Original Article

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Place-Based Education in High School Science: Situating Energy and Climate Change in Students' Communities

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Abstract

The field of physics education has struggled to create culturally based, responsive, and relevant curriculum to engage students of color. This may be partly due to the perception that physics is apolitical and acultural, despite many concepts, such as energy and climate change, being socio-politically situated in our current society. To the extent that physics maintains an acultural and apolitical stance, physics education cannot be place based because the notion of place is politically and culturally situated to students' environments. To bridge this gap, the authors of this article worked with physics teachers in a yearlong professional learning community (PLC) to incorporate place-based education into their science curriculum. Place-based education teaches students to take care of their environments by situating potential actions they can take to support their local communities in addressing climate change impacts. The two case studies described herein demonstrate how physics teachers situate the concepts of energy and climate change in students' local environments. Physics teacher Molly German situated water resources to the students' farming community and the impacts climate change and energy have on their water resources. Physics teacher Rey Horowitz localized energy and climate change impacts to power plants that are visible in many neighborhoods in the city, and which operate on fossil fuels. These case studies demonstrate that physics education can indeed become culturally based, responsive, and relevant through the integration of place-based education.

Keywords: climate change; energy; place-based education; physics education

Introduction

Place-based education is deeply rooted in Indigenous epistemologies and teachings as it is an important cultural principle that Indigenous people hold to their environments or places (Semken et al., 2017; Thornton et al., 2021). This worldview allows Indigenous people to localize their knowledge systems to their environments while maintaining and sustaining the knowledge they have acquired since time immemorial. Indigenous people are able to sustain and maintain such knowledge because of passed down intergenerational teachings. The ability to localize their knowledge has allowed them to successfully steward their environments over a long period. This traditional process demonstrates the importance of place-based education and learning, especially as our environments continue to face drastic impacts due to climate change. Climate change continues at a rapid rate, thus making it harder to reduce emissions and impacts. Therefore, place-based education is now more important than ever to incorporate in all scientific courses.

Recently, place-based education has been introduced into academic settings and has been shown to be useful for all students (including non-Indigenous students) because it teaches how to approach real-world

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problem solving (Glasson et al, 2006; Semken et al, 2017; Smith, 2002; Thornton et al., 2021), especially when it pertains to climate change in students' own communities. Place-based education has also demonstrated that when the complexities and impacts of climate change are contextualized to students' environments, students become more engaged with these concepts (Schweizer et al., 2013) and show a greater willingness to connect them to their local communities (Hu & Chen, 2016). Place-based education also helps teachers address their students' climate literacy, which is generally limited (Hallar et al., 2011). Thus, the authors contend that place-based education should be utilized more by physics teachers. Physics is one of the main scientific disciplines that founded climate science (Rincon, 2021; Schweizer et al., 2013) and can therefore help to explain the concepts and how they were derived. Through place-based education, physics can include climate change as part of the core curriculum, especially by localizing climate change within the concept of energy. In this way, place-based education could be more easily utilized by physics teachers.

Physics Education, Climate Change, and Students of Color

As a discipline, physics tends to be seen as a "culture of no culture" (Cochran et al., 2021; Traweek, 1992)—as if the field were racially and ethnically neutral and epitomized only by universal and delocalized values. As a result, race is rarely discussed in physics and thus, topics that connect to race in any capacity are also removed from physics education (White, 2016). The majority of practicing physicists and physics teachers are White and male. People who identify as White often don't experience themselves as having a culture (Banks, 1994; Prescod-Weinstein, 2020), and classrooms led by White teachers are seen as being culturally neutral (Bowers & Flinders, 1990; Daane, et al., 2017). Physics concepts are often presented as value-free statements of objective truth about nature, independent of place (Baylor, et al., 2021; Harding, 2016; Traweek, 1992) . Energy, for example, seems like one of the most abstract concepts in science: It is something that we cannot perceive directly, it appears in every scientific discipline, it is the subject of one of the most profound laws of science (the law of conservation of energy), and it is one of the most powerful ways to predict the behavior of objects.

The concept of energy, like all science concepts, was developed at a specific historical time and place, for the advancement of specific human causes (Harding, 1998, 2015, 2016; Traweek, 1992). Contemporary energy concepts were shaped primarily in the middle of the 19th century, during the time of the Industrial Revolution, when Great Britain was establishing coal-powered factories to process goods brought from its global trading empire on steamships (Smith, 1998; Turnbull, 2021; Wrigley, 1990). Thus, physics instruction about energy emphasizes the concepts of work, heat, power, and efficiency—concepts that were constructed to characterize and improve the engines in those factories and steamships (Kittel & Kroemer 1980).

