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A Framework for Integrating Energy School Physics Instruction

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Rachel Scherr; Thu Hoàng Huy; Whatai Hai; Katan Gray

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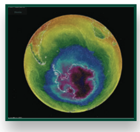
A Framework for Integrating Energy and Equity in High School Physics Instruction



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Rachel Scherr, University of Washington Bothell, Bothell, WA
Trà Huỳnh, Western Washington University, Bellingham, WA
W. Tali Hairston, Equitable Development LLC, Seattle, WA
Kara Gray, Seattle Pacific University, Seattle, WA

National standards in K–12 science education appropriately prioritize equity in science learning.[1,2] However, teachers can struggle to see how equity and justice relate to science content. For many teachers, physics is a particularly difficult area in which to make connections to equity—and the more specific the disciplinary content, the more difficult it is to make these connections.[3–6] As physics teachers stated in an equity-focused professional development course:

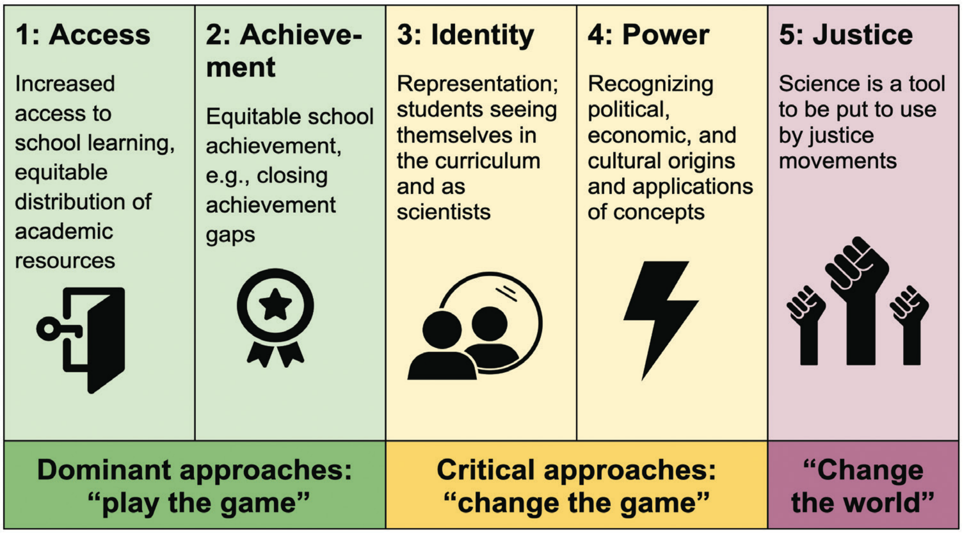

Fig. 1. Pilot framework of approaches to equity in science education.

> *Often I teach content and then social justice separately by bringing up "hidden figures"[7] and talking about women in physics and people of color in physics and LGBTQ people in physics and space travel and that sort of thing. But it's not interwoven into the curriculum: it's "here's these people," and "here's physics."*
> —Rebecca, high school teacher
>
> *How do you actually incorporate this stuff into the curriculum? We talk about gravitational potential energy or whatever it is; how does that incorporate into the equity and justice issues we've been discussing?*
> —Elena, high school teacher

Energy learning is the foundation for informed decision-making about sustainable and just use of energy resources. National documents, including the *Next Generation Science Standards*[2] and the Energy Literacy Framework,[8] press teachers to recognize that energy issues are not only issues of science and technology, but must be integrated with "civics, history, economics, sociology, psychology, and politics" in order to understand and solve modern energy problems such as fossil fuel supply and climate change.[8] Placing the scientific concept of energy in its social and material context presents an ideal opportunity to realize the vision of equitable and culturally responsive science education laid out in the *Framework for K-12 Science Education.*[1] However, as the quotations above illustrate, teachers do not necessarily understand how to make these connections.

The authors of this article are leaders of the Energy and Equity Project, whose purpose is to support high school physics teachers in integrating equity and justice into their energy instruction.[9] In the process, we are developing and implementing an integrated energy and social justice perspective, contributing to the goal of socially significant energy learning and the vision of equitable science education. Energy is an ideal context for this theory building because it is socially significant and a crosscutting concept, central to many disciplines.[1,2] Teachers who have participated in professional development led by this project team transformed their physics and physical science classes to make them more inclusive and culturally relevant.[10–18] In what follows, we offer a pilot framework for how teachers may integrate science concepts with equity education.

