elicit ideas about where students go to find covid information and which sources they think are reliable.				
		Elicit		Removed			Elicit				Elicit					
	1.3 Intended purpose of data	Elicit	Elicit ideas about important variables to measure, easy of measuring	Kept, Moved up		1.5 Where do we find COVID-19 data?	Elicit	Elicit ideas about what makes a source reliable.		1.4 Where do we find COVID-19 data?	Elicit	Elicit ideas about what makes a source reliable.				
		Elicit		Kept, but added scaffolds and screenshots to support learning and using the map.			Elicit				Elicit					
	1.4 COVID-19 variables sort	Elicit	Discover the different variables states collect and discover differences in state reporting	Kept, Moved up		1.5 How do we determine if data is verified?	Elicit	Students share their ideas and create a list together to evaluate sources. Students discover how other organizations evaluate sources, compare to their list, and revise their list. Students use their revised list to evaluate a source.		1.5 How do we determine if data is verified?	Elicit	Students share their ideas and create a list together to evaluate sources. Students discover how other organizations evaluate sources, compare to their list, and revise their list. Students use their revised list to evaluate a source.				
		Discover		Kept			Discover				Discover					
	1.5 Different states, different variables	Discover	Discover differences in race/ethnicity reporting of COVID data. Distinguish different covid stories different graphs can tell	Kept		1.7 Group validity criteria	Discover + Distinguish	Discover the different variables states collect and discover differences in state reporting. Discover differences in race/ethnicity reporting of COVID data. Add emphasis on missing data.		1.6 Group validity criteria	Discover + Distinguish	Students distinguish how different organizations evaluate sources, compare to their list, and revise their list. Students use their revised list to evaluate a source.				
		Distinguish		Removed			Reflect				Reflect					
Lesson 2 - Investigation 1, COVID trends overtime	How has COVID-19 changed overtime?		Students practice making predictions with COVID Berkeley example		Lesson 2 - Investigation 1, COVID trends overtime	How has COVID-19 changed overtime?		Students create and investigate an inquiry question using public COVID-19 data sets. Students practice making predictions with COVID Berkeley example. Students practice reading a graph and reflecting on their predictions with COVID Berkeley example. Students pick a location (Alameda CO, Detroit, Guat(EL)S) and dry up work. Students explore data set and create a question to investigate, minimal scaffolding for exploration and question generation. Students write a prediction and create a prediction graph. Students great graphs and distinguish if the graph matches their prediction minimal scaffolding. Group comes together to answer question. Minimal scaffolding for reflection.	Lesson 2 - How has COVID-19 changed overtime?	How has COVID-19 changed overtime?		Students can create and investigate an inquiry question using public COVID-19 data sets. Students sort graphs with certain time periods to make predictions about COVID-19 changed overtime. Students discover characteristics of graphs, and how these characteristics (tbp, axis, etc.) help someone understand a graph. Students choose a question to investigate form 3 pre-generated questions. Students created a hypothesis and prediction graph. Students create a graph, distinguish how the graph is different from their prediction, and answer their question. Students critique an imaginary peer's investigation.				
	2.1 COVID-19 data patterns in berkeley prediction		Students practice making predictions with COVID Berkeley example			2.1 COVID-19 data patterns in berkeley prediction				2.1 Predict: How did COVID-19 change overtime?						
	2.2 COVID data patterns in berkeley reflection		Students practice reading a graph and reflecting on their predictions with COVID Berkeley example			2.2 COVID data patterns in berkeley reflection				2.2 designing an informative graph						
	2.3 Instructions and prep		Students pick a location (Alameda CO, Detroit, Guat(EL)S) and dry up work			2.3 Instructions and prep				2.3 choose a question to investigate						
	2.4 Identify a question		Students explore data set and create a question to investigate, minimal scaffolding for exploration and question generation			2.4 identify a question				2.4 Prediction graph and hypothesis						
	2.5 make a prediction		Students write a prediction and create a prediction graph			2.5 make a prediction				2.5 Graph your data						
	2.6-2.8 time periods		Students great graphs and distinguish if the graph matches their prediction minimal scaffolding.													