These concepts carry not only the economic values that were prevalent in Britain in the 1800s, but also the moral values (Kittel & Kroemer 1980; Smith, 1998; Wrigley, 1990). Efficiency, for example, was significantly a theological concept, referring to the ideal of maximizing the human use (e.g., processing and manufacture) of divinely provided natural resources (Smith, 1998). This belief surrounding efficiency is why many Indigenous communities of the Americas were deemed to be wasting their natural resources: They were not harvesting or cultivating their natural resources for maximum human use. Due to recent climate change events and temperature rises, however, we cannot continue to perceive the concept of energy within physics without conceptualizing it to place. Energy plays a major role in our society's high dependence on extractive energy sources: fossil fuels, oil, and so on (Nikas et al. 2021; Odum. 2007).

For those who consider physics to be culturally neutral, the overall low participation by people of color can seem perplexing. Recognizing the importance of place in science education can shed light on this disparity. Physics as it is most often taught in schools has little connection to real-world problem solving (Oktrisma, 2021; Williams, 2018). Most students are required to solve well-defined problems rather than the more loosely-circumscribed problems that better model the real world (Dobson, 2000; Williams, 2018). Additionally, White teachers and instructors may have a hard time relating to students of color or making their lesson plans culturally relevant and responsive. This is one of the factors that contributes to a lower rate of enrollment in high school physics classes among students of color, primarily Black, Indigenous, and Latinx, compared to White or Asian students (White & Tesfaye, 2011). Place-based education uses the local environment, heritage, and experiences of the students to help them form their

SCC-2021-0058-ver9-Hernandez_3P.3d 02/08/22 4:33pm Page 2

understanding and knowledge. This approach to education has been successful in attracting underrepresented students to STEM since it creates a culturally inclusive environment that is important for their success (Johnson et al., 2020).

Given that high school physics continues to be taught mostly by White males (Rushton et al., 2017), students of color have a harder time feeling connected to the teacher and subject matter included in physics courses. This ultimately transfers to higher education where students of color, especially Black, Indigenous, and Latinx students, continue to be underrepresented in physics at the college and post-college level (Good et al., 2020).

Research has also demonstrated that students of color do not have a sense of belonging in physics (Dortch & Patel, 2017; Rainey et al., 2018). Representation in the curriculum can sometimes help address the lack of a sense of belonging among students of color, especially if they do not have representation among their teachers, educators, and faculty (Schwartz, 2012). This lack of representation coupled with a lack of sense of belonging hinders students' ability to make informed, sustainable decisions about their individual contributions to climate change (Hallar et al., 2011). Given that climate change impacts communities of color the most, students of color need to be positioned and empowered to make sustainable decisions that can help them construct action-driven solutions within their communities. Being able to implicate ourselves in the climate change problem and recognize our own obligations in mitigation has been demonstrated to be crucial among students of color (Stapleton, 2019).

Communities of color continue to be drastically affected by climate change impacts (Shepard & Corbin-Mark, 2009; Spencer et al., 2020; Sultana, 2021). For example, these communities are more likely to be located near a pollution site that leaves them exposed to disproportionally more environmental hazards (Wilson et al., 2010). As a result, communities of color have been at the frontlines of the climate justice movement, which aims to achieve equitable distribution of climate change impacts by highlighting how the disproportion falls more heavily on communities of color, especially Black, Indigenous, and Latinx communities (Colon, 2016; Levenda et al., 2021; Sanders, 2020; Schlosberg & Collins, 2014). The climate justice movement highlights the disparities that communities of color face, from health to economic issues (Chalupka et al., 2020; Colon, 2016; Gutierrez & LePrevost, 2016).

Given the significance of climate change impacts on communities of color, connecting climate change to physics education allows teachers to contextualize physics scenarios within these students' communities, which is especially important for Black, Indigenous, and Latinx students. By connecting physics education to climate change through place-based education, physics education can address the need for representation and a sense of belonging among students of color. Place-based education has been found to address the disconnect between school subjects and students' lives (Khadka et al., 2021; Smith, 2002). Thus, this methodology should be instrumental in addressing a sense of belonging and representation for students of color, especially in physics classes.