Approaches to equity in science education

Our effort is to align scholarship on equity in science education with teachers' actions to integrate equity into their physics teaching, producing a coherent framework that can support teachers and teacher-educators to organize their efforts and stretch their thinking. Our pilot framework (Fig. 1) combines two synthetic perspectives, based on our current insight into teacher interests and needs: Gutierrez's "dominant and critical" approaches to equity[19] and Philip and Azevedo's "equity discourses" in science education.[20] While we believe this framework is relevant to science education broadly construed, its development so far has been in the context of high school teaching of energy in physics. We are in the process of further articulating and refining this frame-

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work based on our data on physics teachers' equity efforts in real classrooms.

Dominant approaches: Supporting students to "play the game"

"Dominant" approaches to equity, shown in green in Fig. 1, are so named because they are intended to support students to succeed in physics as it is: they uphold current norms and expectations in physics while expanding access and improving achievement for students in groups that are underrepresented in the field.[19] These approaches include:

1. **Access:** All learners should have full access to learning: students should have equal opportunity to learn in school, and academic resources should be distributed equitably.[19,21]
2. **Achievement:** School achievement should be equitable; achievement gaps[22] and gaps in representation in the STEM workforce[23] should be closed.

These important approaches are most likely to be supported by schools and professional societies. The fact that these approaches don't "rock the boat" makes them especially valuable for teachers in politically sensitive geographical areas.[14] However, these approaches do not address how knowledge is constructed or applied in physics, and thus do not strongly support the integration of equity into physics teaching.[9]

Critical approaches: Supporting students to "change the game"

"Critical" approaches to equity, shown in gold in Fig. 1, are so named because they critique physics as it is, identifying this field along with all structures and institutions in US society as having been fundamentally shaped by systems of oppression.[24–28] As they are less familiar to most high school teachers, we explain two major critical approaches to equity with brief examples; a more extended example of both of these is described in the next section.

3. **Identity:** Present-day school resourcing and practices cannot be separated from historic systems of oppression that operate along lines of social identity and experience. For example, along racial lines: enslaved children were prohibited from schooling, schooling was racially segregated in the Jim Crow era, and Indigenous children were forced into schooling that severed them from their culture. Both students and teachers bring multidimensional identities and experiences into the learning space, including those of race, ethnicity, gender, class, LGBTQ+, first generation, veteran, language, disability, learning differences, neurodiversity, religion, age, and intersections thereof. These identities and experiences influence students' and teachers' perspectives and choices in the classroom environment as well as student learning. Students are better able to learn and succeed when they see their identities reflected in the curriculum.[24,27–29]
4. **Power:** Physics, like all science disciplines, emerges from political, economic, and cultural contexts that favor dominant interests and groups of people.[28,30–38] For example, the concept of energy as it is taught in schools today is a product of the British Industrial Revolution, when Britain was establishing coal-powered factories with which to process goods from its global trading empire, brought to England on steamships.[39,40] The concept of energy was developed for the purpose of improving those factories and steamships, e.g., predicting and preventing the overheating of factory machines. The physics energy concept is part of the transition from domestic to industrial manufacturing, and is implicated in extraction and processing of resources from lands that Britain colonized. Far from being an abstract, pure description of nature, the concept of energy is laden with its historical origins, carrying forward the values of capitalism and colonialism that it was developed to serve.[17] Challenging these power structures means creating opportunities for students to draw on their cultural and linguistic resources, instead of only those from the dominant culture.[19,29,41–43]

Justice approaches: Supporting students to "change the world"

"Justice" approaches to equity, shown in purple in Fig. 1, represent potential efforts to "change the world," placing physics learning in the service of community movements:

5. **Justice:** Science disciplines are tools to be put to use by justice movements to support the resilience and thriving of people and lands.[27,28,35,44–47] For example, the study of plastics in marine food webs can use methods and create findings that counter assumptions of unlimited access to Indigenous lands and genocide of Indigenous people.[35] One major route toward justice-centered science education is *place-based education*, in which students study locally relevant phenomena and identify authentic design problems that foster local agency, responsibility, accountability, and relationships.[10,35,48–52] Rather than learning decontextualized science concepts that may reduce student agency by disconnecting science from students' local communities and environments, students are empowered to see the local community and environment as the starting place for learning: learning goals include strengthening community bonds, appreciating the natural world, and citizen engagement.[35,48–52]

The "critical" and "justice" approaches to equity are exciting for many teachers, and also may entail greater political risk. Professional learning communities outside teachers' local networks, such as those offered by the Energy and Equity Project, can provide teachers with valuable support for the efforts they choose to make.

