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Reflexión documentada

CAN WE TEACH PHYSICS FOR EPISTEMIC JUSTICE?

¿PODEMOS ENSEÑAR FÍSICA PARA LA JUSTICIA EPISTÉMICA?

PODEMOS ENSINAR FÍSICA PARA A JUSTIÇA EPISTÊMICA?

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Abstract

This article critically examines the intersection between philosophical perspectives and pedagogical practices in promoting epistemic justice within physics education. It addresses the historical context of science education movements and their impact on social equity, highlighting the persistent underrepresentation of marginalized groups in the sciences. By exploring the concepts of realism and relativism in the philosophy of science, this work discusses the challenges of integrating diverse epistemologies into physics education. It advocates for a multifaceted approach, emphasizing critical pedagogy and the inclusion of multicultural and multi-ethnic perspectives to foster a more equitable and inclusive physics curriculum. It argues that transforming physics education through ethnic-racial solidarity can enrich the discipline without falling into the relativist discourse. This document draws on the critical literature to exemplify how physics education and other physics communities can promote ethnic-racial solidarity. Through this approach, educators can create inclusive learning environments that empower students to engage critically with scientific knowledge and contribute to a more just and diverse future in physics education and practice.

Keywords: epistemic justice, physics education, philosophy of science, critical pedagogy.

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Resumen
Este artículo examina críticamente la intersección entre perspectivas filosóficas y prácticas pedagógicas en la promoción de la justicia epistémica para la enseñanza de la física. Aborda el contexto histórico de los movimientos de educación científica y su impacto en la equidad social, destacando la persistente subrepresentación de grupos marginados en las ciencias. Al explorar los conceptos de realismo y relativismo en la filosofía de la ciencia, este trabajo discute los desafíos de integrar epistemologías diversas en la educación en física. Aboga por un enfoque multifacético, enfatizando en la pedagogía crítica y las perspectivas multiculturales y multiétnicas para fomentar un currículo de física más equitativo e inclusivo. Argumenta que transformar la educación en física a través de la solidaridad étnico-racial puede enriquecer la disciplina sin caer en el discurso relativista. Este documento se basa en la literatura crítica para ejemplificar cómo la educación en física y otras comunidades de física pueden promover la solidaridad étnico-racial. A través de este enfoque, los educadores pueden crear entornos de aprendizaje inclusivos que capaciten a los estudiantes para comprometerse críticamente con el conocimiento científico y contribuir a un futuro más justo y diverso en la educación y práctica de la física.
Palabras clave: justicia epistémica, educación en física, filosofía de la ciencia, pedagogía crítica.

Resumo
Este artigo examina criticamente a interseção de perspectivas filosóficas e práticas pedagógicas na promoção da justiça epistêmica na educação em física. Aborda o contexto histórico dos movimentos de educação científica e seu impacto na equidade social, destacando a persistente sub-representação de grupos marginalizados nas ciências. Ao explorar os conceitos de realismo e relativismo na filosofia da ciência, o artigo discute os desafios de integrar epistemologias diversas na educação em física. Defende uma abordagem multifacetada, enfatizando a pedagogia crítica e a inclusão de perspectivas multiculturais e multiétnicas para promover um currículo de física mais equitativo e inclusivo. O artigo argumenta que transformar a educação em física através da solidariedade étnico-racial pode enriquecer a disciplina sem cair no discurso do relativismo. O documento se baseia na literatura crítica para exemplificar como a educação em física e outras comunidades de física podem promover a solidariedade étnico-racial. Através dessa abordagem, os educadores podem criar ambientes de aprendizagem inclusivos que capacitem os estudantes a se envolverem criticamente com o conhecimento científico e contribuírem para um futuro mais justo e diversificado na educação e prática da física.
Palavras chave: Justiça Epistêmica, Educação em Física, Filosofia da Ciência, Pedagogia Crítica.

1. Introduction

The aim of this article is to reflect on the challenges associated with creating a physics education that promotes epistemic justice. Recent developments in science education have shifted the focus towards social justice, inviting reflections on how this shift interacts with our views on the epistemology of physics. This introduction will explore these developments and their implications for a more just and inclusive physics education.