The Role of Physics in Climate Change

Science teachers, including physics teachers, tend to teach about climate change outside of the standard curriculum (Demant-Poort & Berger., 2021; Wise, 2010) despite research demonstrating that physics teachers have a more in-depth knowledge about climate change than other science teachers (Egri et al., 2021; Milér̆ et al., 2012). Many physics concepts and theories can help explain climate change and global warming. For example, combining dynamical systems theory and nonequilibrium statistical physics has helped advance predictions in climate change models (Ghil & Lucarini, 2020). Schmidt (2007) has also explained how physics plays a key role in climate change and models through three different categories, including fundamental principles such as the conservation of energy, equations such as the transfer of radiation, and empirical physics such as the function of wind speed and humidity. However, because physics does not localize itself with place-based scenarios, but rather continues to immerse itself in theory, equations, and abstract concepts such as energy, physics teachers continue to separate physics from formal climate change lessons (Wise, 2010).

There has been a call to transform physics education to make it more relevant to student populations, especially those whose communities are facing drastic changes to their environments because of climate change (Brown 2021; Wieman & Perkins, 2005). To bridge the perceptual gap between physics and climate change, place-based education must be incorporated into physics education. Such change will transform physics education from its traditional instruction methods to

SCC-2021-0058-ver9-Hernandez_3P.3d 02/08/22 4:33pm Page 3

pedagogical approaches that are more culturally relevant, culturally based, and culturally responsive. Physics education as an apolitical subject enables, for example, energy to continue to be defined as an abstract concept instead of a sociopolitically situated construct that plays a role in climate change. Given that energy is one of the core components in the physics discipline, energy justice can be approached as an intersection between energy, equity, and climate change that derives from the concept of energy; thus energy also stands as a cultural category within physics that is ultimately connected to energy consumption as a commodity (Forinash 2010; Hernandez et al., 2021; Hornborg, 2020).

Recently, the sociology of energy has been further explored, linking natural laws such as the law of thermodynamics to societal impacts (Holleman, 2012). This linkage demonstrates that energy does indeed play a role in climate change, despite the abstract nature of the concept that the discipline continues to perpetuate. Equity plays an important role in the concept of energy since energy distribution and consumption cause communities of color to experience greater climate change impacts than their counterparts in White communities (Axon & Morrissey, 2020). Energy, then, becomes a concept that can be easily applicable to place-based education in which teachers contextualize energy and climate justice in their local communities, especially if they are serving students of color from low socioeconomic backgrounds. Therefore, the authors prioritized place-based education in their yearlong professional learning community (PLC) that focused on energy and equity.

Methodologies

As part of a larger project to integrate equity education into physics teaching and learning, the authors supported the formation of a yearlong professional learning community (PLC) in which six high school physics teachers worked together to support each other's physics lesson development. The PLC focus was on the foundational concept of energy in the physics curriculum and equity, which plays an integral role in a web of sociocultural realities and inequities (Hernandez et al., 2021). Teachers were not provided with model curricula or specific pathways by which to develop lessons; instead, teachers developed instructional activities specific to their local context, and the PLC gave feedback, support, and consultations on the activities both before and after implementation. This focus gave support to the teachers through a robust model of energy centered on climate change impacts, which ultimately translated into creating and implementing place-based education within the physics curriculum. In this PLC, teachers were supported in creating and implementing an activity or project that would bring into their classrooms issues around energy, equity, or the intersection of energy and equity. Part of the process included a group presentation on the curriculum, feedback from other colleagues, and individual consultations. Ultimately, two of the teachers who implemented and integrated place-based education became the subjects of these two case studies. Although their communities were culturally very different, both teachers were able to contextualize the concept of energy and relate it to the specific impacts of climate change that their students' communities face. Due to the nature of the PLC focus on the role of the teachers and the curriculum, assessment of student conceptual understanding is not analyzed or described in this article.

Case Study #1: Water Justice in Northern California

Molly German (she, her) teaches in a high school located in a rural agricultural area in the Sacramento Valley of northern California where the primary crops are walnuts, rice, and peaches. Nearly every student has family members or friends who own or manage a farm or work to harvest the crops. An irrigation canal runs immediately behind the school campus, which is on the edge of town. Many students live outside the city limits and get their home water from wells. Some students had the experience of drinking only bottled water during a specific past event when city water was contaminated with pesticides. Thus, students and families in the community have many lived experiences that intersect with water and society's dependence on energy.

The curriculum for the place-based educational unit was built around the properties of water and the relationship of water to the concept of energy. German's prior teaching included many abstract key concepts about water, e.g., cohesion, polarity, solubility, ionic bonds, covalent bonds, and macroscopic properties. Although many of the learning goals for the PLC educational unit were more oriented toward chemistry than physics, with support from her colleagues in the PLC, German made connections to physics and energy with reference to the nearby Oroville Dam, which is a source of hydroelectric power in the area. Dams have been used as conceptual models to

SCC-2021-0058-ver9-Hernandez_3P.3d 02/08/22 4:33pm Page 4

explain fluids, forces, flood control, water storage, and water quality (Maungchang & Dam-O 2021) in physics education. To connect these concepts with climate change, German used environmental issues related to the Oroville Dam, which had flooded in 2017, forcing many community members to be evacuated (Koskinas et al., 2019).

