Physics teachers integrating social justice with science content

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In this study, we showcase the various ways high school physics teachers make connections between science content and social justice, pushing the boundary of what is counted as science content by bringing social justice engagement to the center of science learning. We analyze lessons submitted by eighteen high school physics teachers who participated in a professional development program that supported the integration of equity into their science teaching. Three themes represent teachers' approach toward integrating social justice in their science lessons: (1) investigating the nature of science in specific science concepts and re-evaluating/redefining science concepts, (2) connecting students' everyday activities with science and global social justice issues, and (3) using science knowledge to engage with and advocate for social justice issues in students' local communities.

2022 PERC Proceedings edited by Frank, Jones, and Ryan; Peer-reviewed, doi.org/10.1119/perc.2022.pr.Huynh

I. INTRODUCTION

Foregrounding social justice in science teaching is one of the main approaches for science education to address social inequities. Although all equity-oriented work is important, not all equity-oriented work is equally transformative [1-3]. Transformative work that goes beyond providing equal access to learning is necessary to ensure all students, particularly marginalized students, engage meaningfully in their science learning experiences because the sciences are not culturally free and politically neutral -- they privilege the ideologies and epistemologies that reproduce hierarchies in society [2-4]. Centering social justice in science learning is one way to support students to develop social critical analysis, to engage with diverse communities' alternative ways of knowing and being, and to use science knowledge to solve their own personal and community-based problems.

Collective effort has contributed to social justice transformation in K-12 science education through multiple approaches across different levels. Most of these efforts are aimed toward training future science teachers in sociocultural awareness, social justice topics and social justice pedagogy [5-7] or providing teachers with practical tools and frameworks to create learning opportunities that are more social justice-centered [8,9]. While much of the current work has focused on supporting teachers in enacting equitable teaching strategies and implementing social justice topics in science classroom, few studies have focused on how teachers themselves choose to integrate social justice into curricular science content. Most examples of this work take place in mathematics including [10, 11] and fewer in other sciences including [12-14]. We add to this corpus of work by analyzing teachers' lessons and identifying ways in which teachers choose to connect social justice with science content, especially in ways that support students to use science as a tool for investigating and taking action towards social transformation. This work is important because research has found that students from marginalized groups in science find school science unrelated to their lives and disconnected from the knowledge they bring to the classroom [14, 15]. We contend that integrating social justice into science content is necessary for beginning to bring alternative perspectives into science and for transforming science rather than reproducing the existing knowledge that has dominated scientific discourses.

Teachers who want to integrate social justice into science content encounter structural barriers and challenges including negotiating social justice commitments with content goals [7, 16, 17]. Professional development (PD) programs such as Energy and Equity are designed to fill that gap by supporting teachers in creating materials that integrate science with equity and social justice in ways that fit within their contexts. PD programs with appropriate features that center teachers' experiences, agency, and pragmatic applications, are significantly impactful in supporting teachers to make changes, including implementing new instructional materials, in their teaching [18]. Recent work [19] has emphasized the role of teachers' agency especially in bridging professional development and school reform. Therefore, our PD is built with intentional structures that aim to support teachers' development, including a long-term and collaborative program where teachers participate as partners, co-determining the content focus of the PD and sharing lessons while being provided personalized, contextualized support in developing their lessons. In this paper, we focus on the different approaches high school physics teachers take to integrate social justice into their science lessons. Our motivations are to share inspiring and practical ways that high school teachers are engaging in this work and to make visible the types of lessons that are most often taken up during the PD. The latter purpose—identifying the themes that permeate across lessons—helps us make inferences about the material elements of the PD that were impactful to the teachers' lesson development while also noticing teachers' agency and expertise in integrating the PD content into their work. Although making direct causal connections between certain material elements of the PD and the development of particular curricular materials requires more extensive research, our preliminary findings of these themes suggest which topics resonated with teachers and were accessible practices to creating social justice focused science lessons that fit with their teaching contexts. Our study aims to address the research question: "Given the context of our PD, how did the teachers integrate social justice with science content in their lessons?"