Some 20 to 30 years ago, the science education teaching and research communities were heavily influenced by movements such as Science as a Process (Millar & Driver, 1987); Science, Technology, and Society (STS); and Science for All (Atkin & Black, 2003). At that time, we teachers and researchers focused on teaching and learning processes and on the products of science without duly considering who that education was for.

Starting in the 1980s, the STS movement (Mansour, 2009; Bennett *et al.*, 2006) sought to incorporate social, cultural, and political aspects into science education, showing students the societal impact of science and technology on daily life. The STS movement has successfully impacted science education, encouraging students to think critically about social issues and raising awareness about ethics in science, citizen privacy through technology, and the environmental impact of science (Mansour, 2009).

Despite progress in addressing social issues, STS projects had yet to comprehensively tackle social inequity and injustice. Issues such as the underrepresentation of women, people of colour, and other socio-ethnic-religious minorities in the sciences remain unaddressed (Archer *et al.*, 2015). The immense social inequality dividing the rich and the poor has made science education unattractive to economically disadvantaged and Black children, perpetuating existing inequalities (Calabrese Barton *et al.*, 2003; Calabrese Barton, 2001).

In recent discourse surrounding science education, the pursuit of social justice has become an indispensable theme, encompassing terms such as humanism, decolonisation, inclusion, equality, equity, democracy, and citizenship (Gandolfi, 2021; Bajaj, 2015; Garibay, 2015; Bazzul, 2012; Hodson, 2003; Calabrese Barton, 2001). The broader context of science education, which extends beyond the disciplinary syllabus for canonical knowledge and technical skills, stresses the transformative potential of education in contributing to a more equitable world. Today, this view is even more pressing, given the current international political landscape (Galamba & Matthews, 2021).

The shift in focus to social, cultural, and economic issues in science education represents a significant step forward in the development of science education. However, it is also the most challenging, as it has implications for our views on the nature of science (Yucel, 2018). While this work concurs with the cited authors regarding the importance of addressing said hindrances in the learning of science (Galamba & Matthews, 2021, 2023), it aims to narrow down the debate from broad social justice issues to exploring the challenges of addressing epistemic justice in physics education. Indeed, the literature has not given this issue the attention it deserves. In particular, this article takes interest in the intersection of philosophical perspectives, pedagogical practices, and the promotion of epistemic justice within the context of physics education. It problematises this intersection by exploring the meaning of epistemology and the tension between realism and relativism in the philosophy of science. It seeks to elaborate on their implications for physics pedagogy and epistemic justice, exploring areas that necessitate further research.

At the outset, it must be clarified that the author's concerns about epistemic justice in physics stem from the recent movements to decolonise science education (which he supports). The literature generally agrees that decolonising the curriculum involves recognising the impacts of colonisation and dismantling its inherent power structures, which marginalise non-Eurocentric cultures and ways of knowing. This process addresses the bias that prioritises certain people over others, as seen in the dominance of coloniser values in discourse. Scholars like Santos (2014), Mignolo (2007), and Escobar (2018) argue that the negative effects of colonisation on marginalised communities persist beyond the end of political colonisation and continue to permeate both private and public life, perpetuating the belief that European culture, values, religion, and epistemologies are inherently superior to other ways of living.

The first part of this article will address Boaventura de Souza Santos's very influential book titled *Epistemology of the South*, explaining why his argument is problematic to the epistemology of physics. This will be followed by arguing that his view of ethnic-racial solidarity is a promising route to foster epistemic justice in physics. Then, this document will move on to examine the position of philosophers of science, who argue that physics is a universal and impersonal discipline, shaped by historical narratives in science education and philosophy. This belief represents a huge barrier to advocating for epistemic justice, and it necessitates a critical examination of existing paradigms. To navigate through this barrier, this work argues for a multifaceted approach to build towards a physics curriculum that is epistemologically just while acknowledging the limitations of the reach of this proposal. Central to this approach is the engagement with critical pedagogy, which will be detailed later in the article. It will be argued that critical pedagogy extends the teaching of physics beyond traditional boundaries, fostering ethical and socially responsible activism among students (Galamba & Gandolfi, 2023), which might lead to epistemic justice.