German hoped that student engagement would increase if they saw connections to their own lives, families, and cultures. To shape students' sense of belonging to both the classroom and communities, she wanted to incorporate a fun activity that would involve a hands-on component. She began with a water filtration challenge. On the first day, students were tasked to make dirty water by using dirt and leaves from the outdoors. They also incorporated household products such as cooking oil, food coloring, coffee grounds, garlic powder, and students' leftover drinks. Student discussion included access to clean drinking water and the consequences of not having it, as they had experienced themselves during a local pesticide contamination event.

For the next two days of the activity, students worked in groups to figure out how to remove contaminants from the water. Most groups used some combination of sand, gravel, coffee filters, or paper towels to try to clean the water. Some students were familiar with filters since they regularly use them at home or while camping. Thus, for many of them water filters became an effective access point to bridge the gap between energy, water, and climate change. Some groups pursued a strategy beyond just utilizing the water filter—boiling the water. This led to discussions about which parts of the contaminated water would evaporate and which would remain liquid, and how to engineer an apparatus that would collect and condense the evaporated water.

To assist in demonstrating the concepts, German also presented the documentary *Thirsty for Justice* (Ramsden & Slattery, 2013), which highlights various water concerns in different communities in California. Watching this documentary allowed her students to start contextualizing the film's topics to their own communities. The goal was to prompt students to think about local water issues in their community and how climate change impacts their water resources. German also required her students to interview a community member about water. Several students interviewed family members who were concerned about the water quality of their well and tap water. One student interviewed his grandmother about her experience with polluted water in their hometown of Zacapala in Puebla, Mexico. From his interview, he learned how people in the town worked together to draw attention to the problem and ultimately succeeded in getting a new well built. He reported realizing that "many people who have water issues are able to create change. They are able to unify and try to influence their region."

After watching *Thirsty for Justice* and conducting informal interviews, students were assigned to research a local water topic of their choice. Some students fish frequently and opted to investigate mercury contamination of fish from past gold mining operations in the nearby foothills. Others investigated Indigenous tribal water rights and the effects of nearby hydroelectric dams on ecosystems, especially as they relate to the health of salmon. As students discovered, community wells are drying up due to climate change, and salmon populations are dying at extreme rates in the community's water canals and reservoirs (Jasechko & Perrone, 2020). Many students chose to test the water quality of a local water source, such as the irrigation canal behind the campus (their school is surrounded by walnut orchards and rice fields). German provided test strips designed for drinking water that included 15 different tests such as nitrates, pH, water hardness, and so on. The results prompted questions about what levels of these various factors were safe and what levels were dangerous. The locally relevant implications of climate change sparked students' sense of belonging and desire to take action. They were able to connect what they were learning in their classroom to events or climate change impacts that their communities were experiencing. Student research projects culminated in presentations including slide shows, posters, and videos.

Students' research projects sparked strong conversations about climate justice as they started questioning who had access to clean water. They also connected these dialogues to their local hydroelectric dam systems and the impacts they have on their water resources, such as the flooding they had experienced from the Oroville Dam. They started questioning the role of energy usage within the large agricultural systems that surround their community and how these contribute to climate change and ultimately impact their communities more than others. German was excited to see such heightened involvement from her students. She recalls, "I love how engaged my students were in learning about energy in their local context. Students were

SCC-2021-0058-ver9-Hernandez_3P.3d 02/08/22 4:33pm Page 5

curious to find out more and started having important conversations about the relationship between physics and climate change."

In this case study, students were able to contextualize abstract concepts such as energy, water cohesion, and so forth, and apply them to their communities' experiences. They began to notice and then connect these concepts to climate change impacts within their own communities, demonstrating how place-based education can indeed benefit students' learning in physics education. In addition, German feels that the students' sense of belonging increased because they were able to see themselves and their communities reflected and represented in their physics curriculum.

Case Study #2: Energy Justice in New York City

Rey Horowitz (they, them) teaches neurodiverse students of color in a school located in New York City. For this place-based curriculum, Horowitz developed a semester-long study of energy topics. The lessons began with basic definitions of energy and its forms, moved through comparing sources of energy generation, and supported students in analyzing personal and home electricity use. The culmination of the semester was planned to engage students in understanding local energy justice campaigns taking place in their community in New York City, especially those that focused on renewable energy (Rabaia et al., 2021).