Lesson 3: Investigation 2, COVID-19 in populations and risk factors	How were communities impacted by COVID-19?	Students can create and investigate an inquiry question using public COVID-19 data sets. Students can explain factors that led to inequitable impacts of COVID-19 for marginalized communities. Students are shown graphs from 1.7, reminded that graphs can tell different stories.	Removed	Lesson 3: Investigation 2, Impact of COVID-19 on communities	How were communities impacted by COVID-19?	Students can create and investigate an inquiry question using public COVID-19 data sets.	Lesson 3: Investigation 2, Impact of COVID-19 on communities	How were communities impacted by COVID-19?	Students can create and investigate an inquiry question using public COVID-19 data sets.
3.1 Revisit What stories do these graphs tell?	N/A			3.1 Choose data sets to explore	N/A	Students choose the data set they want to investigate.	3.1 Explore maps	Discover	Students use a map to explore differences in COVID-19 outcomes for different groups.
3.2 Choose your investigation county or state	N/A	Students choose the data set they want to investigate. Students can compare counties in CA or US States. Only two choices		3.2 (A-D) Explore chosen data set	Discover	Students discover what is in their data set, including variables, units of measurement, and draft 5 questions.	3.2 Why might we see these trends?	Elicit	Students ideas about why they see certain trends in the map dat are elicited
3.3 trends	Discover + elicit	Students explore data set and create a question to investigate, minimal scaffolding for exploration and question generation		3.3 Asking questions	Distinguish	Students sort example questions based on whether they can be answered by an example graph or additional information is needed.	3.3 What makes this data different?	Distinguish	Students distinguish the difference between daily data and cumulative data.
3.4 making predictions	Elicit	Students write a prediction and create a prediction graph		3.4 Questions critique	Distinguish + reflect	students critique and revise a question from one of the posters created in step 3.2	3.4 Choose a data set	N/A	Students choose the data set they want to explore.
3.5 Data exploration	Discover + Distinguish	Students great graphs and distinguish if the graph matches their prediction. minimal scaffolding. Students explore the D4BL map, focus on states with highest and lowest impact on Black population. Students asked what story this map tells about COVID-19	Hard to navigate the colors, tried to check with org but they did not clarify.	3.5 Narrow your investigation	Elicit	Students solidify their investigation question, create a hypothesis and prediction. Students investigate their question using the data explorer. Students have small scaffolds to pick relevant variables.	3.5 Explore your data set	Discover	Students complete a scaffolded activity that explores them to discover information about their data set (variables, units, etc.). Students generate draft questions.
3.6 Map exploration D4BL	Discover	Students share initial ideas about how environmental or economic issues impact COVID-19 outcomes for particular groups.		3.6 (A-D) Data Explorer	Discover	Students answer their question based on what they discovered using the data explorer	3.6 Create an investigable question	Distinguish	Students critique an example question, then write their own question to investigate
3.7 Why do we see these trends	Elicit	Jig part of jigsaw. Students discover ideas by reading and/or interpreting graphs about the issue. Students asked to relate findings to the graph they created.	Removed. Iteration 2 then missing major discussions around equity and causes.	3.7 Answer your question	Reflect	students share what they learned + their graph via the discussion tool and answer impacts question using graphs as evidence.	3.7 Choose a type of graph	Distinguish	students distinguish between the different characteristics of different graphs and distinguish which type of graph would be best to answer their question
3.8-3.10 Causes (aamtha + healthcare access, essential workers, persons per household)	Discover + Reflect			3.8 Shared what you learned	Reflect		3.8 Prediction graph	elicit	students generate a hypothesis and a prediction graph.
3.11 Jigsaw share what you learned	Distinguish	Saw part of jigsaw. Students share findings	Removed	NOTE: Explore maps added as a customization by Marcy in step 3.1		Added into regular instruction in V3	3.9 create your graph	Discover	students use the data explorer to create their graph.