2. Decolonisation and epistemic justice

In the literature on the decolonisation of science (and physics) (*e.g.*, Moura *et al.*, 2022; Galamba & Gandolfi, 2023; Monteiro *et al.*, 2019), it is noteworthy that issues of ethnicity, race, and gender inclusion have been addressed much more extensively than epistemic justice.

Much of the recent debate about epistemic justice in science arose after Boaventura de Souza Santos's *Epistemologies of the South* (2014). Santos argues that, as a result of the European project of modernity, initiated with the Enlightenment (Dussel, 1980), the world has been dominated by Euro-centred epistemologies, reducing the understanding of the world to a Western perspective. To counter this domination, Santos calls for the development of an epistemology of the South, which must provoke an *epistemological break* with Euro-centred traditions.

Santos's position, which has influenced much of the recent literature in science education, is somewhat troublesome. As shown later in the article, if we look at how epistemology has been defined in the literature related to philosophy and science education, an *epistemological break* in physics is very problematic, if not impossible. Therefore, this work will seek to point out alternatives to build an epistemically just physics.

In *Epistemology of the South*, Santos (2014) approaches epistemology by looking at how it has been used by the global North as a means to maintain power and domination over the global South. Any knowledge born outside of the Euro-centred and validated theoretical frameworks and methods is deemed to belong to the "dark world of passions, intuitions, feelings, emotions, affections, beliefs, faiths, values, myths" (p. 5), and therefore not important to the development of

– broadly speaking – science. This has provoked what Santos calls "epistemicide, the murder of knowledge" (p. 92).

His account of epistemology encompasses the epistemology of science with a focus on *socio-scientific issues* (although, in several parts, it is unclear whether he is speaking of natural sciences, of social sciences, or of both). For instance, he questions whether Western modern science, while in service to the project of domination and capitalism, has been ecologically responsible and able to deal with global warming, deforestation, and the genocide of indigenous people. In the context of socio-scientific issues, he claims that modern science was given an epistemological privilege and "the monopoly of the universal distinction between true and false" (p. 119).

Such privilege fits into the paradigm of modernity, which takes *knowledge as regulation* (control), as opposed to *knowledge as emancipation* (solidarity). To achieve epistemic justice and deal with socio-scientific issues, Santos advocates for an *ecology of knowledges*, aiming to cultivate a rich and varied intellectual landscape that reflects the diversity of human experiences and perspectives, contributing to a more socially just educational framework.

At this point, and before continuing to illustrate the relevance of Santos's work in science education, some considerations must be made about Santos's positions. His keenness to advocate for epistemologically just science is commendable, as we must strive to eliminate the inequities perpetuated by modern science while ensuring its vast potential benefits for everyone, preventing it from becoming a means of oppression. In fact, he claims that, in knowledge as emancipation, the point of knowing is solidarity, "the recognition of the other as an equal and as an equal producer of knowledge" (p. 156). Within an ethnic-racial perspective, educators and the physics community must embrace knowledge as emancipation through solidarity. This will, at a minimum, work to compensate physics and physicists' contribution to colonialism and fascism (Galamba & Matthews 2021; Crease *et al.*, 2019).

However, his argument must be taken cautiously. It is unclear whether he is referring to ethnic-racial solidarity – which has been embraced by the critical literature on science education – or advocating for relativism in science and the equivalence of all forms of knowing. Relativism does not seem to have currency in physics communities (this issue will be discussed later in this document), as the epistemology of science undergoes rigorous methods and reviews, leading to reliable knowledge. We must constantly remind ourselves that, despite its limitations and social challenges, science remains our most powerful tool against pseudoscientists, charlatans, fundamentalists, cynical politicians, and moralists. As highlighted by Roy (2018), addressing the persistent influence of colonialism in science is crucial. However, there is a risk that overly radical efforts in this direction might inadvertently empower religious fundamentalists and ultra-nationalists (Galamba & Matthews, 2021). It should be added that the importance of science extends beyond this defensive role; it represents a sophisticated and systematic method for developing knowledge. Through scientific inquiry, humanity has achieved a much more efficient way to understand both the material and the social world. This collaborative effort has revolutionised our grasp of the universe, leading to advancements that enhance our lives and broaden our perspectives. The structured methodology of science ensures that our knowledge grows in a reliable and verifiable manner, fostering innovation and progress across all fields. An ecology of knowledge should not be used as a loophole for pseudoscience.