Energy justice campaigns are prominent in New York City given the city's massive population and energy consumption. However, students often do not understand the science related to energy and the effects of its uneven distribution. This is what inspired Horowitz to incorporate current and place-based events into the energy unit. After initiating a classroom discussion of the values that drive choices of electricity generation and consumption, students were asked to list their priorities if they were to have the power to select electricity sources for their family, their neighborhood, and their country. During this exercise, Horowitz noticed that students often used words like *clean* and *efficient*, as well as phrases such as "takes less space" and "available in natural disasters." The most common phrases students utilized during this part of their unit were "no pollution" and "renewable energy." However, Horowitz noticed that human-centered values were missing from the students' priorities list, so Horowitz developed a goal to help students think critically about the impact of energy use on people. Horowitz wanted to extend students' thinking to analyze how nature, as well as communities of color and low-socioeconomic communities, is exploited for energy resources.

Through collaboration with colleagues in the PLC, Horowitz connected the curriculum to the peaker plants in the local community. Peaker plants are electricity-generating substations designed to run only at times of peak electricity demand. Located in and around residential areas in the city, they are used more frequently than originally planned because of higher-than-anticipated energy demands; they use highly polluting fossil fuels (such as oil or kerosene) and are expensive to maintain. Because peaker plants are often situated in low-income communities that are predominantly communities of color, it is these populations that are the most affected by the health impacts from the air pollution these power plants generate. Thus, many local organizations such as the New York Lawyers for the Public Interest, New York City Environmental Justice Alliance, and UPROSE (originally United Puerto Ricans' Organization of Sunset Park) are campaigning to replace these plants by 2030. This is where the energy justice campaigns came into play in Horowitz's lesson plans.

Students could recognize smokestacks of peaker plants from car trips they had previously taken with their families through the five boroughs of New York City. One student reported that one of their sports events had been held at a field adjacent to a peaker plant. Another student discovered that peaker plants were the target of environmental campaigns nationally, thus connecting local energy campaigns to national energy campaigns. Another student created a sardonic news article with the headline, "Corrupt Capitalism Inc. Presents a New Product: Peaker Plants!" Writing from the perspective of "corrupt capitalism," this student ironically touted the benefits of these polluting plants with adjacent commentary from a skeptical editor. By employing this creative tactic, this student was able to express outrage and demonstrate the environmental, financial, and human health impacts of these peaker plants and the absurdity of their disproportional impacts on communities of color and low-socioeconomic communities. The student's article read:

> Peaker Plants are the newest innovation produced by our company's partner, Outdated Tech! They are built to start up at times when energy demand is high and are typically situated along rivers or near low-income

neighborhoods, in order to improve the quality of life of the people who live there! *(Note from editor: This information is blatantly false…).*"

As a mayoral race unfolded in New York City, candidates' positions on energy consumption and pollution were frequently outlined in the students' local media. One report included positions on peaker plants, with the most progressive candidate supporting the closure and replacement of peaker plants by 2030. This example helped students recognize the importance of the topic they had been studying in their energy unit. One student commented that the 2030 target seemed too far away, which opened a discussion about how positive change that reduces environmental impacts and climate change is addressed both politically and socially.

Horowitz helped the students recognize the parts they play in the energy justice discourse by contextualizing this energy unit to students' individual and community experiences. Horowitz's place-based unit made topics more relevant and more engaging, gave an example of how change can occur locally, and showed students what role individuals can play in effecting change.

Students made it clear to Horowitz that they had a lot of anxiety about the climate crisis and continue to worry about their future. Students expressed fear that their future has already been determined by past and current politicians because politicians ultimately decide which policies to enact, ratify, and support. Focusing on the local and place-based issue of peaker plants helped students visualize realistic steps they can take to combat the climate crisis. It also made the climate change discourse less existential and more practical and concrete, helping to address students' concerns about their future. Horowitz saw firsthand the increased impact of connecting energy and energy justice to students' local context in New York City.

Lessons Learned from Place-Based Education in Physics Curriculum

From these two case studies, the authors learned that place-based education can support students of color by increasing their sense of belonging through the physics curriculum. The students were able to contextualize the concept of energy and climate change to their local communities. Often, students of color do not see themselves or their communities reflected in physics education. Through this adjustment to the course, however, they were given the opportunity to apply what they learned in class to real-life examples and situations impacting their communities, and they saw themselves reflected and represented.