3.12 Collaborative explanation	Reflect	Students bring their ideas together to create a collaborative explanation about how env. or economic factors impact COVID-19 outcomes.	Removed				3.10 Discuss your graphs	Reflect	Students answer their question, share findings via the discussion tool, and answer the impacts question using graphs as evidence.
Lesson 4: using data responsibly	How can we use data to fight against COVID-19?	Students can explain ways that COVID-19 data is used to help people and communities fight the COVID-19 pandemic. Students can explain the difference between using data as a tool for harm, and data as a tool to help people.		Lesson 4: using data responsibly	How can we use data to fight against COVID-19?	Students can explain ways that COVID-19 data is used to help people and communities fight the COVID-19 pandemic. Students can explain the difference between using data as a tool for harm, and data as a tool to help people.	Lesson 4: How do we explain the trends we see in data?	How do we explain the trends we see in data?	Students can explain factors that led to inequitable impacts of COVID-19 for marginalized communities.
4.1 Help vs. Harm	Distinguish + Elicit	Students see D4BL definitions of help and harm. Students sort data uses for help/harm and propose additional ways data can help.	Kept	4.1 Help vs. Harm	Distinguish + Elicit	removed	4.1 What have you learned so far?	Reflect	Students reflect on what they learned from the different graphing activities and what is still unanswered using a sorting activity.
4.2 Misleading data representation: COVID-19 graph	Discover	Students read and interpret a misleading graph and highlight issues with the graph	Kept	4.2 Misleading data representation: COVID-19 graph	Discover	Students read and interpret a misleading graph and highlight issues with the graph	4.2 What causes unequal impact?	Discover	Students discover what contributes to unequal impacts via video, sorting activity, and graphs
4.3 Compare and contrast graphs	Distinguish	Students compare the misleading graph with the corrected graph to distinguish differences in the stories they tell about COVID-19.	Kept	4.3 Compare and contrast graphs	Distinguish	Students compare the misleading graph with the corrected graph to distinguish differences in the stories they tell about COVID-19.	4.3 Example 1: location of testing sites	Distinguish	Students use maps to distinguish how location of testing sites can impact COVID-19 outcomes for different communities in San Francisco.
4.4 Why might someone make a misleading graph?	Reflect	Students reflect on why an organization or person might create a misleading graph.	Kept	4.4 Why might someone make a misleading graph?	Reflect	Students reflect on why an organization or person might create a misleading graph.	4.4 Example 2: Access to vaccinations	Distinguish	Students use a video and article excerpts to distinguish how access to vaccines impacts COVID-19 outcomes for different communities.
4.5 Success story - masks and cases of COVID-19	Discover	Students discover how data was used to inform mask mandates and how data demonstrates the effectiveness of mask mandates.	Kept	4.5 Success story - masks and cases of COVID-19	Discover	Students discover how data was used to inform mask mandates and how data demonstrates the effectiveness of mask mandates.	4.5 How do we fight injustice and support our communities?	Discover + Reflect	Students discover ways other young people have helped their community and propose ways to do so
4.6 Using data to inform vaccine rollout 1	Discover	Students discover how data was used to inform vaccination plans.	Removed	4.6 Vaccinating Oakland	Discover + Distinguish	Students discover challenges in vaccination, particularly in vaccinating at risk communities.			
4.7 Using data to inform vaccine rollout 2	Distinguish	Students use graphs of county data to critique Alameda county vaccination plans.	Removed	4.7 What can you do to help your community?	Discover + Reflect	Students discover ways other young people have helped their community and propose ways to do so			
4.8 Using data to inform vaccine rollout 3	Discover + Distinguish	Students discover challenges in vaccination, particularly in vaccinating at risk communities.	Elaborated with examples and scaffold for planning support for community.						
4.9 What can you do to help your community?	Reflect	Students watch video about how they can help their community. Students share one way they can help, but no further action							