That said, it is possible to foster epistemic justice by investing in ethnic-racial solidarity, as demonstrated by several works.

3. Epistemic justice as ethnic-racial solidarity

Some of the latest publications on science education build a collective argument that supports ethnic-racial solidarity to foster epistemic justice. For instance, collaborations with native populations, as advocated by Gandolfi (2021), offer avenues for addressing historical exploitation and fostering inclusivity in the field of science. Anti-racist and decolonial movements in Brazil have catalysed vital discussions about how pedagogical practices and the initial education of science teachers continue to perpetuate structural racism, as stated by Benite (2018), who points out that anti-racist political and educational processes have been implemented in the context of teaching physics and astronomy. Alves-Brito and Teresinha Massoni (2020) have analysed the life and scientific contributions of Cheikh Anta Diop, one of the most significant scientists and intellectuals of the twentieth century, shedding light on the exclusion of Black authors from the history of science, particularly in the exact sciences. They argue that "historiography, as well as science teaching, need to take into account invisible alterities to promote liberating and inclusive science education and dissemination in the twenty-first century" (Alves-Brito & Teresinha Massoni, 2020, p. 292-293). Moreover, Alves-Brito (2021) delves into *racialised cosmologies*, investigating how nineteenth-century European scientific thought gave rise to the concepts of race and scientific racism. He contends that scientific racism in Brazil not only reinforces stereotypes and negative perceptions of Black people but also contributes to the "invisibility and subalternisation of the place of production of knowledge about Africa and the Afro-diasporic legacy in the Exact Sciences" (Alves-Brito, 2021, p. 1). Alves-Brito emphasises the prevalent exclusionary practices within physics communities and underscores the necessity of acknowledging and appreciating varied perspectives, advocating for the inclusion of marginalised groups such as people of colour, women, LGBTQ individuals, indigenous populations, and those on the fringes of power structures. By shedding light on the intersectionality of discrimination, Alves-Brito highlights the urgent need to address systemic biases within the scientific realm. Mignolo (2007) discusses the processes of racialisation, the absences, and the distortions in historical narratives that diminish or erase the history of African peoples, thereby perpetuating their subalternisation. Adding to this perspective, Johansson *et al*. (2023) reveal the persistent gender disparities and underrepresentation of minoritised ethnic/racial groups in physics, pointing to an entrenched culture of exclusivity and elitism within physics communities. Their findings, particularly the severe underrepresentation of women of colour in the United States, underscore the perpetuation of discriminatory practices, hindering full participation and inclusion. Moreover, these authors emphasise the adverse impact of stereotypical perceptions of physics as a discipline exclusively suited for a select few, reinforcing existing biases and erecting barriers for marginalised individuals pursuing careers in the field.

These insights stress the imperative to challenge discriminatory practices and foster a more inclusive environment within physics communities. Their efforts highlight the emergence of a critical pedagogy that seeks to recognise and address the subalternisation of cultures within science education. The epistemology of any science is shaped by the individuals dedicated to its practice (Kelly, 2008). Creating an inclusive and multicultural population in physics will build epistemic justice through ethnic-racial solidarity. But will it have any impact in the development of the products of physics?

4. What epistemic justice means in physics

The ethnic-social epistemic justice presented above must have its space in physics as much as in

any other scientific community. Now, some issues in the epistemology of physics will be explored. Many of these points could be extrapolated to other natural sciences.

Epistemology is an overloaded concept, making it challenging to define – Plato, Locke, Kant, and Russell each approached it from a different perspective. In the more recent literature in the fields of philosophy of science and science education, *epistemology* is defined along the lines of 'how have we come to know what we know?'. Some definitions refer to the use of conjectures, observations, perceptions, introspection, and reason, which interplay with a range of human practices, such as laboratory experimentation, technological development, the use of evidence, socialisation, and trust between peers. For example, according to the Stanford Encyclopaedia of Philosophy (n.d.), epistemology refers to how we can justify the knowledge we have about something. They say: "much recent work in formal epistemology is an attempt to understand how our degrees of confidence are rationally constrained by our evidence" and add that "epistemology seeks to understand one or another kind of cognitive success". In the literature on science education, we find definitions such as "epistemology is the study of knowledge (…) [In science,] epistemology typically examines issues such as the growth of knowledge, the nature of evidence, criteria for theory choice, and the structure of disciplinary knowledge" (Kelly, 2002, p. 99). Another definition reads: "the epistemology of science addresses the ways in which knowledge claims in science are developed and justified, *e.g.*, how scientists assess the quality of data and how theoretical models relate to the phenomena they explain" (Ryder & Leach, 2008, p. 289).