Both teachers described in the case studies also observed an increase in student engagement and eagerness to participate in the projects. Their students were also able to use their creativity when it came to problem solving. In German's case, students learned about climate change and the impact of a nearby dam on their community's water resources. In Horowitz's case, students explored the climate change and pollution impacts peaker plants have on policy and local communities.

Place-based education helped the teachers address their students' climate literacy (Hallar et al., 2011). Students also came to realize that living near a pollution site exposes them and their communities to social and environmental hazards such as water contamination, the decline of salmon populations, and air pollution (Wilson et al., 2010). By critically analyzing and reflecting on society's large dependence on energy sources, such as hydroelectric power and fossil fuels, students also started questioning societal structures that contribute to climate change and its disproportionate impacts on communities of color. In Horowitz's case, students also started critically questioning the role of politics and politicians in the climate change discourse in relation to peaker plants.

Conclusion

Place-based education in physics at the high school level continues to be limited in the United States. However, teachers can light a path forward through innovative approaches as were highlighted in the case studies described in this article. By doing so, teachers can also transform physics education to make it more relevant to student populations, especially those whose communities are facing disproportionate climate change impacts (Wieman & Perkins, 2005). Place-based learning could also transform physics education from its traditional instruction methodology to pedagogical approaches that allow students to become agents of change in the climate change discourse. In these two case studies students were able to contextualize why their communities have been drastically affected by climate change impacts (Shepard & Corbin-Mark, 2009; Spencer et al., 2020; Versey, 2021). The communities involved are both located near an energy reservoir—either a hydroelectric dam or a peaker power plant—that exposes them to social and environmental hazards (Wilson et al., 2010).

SCC-2021-0058-ver9-Hernandez_3P.3d 02/08/22 4:33pm Page 7

Helping students to connect scientific concepts to real-life situations fosters growth, responsiveness, and engagement. Ultimately, place-based education helps teachers conceptualize to their students how climate change relates to energy and helps students recognize and understand the sociopolitical implications both concepts hold within the climate justice discourse. These case studies demonstrate how teachers can push physics from its acultural and apolitical stance into politically and culturally situating core concepts in local environments.

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References

Axon, S., & Morrissey, J. (2020). Just energy transitions? Social inequities, vulnerabilities and unintended consequences. *Buildings and Cities, 1*(1), 393-411.

Banks, J.A. (1994). *An introduction to multicultural education*. Allyn & Bacon.

Baylor, M. E., Hoehn, J. R., & Finkelstein, N. (2021). *Infusing equity, diversity, and inclusion throughout our physics curriculum: (Re) defining what it means to be a physicist*. Cornell University. Xiv preprint arXiv:2108.11435

Bowers, C. A., & Flinders, D. J. (1990). *Responsive teaching: An ecological approach to classroom patterns of language, culture, and thought*. Teachers College Press.

Brown, B. A. (2021). *Science in the city: Culturally relevant STEM education*. Harvard Education Press.

Chalupka, S., Anderko, L., & Pennea, E. (2020). Climate change, climate justice, and children's mental health: A generation at risk? *Environmental Justice, 13*(1), 10-14.

Cochran, G. L., Hyater-Adams, S., Alvarado, C., Prescod-Weinstein, C., & Daane, A. R. (2021). Social justice and physics education. In C. C. Ozaki & L. Parson (Eds.), *Teaching and learning for social justice and equity in higher education,* (pp. 125-147). Palgrave Macmillan.

Colon, J. (2016). The disproportionate impacts of climate change on communities of color in Washington state. *Front and Centered.*

Daane, A. R., Decker, S. R., & Sawtelle, V. (2017). Teaching about racial equity in introductory physics courses. *The Physics Teacher*, *55*(6), 328-333.

Demant-Poort, L., & Berger, P. (2021). "It is not something that has been discussed": Climate change in teacher education in Greenland and Canada. *Journal of Geoscience Education, 69*(2), 207-219.

Dobson, K. (2000). Is physics debatable? *Physics Education, 35*(1), 1.

Dortch, D., & Patel, C. (2017). Black undergraduate women and their sense of belonging in STEM at predominantly white institutions. *NASPA Journal about Women in Higher Education*, *10*(2), 202-215.

Egri, S., Horányi, G., & Ádám, P. (2021, May). The future of physics teaching: Features of the new Hungarian National Core Curriculum and curriculum frameworks. *Journal of Physics: Conference Series* (Vol. 1929, No. 1, p. 012066).

Forinash, K. (2010). *Foundations of environmental physics: Understanding energy use and human impacts.* Island Press.

Ghil, M., & Lucarini, V. (2020). The physics of climate variability and climate change. *Reviews of Modern Physics, 92*(3), 035002.