Figure 24

Full Henrietta Lacks Unit Map

Pilot Lesson Sequence - spring 2022	Lesson Driving Question	Lesson Objective		Revision 1 Lesson Sequence - spring 2023	Driving Question	Objective		Revision 2 Lesson Sequence - spring 2024	Driving Question	Objective	
Lesson 4 Henrietta Lacks: science, ethics, and privacy	What happened to Henrietta Lacks? What happened to Henrietta Lacks' cells?	Students can explain how Henrietta Lacks' story violates ethical guidelines and how her cells were used for research.		Lesson 4 - Making decision about health data (Eric)	How does Eric make decisions about his health data?	Students can explain how a young person might make decisions about their health data.		Lesson 4 - Making decision about health data (Eric)	How does Eric make decisions about his health data?	Students can explain how a young person might make decisions about their health data.	
	Challenges, opportunities, changes to this step				Challenges, opportunities, changes to this step				Challenges, opportunities, changes to this step		
	4.1 What does ethically mean?	Ellicit, discover			4.1 Who is involved in supporting Eric's health?	Discover, distinguish			4.1 Who is involved in supporting Eric's health?	Discover, distinguish	
	4.2 Henrietta Lacks' story	discover			4.2 What data does each person have?	distinguish			4.2 What data does each person have?	distinguish	
	4.3 What does it mean to get permission?	Distinguish			4.3 what data should eric share with the doctor?	Ellicit			4.3 what data should eric share with the doctor?	Ellicit	
	4.4 Henrietta's cells and scientific research	Ellicit			4.4 What data should eric share for research?	Discover			4.4 What data should eric share for research?	Discover	
	4.5 HeLa discoveries	discover			4.5 Why are research participants so important?	Discover			4.6 Help Eric decide!	Reflect	
	4.6 Share what you learned	discover			4.6 Help Eric decide!	Reflect			4.7 What did eric's family decide	N/A	
	4.7 reflect	reflect							4.8 Why are research participants so important?	Discover	
Lesson 5 What makes Henrietta's cells so special? Mutations	Why were Henrietta's cells good for research? How do we decide which cells to use for research?	Students can explain how mutations led to differences in how HeLa cells divide. Students can use a decision tree to weigh pros and cons of using certain cell lines for research.		Lesson 5 The Story of Henrietta Lacks	Who is Henrietta Lacks? How is her story different from Eric's?	Students can explain how Henrietta Lacks' story differs from modern permission standards and treatment.		Lesson 5 The Story of Henrietta Lacks	Who is Henrietta Lacks? How is her story different from Eric's?	Students can explain how Henrietta Lacks' story differs from modern permission standards and treatment.	
	5.1 Henrietta Lacks' cells	elicit			5.1 What did Eric's family decide?	N/A			5.1 Who was henrietta lacks?	Discover	
	5.2 introduction to mutations	discover			5.2 Who was henrietta lacks?	Discover			5.2 Why were Henrietta Lacks' cells so special?	Discover, distinguish	
	5.3 What is mitosis	Discover			5.3 Why were Henrietta Lacks' cells so special?	Discover, distinguish			5.3 What research has been done with HeLa cells?	Discover, distinguish	
	5.4 mutations and cancer	Discover			5.4 What research has been done with HeLa cells?	Discover, distinguish			5.4 Permission in 1950	distinguish	
	5.5 How fast do cancer cells divide?	Distinguish			5.5 Permission in 1950	distinguish			CLASS DISCUSSION (customizations)		
	5.6 Bring it all together, what made Henrietta's cells good for research?	Reflect			CLASS DISCUSSION (customizations)				5.5 Permission today	Reflect	
	5.7 How do we decide which cells to use for research?	elicit			5.6 Permission today	Reflect			5.6 How are Henrietta and Eric' stories	Distinguish, Reflect	
	5.8 Decision tree example	Discover			5.7 Henrietta's family's reaction	Reflect			5.7 Henrietta's family's reaction	Reflect	