Notably, the definitions above do not make explicit considerations about ethnicity, gender, race, culture, or any other background. They suggest that the epistemology, practices, and products of science are fully independent of who is practising it.

This work argues that they are not. It draws on Kelly (2002) to defend that intersubjectivity is at the core of scientific epistemology. The social practices of scientific communities, such as the communication of works in conferences, involve the interaction of members of the community with the interpretations of other members. To become a member of that community, one needs to be socialised into it and acquire its "conceptual, linguistic, and artefactual tools" (p. 102). For instance, the members of that community learn about and produce inscriptions (*i.e.*, models, graphs, symbols) (Duschl, 2008), which, one should recall, in the case of physics, are deeply Euro-centred. As Kelly (2002) has added, new members of any community "create through social interaction particular ways of talking, thinking, acting, and interacting" (p. 105).

The above-presented sociological views on the nature of science beg for a review of what we mean by the *essential elements of the epistemic practice*; in addition, the definitions of the epistemology of physics should be rewritten to include social aspects. The demographics of physics, addressed in the previous section, have implications for power dynamics and social relations within the physics communities and society (Gonsalves, 2014). Historically, the models, diagrams, conjectures, theories, and experiments created, accepted, and used in the history of physics belong to the work of male scientists – to a large extent, to European white males. Therefore, due to that historical epistemic injustice, which prevails today (Eaton *et al.*, 2020), the archetypal physicist is represented and controlled by that particular group of people in our society, which is reinforced through cultural representation, historical documentation, and academic acknowledgment. They are reflected in the names of several physics laws, many Nobel Prize winners, notable physicists featured in textbooks, and the names of research centres. Perhaps more subtly, physics epistemology is also attested by

what is seen as a male psychology of objectivity, control, and dominance (Kato *et al.*, 2023; Keller, 1985). Therefore, to foster epistemic justice within the physics community, it is imperative for physics to become diverse in its ethnicities, gender, and race (Taylor, 1994). This will gradually pollinate physics practice with alternative ways of thinking and change the way physics is perceived by society.

In addition to the social aspects of the epistemology of physics, we must also ask whether diversifying the community of physicists will produce better processes and products in physics: Are physics laws universal and realist, or are they subject to who discovers them? Would a diverse community of practice enhance the quality of praxis only or will it also enhance the product outcomes?

5. Can we reconcile realism and epistemic justice?

The Stanford Encyclopaedia of Philosophy (n.d.) states that "it is perhaps only a slight exaggeration to say that scientific realism is characterised differently by every author who discusses it." The authors go on to add that "most people define scientific realism in terms of the truth or approximate truth of scientific theories or certain aspects of theories," and that

> others define scientific realism not in terms of truth or reference, but in terms of belief in the ontology of scientific theories. The scientific realist holds that science aims to produce true descriptions of things in the world (or approximately true descriptions).

Therefore, in arguing whether a philosophical stance may be classified as naïve or critical realism, realists will defend that there is a reality independent of the observer: there is only one truth, which we can describe with some approximations.

The debate between realism and relativism has not been resolved in the literature on the philosophy of science, and strong claims that challenge realism persist (Mizrahi, 2012). In fact, Yucel's literature review on scientists' worldviews (2018) reveals a range of different and sometimes contradictory findings about scientists' ontological stances.