Glasson, G. E., Frykholm, J. A., Mhango, N. A., & Phiri, A. D. (2006). Understanding the earth systems of Malawi: Ecological sustainability, culture, and place-based education. *Science Education, 90*(4), 660-680.

Good, J. J., Bourne, K. A., & Drake, R. G. (2020). The impact of classroom diversity philosophies on the STEM performance of undergraduate students of color. *Journal of Experimental Social Psychology, 91*, 104026.

Gutierrez, K. S., & LePrevost, C. E. (2016). Climate justice in rural southeastern United States: A review of climate change impacts and effects on human health. *International Journal of Environmental Research and Public Health, 13*(2), 189.

Hallar, A. G., McCubbin, I. B., & Wright, J. M. (2011). CHANGE: A place-based curriculum for understanding climate change at Storm Peak Laboratory, Colorado. *Bulletin of the American Meteorological Society, 92*(7), 909-918.

Harding, S. G. (1998). *Is science multicultural? Postcolonialisms, feminisms, and epistemologies*. Indiana University Press.

Harding, S. (2015). *Objectivity and diversity*. University of Chicago Press.

Harding, S. (2016). Why "physics" is a bad model for physics. In *Whose science? Whose knowledge?* (pp. 77-102). Cornell University Press.

Hernandez, J., Scherr, R., & Robertson, A. D. (2021, July 20). Redefining energy justice in physics classrooms. *Environmental Justice*, ahead of print. https://doi.org/10.1089/env.2021.0042

Holleman, H. A. (2012). *Energy justice and foundations for a sustainable sociology of energy*. University of Oregon.

Hornborg, A. (2020). Energy, space, and movement: Toward a framework for theorizing energy justice. GeografiskaAnnaler: Series B. *Human Geography, 102*(1), 8-20.

Hu, S., & Chen, J. (2016). Place-based inter-generational communication on local climate improves adolescents' perceptions and willingness to mitigate climate change. *Climatic Change, 138*(3), 425-438.

Jasechko, S., & Perrone, D. (2020). California's Central Valley groundwater wells run dry during recent drought. *Earth's Future, 8*(4), e2019EF001339.

Johnson, M. D., Sprowles, A. E., Goldenberg, K. R., Margell, S. T., & Castellino, L. (2020). Effect of a place-based learning community on belonging, persistence, and equity gaps for first-year STEM students. *Innovative Higher Education, 45*(6), 509-531.

Khadka, A., Li, C. J., Stanis, S. W., & Morgan, M. (2021). Unpacking the power of place-based education in climate change communication. *Applied Environmental Education & Communication*, *20*(1), 77-91.

Kittel, C., & Kroemer, H. (1980). Thermal Physics (2nd ed.). W. H. Freeman.

Koskinas, A., Tegos, A., Tsira, P., Dimitriadis, P., Iliopoulou, T., et al. (2019). Insights into the Oroville Dam 2017 spillway incident. *Geosciences, 9*(1), 37.

Levenda, A. M., Behrsin, I., & Disano, F. (2021). Renewable energy for whom? A global systematic review of the environmental justice implications of renewable energy technologies. *Energy Research & Social Science*, *71*, 101837.

Maungchang, R., & Dam-O, P. (2021). Physics meets mathematics: A dam model. *Physics Education*, *56* (5), 055009.

Miléř, T., Hollan, J., Válek, J., & Sládek, P. (2012). Teachers' understanding of climate change. *Procedia-Social and Behavioral Sciences, 69*, 1437-1442.

Nikas, A., Gambhir, A., Trutnevyte, E., Koasidis, K., Lund, H., et al. (2021). Perspective of comprehensive and comprehensible multi-model energy and climate science in Europe. *Energy*, *215*, 119153.

Odum, H. T. (2007). *Environment, power, and society for the twenty-first century: The hierarchy of energy*. Columbia University Press.

Oktrisma, Y. (2021, April). Analysis of contextual-based physics textbook development on static fluid materials for 21st century skills learning. *Journal of Physics: Conference Series* (Vol. 1876, No. 1, p. 012046).

Prescod-Weinstein, C. (2020). Making Black women scientists under white empiricism: The racialization of epistemology in physics. *Signs: Journal of Women in Culture and Society, 45*(2), 421-447.

Rabaia, M. K. H., Abdelkareem, M. A., Sayed, E. T., Elsaid, K., Chae, K. J., et al. (2021). Environmental impacts of solar energy systems: A review. *Science of the Total Environment, 754*, 141989.