Example: Rebecca's efficiency unit

Rebecca, one of the teachers quoted in the introduction to this article, initially felt limited to a "hidden figures" approach to equity. This approach is consistent with approach number 3 in our theoretical framework, "Identity," in which teachers support students to succeed by striving to have diverse social identities visible in their science curriculum; in multicultural education theory, this is called the "contributions approach" to content integration.[24] Over the course of a 5-day summer workshop offered by the Energy and Equity Project, Rebecca and other participants engaged in activities to recognize the sociopolitical values embedded in physics concepts related to energy, identify the impacts of energy phenomena on the land and people in their location, and imagine ways to use science/energy expertise in the service of social justice efforts.[9,14] In so doing, Rebecca began to question the objectivity of physics and wonder about who shaped the construction of canonical energy concepts[9]:

> *I can't believe I never thought about this before but it makes so much sense! Energy is just a construct so of course the people who constructed the idea shaped it towards their thinking patterns and societal goals. It makes me think about how much richer, deeper, and more profound science could be if we had made room at the table for more diverse people to be involved. What understandings did we miss out on by not hearing all of the voices that could have had so much to contribute?*

In having these realizations, Rebecca began to adopt approach number 4 in our theoretical framework, "Power," in which science concepts are understood to be shaped by their sociohistorical origins. She then began critiquing the energy concept of "efficiency"[17]:

> *I am really excited about teaching about efficiency as a construct that a certain group of people created for a certain purpose. I am excited to try to allow my students to define it! I am thinking about introducing the "standard definition" and then telling them that it is antiquated because now we have different values about what is efficient.*

Eventually, Rebecca designed a lesson plan in which her students situated the concept of efficiency in its sociohistorical context, learned how that context shaped the substance of the concept, and constructed new definitions of efficiency based on their own values (excerpt in Fig. 2):

> *I want to first define efficiency the way I always do in my energy unit. Then, I want to have students design a matchbox car and design an experiment to measure the classical definition of efficiency for their car using the energy diagrams. Then I want to talk about who those people were and why they created efficiency that way. Then I want to tell students that they are a car company and that they have to redefine efficiency based on their values … I think I will show some TED talks about energy consumption harming the environment and who is harmed. I like the idea of whose land we are using for the energy resources (i.e., white people are benefiting from land that we stole from natives). I want to provide some more readings and resources that students can choose to look into for their own definitions of what is "efficient."*

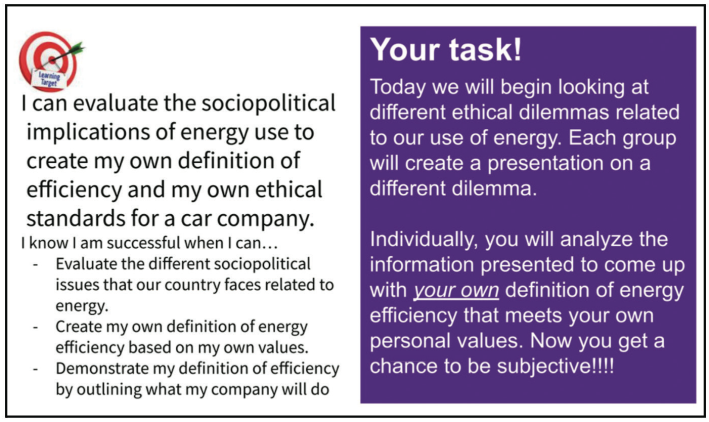

Fig. 2. Excerpt from Rebecca's efficiency unit.

Rebecca fully developed this lesson and shared it with other teachers along with her reflections about implementation using the Energy and Equity Portal, an online resource for teachers to share their lessons and insights.[53] Other teachers have made use of her materials for their own lessons.

Conclusion

The Energy and Equity Project supports high school physics teachers to integrate equity and justice into their energy instruction. By synthesizing literature and observing teachers participating in our project, we have created a pilot framework of approaches to equity in science education. A brief example illustrates (1) two different approaches to integrating equity into physics instruction, associated with the "Identity" and "Power" approaches to equity; and (2) a teacher expanding her sense of how equity issues may be integrated into science content instruction, e.g., moving from the "Identity" to the "Power" approach. In future research, we will further articulate and refine this framework based on physics teachers' equity efforts in real classrooms.

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Rachel E. Scherr *teaches physics at the University of Washington Bothell and leads the Energy and Equity Project, working with high school physics teachers to integrate equity into the teaching and learning of physics.*
rescherr@uw.edu

Trà Huỳnh *is an assistant professor at Western Washington University. Her current work focuses on understanding the structure of equity and justice in physics and physics education.*

W. Tali Hairston *is the principal owner of Equitable Development LLC, an educational and community development research firm.*

Kara E. Gray *is an associate professor of physics at Seattle Pacific University. Her current work focuses on supporting pre-service and in-service teachers.*