II. RESEARCH METHOD AND CONTEXT

A. Professional development context

The data for this study comes from the "Energy and Equity" professional development (PD) which was designed to support high school physics teachers in integrating physics energy content and equity education. The PD program is comprised of multiple components: an intensive virtual summer workshop (SW) that was one to two weeks long, a yearlong professional learning community (PLC) that met virtually bi-monthly following the SW, and an online community library where the teachers and invited contributors can share their materials. The PD is designed with an underlying epistemological stance that science concepts are not socially and culturally value-free but carry sociopolitical and historical baggage as they are created at particular places and times to serve specific purposes [19].

There have been two iterations of the SW and PLC with 42 high school physics teachers (40 from the US, 2 from outside the US) participating in the PD since 2020. The 2020 SW was one-week long and 23 teachers participated; 6 of those teachers took part in the 2020-2021 PLC. The 2021 SW was two-weeks long and 19 teachers participated; 5

teachers from this group and 3 returning teachers from the SW 2020 were regular participants in the 2021-2022 PLC. Both SWs discussed topics including equity frameworks, identity and positionality, models for energy, historical sociopolitical roots of energy concepts, and climate justice. The SW 2021 was expanded to two weeks, with the aim of providing space for teachers to create curricular materials and lesson drafts in the second week. After completion of the SW, teachers were invited to take part in the PLC for continued conversations on various topics of equity and social justice, including place-based education, equity and social justice frameworks, equity and science integration and for continued support for their lesson development. While these topics were covered throughout the two iterations of the PD, the specific materials presented in the two iterations varied because the PD was intentionally designed to evolve and be responsive to the teachers' needs and interests. Teachers developed lessons to integrate social justice and science content consistent with the topics that were covered during their PD experience(s). Our findings suggest that their lessons closely reflect most, but not all, of the presented topics.

B. Data collection and selection

The lessons in this analysis come from the materials submitted by teachers over the last two years (both from the SWs and PLCs). The maturity of the materials uploaded to the community library varies. For example, some teachers uploaded an iteration of a lesson they worked on over the course of the year-long PLC while others uploaded a draft version of the materials they developed over the course of the one to two week-long SW. This analysis accounts for all the materials available on the online community library as of April 2022 with an acknowledgement that some of these materials may continue to evolve.

There were 21 activities PD teachers shared in the community library. We selected 16 of them for our thematic analysis. Three lessons were not selected for this analysis because they were either adopted materials from other sources or designed for populations other than K-12 U.S students (e.g., teachers, staff, and international students) which is the focus of this analysis. Although social justice is a global issue, our study focuses on social justice integration with science content situated in the US K-12 context. The other two lessons were not selected because they focused on teaching social justice in the broad context of science rather than in a specific science content topic area. With the teachers' consent, these lessons are shared on the Energy and Equity Portal (www.energyandequity.org) with registered educators.

C. Methodology

We conducted a hybrid thematic analysis [20, 21] of selected lessons to characterize the themes in which teachers integrated social justice with science teaching. We reflected on the topics that were featured in our PD to guide our theme generation as many of these topics were taken up by teachers when designing their lessons. However, these topics were not taken up equally and they were often combined with adaptation and adjustment for the teachers' specific context, thus, it was important to combine our analysis with an inductive approach to allow observations of other patterns to emerge from the teachers' lessons.

We gathered all the lessons that were available in the community library as of April 2022 in a spreadsheet. For each lesson, we took notes on general information (such as author names, titles, student populations, and if the material is adopted from other materials, etc.), and analyzed its content, writing a description of the ways that social justice ideas were integrated into the science content. This description included but was not limited to the goals of the lesson, the aspects of equity/social justice components of the lesson, the examples of questions that the teachers posed for social justice investigation and culmination projects in their lesson, and the implications that the teachers had for their students through the lesson. It was important to analyze the materials in their entirety because the lessons were varied in their maturity and presentation (i.e., there was no standardized structure we provided the teachers).