Rainey, K., Dancy, M., Mickelson, R., Stearns, E., & Moller, S. (2018). Race and gender differences in how sense of belonging influences decisions to major in STEM. *International Journal of STEM Education, 5*(1), 10.

Ramsden, L., & Slattery, I. (Directors). (2013). *Thirsty for justice: The struggle for the human right to water*. [Film]. The Unitarian Universalist Justice Ministry of California. ejcw.org/thirsty/

Rincon, P. (2021). Nobel in *physics: Climate science breakthroughs earn prize*. BBC News. https://www.bbc.com/news/science-environment-58790160

Rushton, G. T., Rosengrant, D., Dewar, A., Shah, L., Ray, H. E., et al. (2017). Towards a high quality high school workforce: A longitudinal, demographic analysis of US public school physics teachers. *Physical Review Physics Education Research, 13*(2), 020122.

Sanders, M. C. (2020). Equity in addressing climate change: Using law and policy to serve frontline communities. *Traumatology* 27(1) 48-51.

Schlosberg, D., & Collins, L. B. (2014). From environmental to climate justice: Climate change and the discourse of environmental justice. Wiley Interdisciplinary Reviews. *Climate Change, 5*(3), 359-374.

Schmidt, G. A. (2007). The physics of climate modeling. *Physics Today*, *60* (1), 72-73.

Schwartz, J. (2012). Faculty as undergraduate research mentors for students of color: Taking into account the costs. *Science Education, 96* (3), 527-542.

Schweizer, S., Davis, S., & Thompson, J. L. (2013). Changing the conversation about climate change: A theoretical framework for place-based climate change engagement. *Environmental Communication: A Journal of Nature and Culture*, *7*(1), 42-62.

Semken, S., Ward, E. G., Moosavi, S., & Chinn, P. W. (2017). Place-based education in geoscience: Theory, research, practice, and assessment. *Journal of Geoscience Education, 65* (4), 542-562.

Shepard, P. M., & Corbin-Mark, C. (2009). Climate justice. *Environmental Justice, 2*(4), 163-166.

Smith, C. (1998). *The science of energy: A cultural history of energy physics in Victorian Britain*. University of Chicago Press.

Smith, G. A. (2002). Place-based education: Learning to be where we are. *Phi Delta Kappan, 83*(8), 584-594.

Spencer, M. S., Fentress, T., Touch, A., & Hernandez, J. (2020). Environmental justice, Indigenous knowledge systems, and native Hawaiians and other Pacific Islanders. *Human Biology, 92*(1), 45-57.

Stapleton, S. R. (2019). A case for climate justice education: American youth connecting to intragenerational climate injustice in Bangladesh. *Environmental Education Research, 25*(5), 732-750.

Sultana, F. (2021). Climate change, COVID-19, and the co-production of injustices: A feminist reading of overlapping crises. *Social & Cultural Geography*, *22*(4), 447-460.

Thornton, S., Graham, M., & Burgh, G. (2021). Place-based philosophical education: Reconstructing 'place,' reconstructing ethics. *Childhood and Philosophy, 17*, 1-29.

Traweek, S. (1992). *Beamtimes and lifetimes*. Harvard University Press.

Turnbull, T. (2021). Energy, history, and the humanities: Against a new determinism. *History and Technology*, 37(2), 1-46.

Versey, H. S. (2021). Missing pieces in the discussion on climate change and risk: Intersectionality and compounded vulnerability. *Policy Insights from the Behavioral and Brain Sciences*, *8*(1), 67-75.

White, G. (2016). Race and physics teaching, and the fair: A call to all physics educators for manuscripts on a rarely discussed topic. *The Physics Teacher 54*(70), 1-2.

White, S., & Tesfaye, C. L. (2011). *Under-represented minorities in high school physics: Results from the 2008-09 nationwide survey of high school physics teachers*. Statistical Research Center of the American Institute of Physics.

Wieman, C., & Perkins, K. (2005). Transforming physics education. *Physics Today, 58*(11), 36.

Williams, M. (2018). The missing curriculum in physics problem-solving education. *Science & Education, 27*(3), 299-319.

Wilson, S. M., Richard, R., Joseph, L., & Williams, E. (2010). Climate change, environmental justice, and vulnerability: An exploratory spatial analysis. *Environmental Justice, 3*(1), 13-19.

Wise, S. B. (2010). Climate change in the classroom: Patterns, motivations, and barriers to instruction among Colorado science teachers. *Journal of Geoscience Education*, *58*(5), 297-309.

Wrigley, E. A. (1990). *Continuity, chance and change: The character of the Industrial Revolution in England.* Cambridge University Press.

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