5.9 Create a decision tree	Distinguish	students use the information from the scenario to make a decision tree documenting how they would decide which cells to use for scientific research.	dropped, students did not connect with the scenario and problem.	5.8 Honoring Henrietta and her family	Discover	students discover how Henrietta's family have fought for her to be acknowledged and how they are now part of decision making using her cells.	kept	5.8 Honoring Henrietta and her family	Discover	students discover how Henrietta's family have fought for her to be acknowledged and how they are now part of decision making using her cells.	
5.10 Henrietta's family today	Reflect	Students learn about HL family's involvement today and reflect on how they can advocate for themselves.	too much text	5.9 Help Henrietta's family make a decision	Reflect	Students use what they learned to help determine whether Henrietta's cells should be used for a research study.	Added scaffolds (as pick from list of Q rather than come up with Q)	5.9 Help Henrietta's family make a decision	Reflect	Students use what they learned to help determine whether Henrietta's cells should be used for a research study.	
				Lesson 6 Would you participate?	Would you participate in a research study?	Students can explain why they would or would not want to participate in a research study, citing evidence from the research scenario.		Lesson 6 - can patient care still improve?	How is patient care still impacted by racism and discrimination? How can patient care further improve?		
				6.1 would you want to know?	Elucid	Students ideas about if they would want to know if their data is being used are elicited.		6.1 Predict: how is patient care impacted?	elucid	Step summarizes that racism/segregation was important in Henrietta's story. Students predict how patient care is impacted by race of the patient and doctor.	Added to further emphasize larger systems of oppression in medical care. Emphasize that these systems still impact patient care today.
				6.2 study overview	Discover	Students discover information about a research scenario.		6.2 Do medical providers have the same identities as their patients?	Discover	students use a graph to discover information about patient/provider identity matches.	Added to further emphasize larger systems of oppression in medical care. Emphasize that these systems still impact patient care today.
				6.3 I chose to...	Distinguish	Students distinguish why different peers might want or not want to participate in a study.	Added one reason you would participate and one reason you would not participate.	6.3 How are patients treated by medical providers?	Discover, Distinguish	Students use what they learned about Henrietta and what they learned from graphs to distinguish the relationship between provider ethnicity match and patient care.	Added to further emphasize larger systems of oppression in medical care. Emphasize that these systems still impact patient care today.
				6.4 Would you participate?	Reflect	Students bring their ideas together to explain why they would or would not want to participate in the study.		6.4 revise	Reflect	Students revise their explanation from 6.1. Students provide ideas about how patient care might be improved.	Added to further emphasize larger systems of oppression in medical care. Emphasize that these systems still impact patient care today.
								Lesson 7 Would you participate?	Would you participate in a research study?	Students can explain why they would or would not want to participate in a research study, citing evidence from the research scenario.	
								6.1 would you want to know?	Elucid	Students ideas about if they would want to know if their data is being used are elicited.	
								6.2 study overview	Discover	Students discover information about a research scenario.	
								6.3 I chose to...	Distinguish	Students distinguish why different peers might want or not want to participate in a study.	
								6.4 Would you participate?	Reflect	Students bring their ideas together to explain why they would or would not want to participate in the study.	

Supplemental Tables and Figures for Chapter 5

Table 30

Breakdown of Labor Between Myself and My Co-Author (Marcia C. Linn) for Chapter 5.

Study contribution	Authors involved
Study conception and design	Kelly Billings-Yadav and Marcia C. Linn
Data Collection	Kelly Billings-Yadav
Data Analysis	Initial identification of episodes and coding of data - Kelly Billings-Yadav Refinement of episodes and codes - Kelly Billings-Yadav and Marcia C. Linn Analytic memos and planning of reflective interviews - Kelly Billings-Yadav and Marcia C. Linn Reflective interviews and analysis of interview data - Kelly Billings-Yadav
Initial draft of manuscript	Kelly Billings-Yadav
Editing and refining of the manuscript in preparation for submission to Information and Learning Sciences	Kelly Billings-Yadav and Marcia C. Linn
Preparation of manuscript for integration into dissertation	Kelly Billings-Yadav

Table 31
Reflective Interview Protocol

Interview Questions
How long have you been involved with WISE?
Why did you originally become involved with WISE?
How has the WISE group supported your practice over the years?
How would you say your history with WISE shaped your current role or involvement in the collaboration?
How do you think you benefited from teacher collaboration during the workshop?
How do you think you benefited from researcher collaboration time during the workshop?
Can you describe moments or activities during the RPP when your input had an impact on project outcomes?
Describe each co-design episode (3 total). Ask teachers to share their thoughts on their actions, motivations, and goals for each episode.