A subgroup of the authors generated a list of themes based on the social justice topics teachers integrated into their lessons. The materials were iteratively compared and discussed, and the themes were refined until consensus was reached. Then, we generated descriptions for each theme. The first author applied these theme descriptions to code all materials again to ensure the themes fully covered the different ways in which the teachers integrated social justice into science content in their lessons. Most lessons were captured under one single theme, however, one submission was a multiple-lesson unit with combined approaches that covered two themes. All authors had been working closely with the data or/and with the teachers throughout the PD so they were able to provide face-validity to the results.

III. RESULTS

We found three themes that represent the trends by which teachers integrate social justice into their physics lesson.

Theme 1: Investigating the nature of science in specific science concepts and re-evaluating/redefining science concepts

This theme represents an approach in which teachers support students to address the nature of science by investigating specific physics topics' and concepts' sociopolitical origins and statuses. Four lessons were categorized under this theme. Inspired by the SW discussion on efficiency, one lesson walks students through an investigation of the historical development of "efficiency" and challenges students to address what values are (not) accounted for in the concept of efficiency. Another lesson

supports students to conduct research on different forms of energy resources, focusing on who has access to those resources, who benefit from and who is harmed by the production of energy, and how energy production is rife with power disparities. The other two lessons focus on different forms of energy generation in their local states. In these lessons, students investigate the subjectivity in energy generation and energy decisions: prioritizing the maximized power and efficiency values calculated by physics rather than the environment and human well-being.

Although these lessons address different science topics, they share common features in the ways that social justice topics are integrated. These lessons are designed with the goal for students to conduct research and evaluate how certain scientific concepts are not socio-politically neutral but hold the values and beliefs of scientists and stakeholders who benefited from scientific developments. These lessons often culminate with inviting students to reflect on personal beliefs and values and challenge students to re-think the definition of science concepts considering their elicited values and beliefs. The approach that teachers took under this theme might have been strongly influenced by the SW explicit discussion on specific examples of efficiency from socio-historical perspectives, and the continued conversations on connecting socio-economic disparities with science concepts throughout the PD.

It is important to compare the approach characterized in this theme with another common approach to social justice taken in science education where social justice topics are introduced by having students conduct broad investigations of the nature of science and explore other identities that are hidden and underrepresented in science. Although both approaches center around the nature of science, by integrating social justice with specific science content the approach under theme 1 creates opportunities for students to challenge and redefine specific scientific concepts in line with students' own perspectives and experiences. This opportunity is not as readily available with the more common, but broad approach. Although both types of social justice integration are valuable, theme 1 makes visible a particular orientation to integrating social justice that is argued to be necessary to empower students and disrupt the status quo [1, 3]. Physics education resources support both approaches see [22, 23] for examples, but fewer examples can be found from science education that align with the approach presented theme 1, see [24] for example. Our PD intentionally support teachers in taking up theme 1.

Theme 2: Connecting students' everyday activities with science and global social justice issues

This theme represents an approach where social justice is integrated with science by making connections between students' daily activities, science curriculum, and global inequities. Six lessons were categorized under this theme centering daily activities such as physical activities, e.g., jogging, the use of cellphones, food consumption, cooking, recycling, and daily transportation to school.

These lessons often start with a focus on connecting physics/science with students' everyday life through an everyday activity and then connecting the activity to global inequities. For example, one lesson on electricity generation takes place in the context of cell phone operation and expands to include student research on cell phone production and consumption. The lesson leads students to look further into the relationship between cell phone production and consumption and global inequities such as disparities between developing and developed countries where resources (including human and material) and chemical waste for cell phones are derived from and returned to. Similarly, another lesson was grounded on the calculation of the energy needed for a physical activity that a student may engage in. From there, the lesson guides students to investigate how much food would be needed for the activity's required energy, and then goes on to connect food production to global greenhouse gas emission. Another example of theme 2 comes from a lesson that contextualizes the solar radiation topic in solar cooking and opens a space for students to discover different ways that people across the globe use solar radiation.