Yet, it has been shown that realism is well established in the physics community, chiefly because of the predictive power of physics models, regardless of how idealised they might be in the first place (Saatsi, 2016). There is widespread support to the idea that physical science rejects the relativist or multiculturalist accounts embraced by the science education community. In the long run, it rejects multiple realities and context-dependent, opinion-dependent, culturally-situated, local, and non-universal knowledge of the physical world (Cobern & Loving, 2001; Siegel, 1997). Physics strives towards the impersonal interpretation of data and pursues *closure* (Donnelly, 2004), *i.e.*, it seeks to understand and explain a phenomenon under the same set of laws and theories. Historically, science education has aimed to instruct students on the processes and outcomes of science (Rudolph, 2002; Jenkins, 1979). *Processes* involve how scientists operate, their reasoning methods, collaboration, and the traditional techniques for collecting, analysing, and drawing conclusions from data, all consistent with scientific theories and laws. *Outcomes* pertain to established scientific knowledge (*e.g.*, taxonomies, models, theories, and laws) that has been developed over centuries and is applied to understand the technological world, explain natural phenomena, and predict natural behaviour (Matthews, 1994). Harding (1991) has elaborated on the perception of physics as culturally neutral, attributing this to its formal and abstract nature. Meanwhile, research has consistently suggested that physics, as a prestigious field, is portrayed as a discipline that generates universal, unbiased, and objective knowledge, unaffected by societal influences (Schiebinger, 1999). This perception is influenced by the work of past physicists who

dedicated their lives to solitary and resolute efforts in laboratories, seeking to uncover universal laws (Hodson, 1996).

The argument used in the decolonisation of science literature can be construed as one for scientific relativism. For example, building on Santos (2014), Leibowitz (2017) calls for an equal 'treatment' of all forms of knowledge. She advocates for the importance of fostering an *ecology of knowledges*, where dialogues and exchanges between different knowledge systems take centre stage. When the epistemology of the natural sciences has been examined from a perspective of cultural activity, a narrative of class struggle has been used to justify cultural relativism and claim that there is no objective knowledge (Duarte *et al.*, 2022). In this vein, science and pseudoscience should be treated equally. For the reasons explained before, this is very problematic for the physics community. This work contends that physics teachers who adhere to a realist perspective of physics may find themselves in conflict with the ecology-of-knowledges approach to teaching and learning physics, as it will very likely be construed as a euphemism for relativism. In addition, another criticism of relativism is that it poses a serious problem for science: it can be used by fascists, charlatans, and pseudoscientists to spread disinformation (Duarte *et al.*, 2022; Galamba & Matthews, 2021).

In light of the above, from an ontological perspective, epistemic justice can be seen as a challenging aim in physics teaching and practice. As argued before, within the realist philosophical stance, an *equal treatment of all knowledge* can be reconciled with realism as long as it is limited to ethnic-racial solidarity. Leibowitz (2017) should agree with this, since she adds that equality of treatment of all knowledge does not entail an erasure of Western knowledge or a claim that all forms of knowledge are inherently equal. Rather, she argues that we must have a democratic dialogue with all knowers and their knowledge.

The history of science education and philosophy has created deeply ingrained beliefs that physics is universal and impersonal. The author does not think that fighting this belief is the best way to promote epistemic justice in physics. We should not challenge the realist argument purely based on arguments for epistemological justice. Instead, epistemic justice should be pursued as ethnic-racial solidarity. This will transform the practice of physics without falling into the relativist discourse. As argued by Prescod-Weinstein (2020), a multicultural and multi-ethnic physics community will impact the epistemology of physics not by building a new and different physics, but by influencing and changing the areas of physics to be developed, as well as the methods, the models, and the nomenclature used in the field.

How should we then work towards epistemic justice in schools? We should invest in critical ways to teach physics there. The next section seeks to explain what this may look like in classrooms and why previous movements have failed to address social transformation in physics.

6. A pedagogy for epistemic justice

Bazzul and Tolbert (2019) provocatively argue that, in its conservative formulations, science education might merely serve as a distraction from more critical educational priorities, particularly those related to social development. This is the spirit of critical pedagogies: to question how well-established educational practices may conceal or marginalise practices that perpetuate social and epistemic injustices.

The contemporary meaning of *critical pedagogy* largely derives from the influential work by Brazilian educator Paulo Freire and other scholars such as Henry Giroux, Peter McLaren, Peter Leonard, and Ira Shor. Critical pedagogies, in various contemporary forms, aim to bring attention to issues of knowledge and power, culture,

ethnicity, gender, class, and sexual orientation within educational experiences (Galamba & Gandolfi, 2023).