Table 32

Teacher Action Codebook, Examples of Each Code, and Code Counts. Episodes Could be Labeled With Multiple Codes

Code	Sub code	Example	RPP Structure	Elaine			Gregory			Beatriz*		
				Year 1	Year 2	Year 3	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3
Unit Design	Propose new SJSI or unit	Gregory proposed the story of Henrietta Lacks as a new SJSI	Teacher-Researcher Partnership	0	0	0	0	1	0	0	0	0
	Provide feedback on unit	Teachers provided different feedback during a <i>HeLa</i> unit prototyping session	Teacher-Researcher Partnership, Workshops	2	3	4	5	4	1	0	3	3
	Provide feedback on education technology	Elaine and Beatriz provided feedback on the Data Explorer after implementation	Teacher-Researcher Partnership, Summer Internship	1	1	1	0	0	0	0	2	3
	Acquire/discuss OERs	Beatriz shared a map during a pre-implementation meeting, which was added to the COVID-19 unit	Teacher-Researcher Partnership, Summer Internship	0	1	1	0	0	0	0	1	0
	Modify unit design using authoring tool	Elaine modified datasets for the COVID-19 unit	Summer Internship	0	0	1	0	0	0	0	0	0
Customization	Design customizations	Elaine designed an empowerment activity for the COVID-19 unit	Teacher-Researcher Partnership	1	4	3	5	4	4	0	0	2

	Create additional student-facing materials	With Researcher	Elaine and Beatriz co-planned customizations to the COVID-19 unit with the first author	Teacher-Researcher Partnership	0	0	2	0	1	1	0	1	2
		Independently	Elaine created slides for both units	Teacher-Researcher Partnership	1	1	0	5	3	3	0	0	2
		With Researcher	Gregory and the first author co-created an online Padlet	Teacher-Researcher Partnership	0	0	2	0	1	1	0	1	2
		Independently	Elaine adjusted how she used her slides between class periods	Teacher-Researcher Partnership	1	1	1	0	0	0	0	0	0
	Refine customization while teaching	With researcher	Gregory and the first author used passing periods to refine his facilitation of the Padlet customization	Teacher-Researcher Partnership	0	0	1	0	1	1	0	0	0
	Reflect on customizations		Gregory reflected on his Padlet customization	Teacher-Researcher Partnership, Workshops	0	2	1	0	3	3	0	2	2
	Reflect on classroom teaching	With researcher	Elaine reflected on teaching practices while co-writing a journal publication	Teacher-Researcher Partnership, Workshops	1	2	2	2	2	1	0	2	2
		With broader RPP	Gregory reflected on his teaching how when sharing his	Workshops	1	1	0	1	0	1	0	0	0

		experience using the <i>HeLa</i> pilot										
	Lead RPP sessions	Gregory led workshops sessions focused on the <i>HeLa</i> unit	Workshops	0	0	0	1	1	1	0	0	0
	Share customization artifacts with other educators	Elaine shared her <i>COVID-19</i> unit slides at the workshop	Workshops	1	0	0	0	0	0	0	0	0
	Examine student work	Elaine and Beatriz noted gaps in students' ability to create investigable questions from <i>COVID-19</i> datasets	Teacher-Researcher Partnership, Workshops	2	3	3	4	2	1	0	3	4
	Discuss connections across SJSI/units	Beatriz and the first author discussed how to support students to link ideas about healthcare access across units	Teacher-Researcher Partnership	0	0	0	0	0	1	0	0	2
Research	Analysis of student or classroom data	Elaine analyzed student data from the <i>COVID-19</i> pilot to propose updates to the Data Explorer and datasets	Summer Internship, Teacher-Researcher Partnership	0	1	1	0	0	0	0	0	0

Co-writing with researcher s	Elaine and the authors co-wrote a conference paper documenting refinements to the Data Explorer and datasets	Summer Internship, Teacher- Researcher Partnership	0	0	2	0	0	0	0	0	0
Present research findings	Elaine shared her findings and proposed changes to <i>COVID-19</i> unit during research group meetings	Summer Internship, Teacher- Researcher Partnership	0	2	4	0	0	0	0	0	0
Share artifacts with broader communit y	Elaine and the first author presented their paper at conference	Summer Internship, Teacher- Researcher Partnership	0	0	2	0	0	0	0	0	0

*Beatriz attended workshops in year one, but those units were not included in this analysis.