These lessons focus on raising awareness and connecting science content to the global world, which is essential to adolescent development by supporting students in seeing their place in the world [25]. To make this connection, these lessons often include comparisons of individual experiences from across the globe, comparisons of the impacts on humans and nature between different regions or between developing and developed countries. Through specific science content, social justice is integrated in ways that help increase students' awareness of their connectedness to the global community and encourage them to brainstorm ways they can help change the global status quo. Most of these lessons were developed over the second week of the 2021 SW, and the approach characterized by this theme was less directly connected to content topics featured in the first half of the SW compared to the other two themes. Teachers showcased their own resources and expertise when enacting this approach—it is a common approach for the teachers to extend the context of science topics to students' daily activities and global societal issues. However, topics featured in the PD that might have been impactful to the development of these lessons include climate justice and discussions about land use, with the application to a global context, and discussions on ambitious science teaching [26]; inparticular the goal to make science learning relevant to students' experiences.

Theme 3: Using science knowledge to engage with and advocate for social justice issues in students' local communities

This theme represents an approach in which teachers integrate science learning with an investigation of inequities in students' local communities. Seven lessons were categorized under this theme. These lessons shared the common feature of being centered around local community; for example, contextualizing learning in a local social justice issue, engaging students with their local communities, and supporting students to use science knowledge to take part in advocating for local social justice movements [27, 28].

For example, one of the lessons under this theme was designed for learning kinematics by having students log their journeys to school and create motion graphs for different modes of transportation. With the gathered data, students are then invited to discuss issues around resources and access for transportation in their local community and encouraged to find opportunities for local advocacy around transportation. Another example of this theme is from an energy unit where students are supported to engage with their communities in various ways including visiting a local power plant and discussing with local experts the impacts of the power plant on the local environment. By introducing the physics concept of energy and models, such as energy tracking diagram [29] and energy theater [30], the lesson supports students in telling their own energy story of how they see energy transfer across a considered system. The culminating project of the unit supports students to conduct research on energy-related issues in their community and advocate for specific issues with local stakeholders.

Theme 3 is strongly aligned with a place-based education approach [27], which was one of the topics featured throughout the PD programs. Discussions in the PD such as discussions on land and models of energy tracking may have been impactful to the development of this approach. The existence of this theme is an important transformation of teaching for social justice in science. As Philip [1] emphasizes, it is critical to shift to a framing in which our discourse is grounded on communities and social movements, where science knowledge can be in service to those movements, rather than simply hoping learning science can contribute to equity and justice.

DISCUSSION

We agree with previous work [1-3] that although all ways of science and social justice integration are important, they are not equal in their impact on social justice transformation in education. Impactful science teaching for social justice needs transformative work that not only supports students to investigate social justice issues that permeate the field of sciences but supports them to transform knowledge and use science knowledge to take actions toward social change. While there are many approaches that educators can take to integrate social justice into science content, our study cares about specific approaches that the teachers take up from their PD experiences. Finding these themes helps us to locate the material elements of the PD that were impactful to the teachers' lesson development. At the same time, the existence of the themes showcased in this paper exemplifies teachers' agency and creativity when integrating social justice into various science content topics. For example, the PD facilitators presented energy-related scenarios that were specific to their own contexts, which were then adapted by teachers through re-contextualizing these ideas to their own local social justice movements and embedding lessons in their existing curricular structures and resources. Additionally, while most of the themes were found to be directly connected to the PD's topics, the approach described by theme 2 seems to directly emerge from teachers' own understanding of their students' needs for development. Across the three presented themes, teachers' lessons collectively push against the boundary of what is counted as science and what should be included in science lessons beyond physics canonical concepts. Importantly, these approaches broaden the definition to bring social justice issues such as the use of lands, pollution, impacts on environment and people, global climate into science classrooms.

ACKNOWLEDGMENTS

We are greatly indebted to the teacher participants, Sarah B. McKagan and Adrian M. Madsen – our Energy and Equity Portal development, and Tali Hairston, Selamawit Bariamichael, Clausell Mathis, and the rest of the Energy and Equity PD program organizers and facilitators. This material is based upon work supported by National Science Foundation Grant No. 1936601.

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