Despite the complexity of critical pedagogy, two essential elements are worth addressing. Firstly, teachers need to comprehend the ideological nature of education, recognizing that it is not neutral and often serves to maintain existing social hierarchies. The second element involves questioning the traditional approach to teaching scientific concepts in isolation, which may contribute to maintaining epistemic injustices. Ira Shor (1979) suggests that, instead of a transfer of facts and skills, a Freirean class invites students to think critically about subject matters, doctrines, the learning process, and society. Critical teachers aim to reduce inequalities and oppression by avoiding a reductionist approach to teaching. In contrast to traditional methods like banking education (Freire, 1994, 1970), where teachers deposit knowledge into students' minds, critical pedagogies advocate for dialogue between teachers and students. Critical approaches go beyond merely expanding practical skills; they focus on developing conceptual tools for understanding the social world and its power dynamics.

In the pursuit of fostering inclusivity and tackling discrimination in physics education and practice, scholars have presented a range of alternative pedagogies in science. For example, Rodrigues and Morrison (2019) champion a socio-transformative approach to education, focusing on marginalised youth and building on diversity, equity, and social justice foundations in order to instigate transformative actions. Concurrently, critiques by scholars like Paul McLaren (2010) highlight the economically driven purpose of science education, prioritizing profitability over addressing systemic biases and forms of oppression. Responding to these challenges, Bazzul and Tolbert (2019) advocate for extending love beyond self-interest, while studies in critical peace education (Bajaj, 2015) call for an end to all forms of violence, particularly in conflict and post-conflict situations. These perspectives collectively underscore the necessity of nurturing a mindset that promotes inclusion, tolerance, collaboration, and empathy, challenging views associated with discrimination and societal injustices. In parallel, Santos (2009) criticises the STS approach for perpetuating ideological models that sustain the *status quo*. Instead, Santos advocates for a political agenda in science education that addresses global inequalities in technology access and the oppressive contexts of scientific societies. Meanwhile, Calabrese Barton *et al*. (2003) advocate for teaching approaches that engage in social action for marginalised children, offering new perspectives on education in diverse environments. Alves-Brito (2020) highlights the importance of educating the professional community in the exact sciences to recognise the scientific significance of concepts related to race, gender, and identity. By integrating these concepts into scientific discourse, the community can better interpret reality and address identity under-representations within the field. This integration is essential for advancing inclusivity and diversity in the scientific community, and ultimately, epistemic justice.

These are just some examples of how teachers can plan lessons to address historical injustice in the epistemology of physics. Many other studies could have been cited here. The author urges physics teachers to look for resources on how to address critical social issues in their lessons.

7. Conclusion

The deeply ingrained belief in physics as universal and impersonal, shaped by the history of science education and philosophy, poses a huge barrier to advocating for epistemic justice. Instead of engaging in a philosophical debate that may not directly impact how physics is practised, this work advocates for a focus on social transformation

through education and inclusive government policies. By nurturing multicultural and multi-ethnic physics communities, we can influence the epistemology of physics without resorting to relativism. This approach, as suggested by Prescod-Weinstein (2020), can lead to the evolution of physics in terms of areas of focus, methodologies, models, and nomenclature.

Therefore, rather than challenging fundamental philosophical principles, we should invest in critical approaches to teaching physics in schools. By reimagining classroom practices and curricula, we can create inclusive learning environments that empower students to critically engage with scientific knowledge and contribute to a more equitable and inclusive future in physics education and practice. This shift in focus, from philosophical debates to transformative education, represents a pragmatic pathway towards promoting social justice within the realm of physics. The imperative to build a socially and epistemologically just physics curriculum necessitates a multifaceted approach. Engaging in critical pedagogy and drawing from diverse educational perspectives, educators must extend the teaching of science beyond the traditional boundaries, fostering ethical and socially responsible activism among students.

The insights shared herein highlight the need for a paradigm shift in both educational institutions and the professional community. Addressing historical exploitation and economic power structures, as highlighted by Twumasi *et al*. (2020), becomes pivotal. Research can further contribute to these issues by exploring effective pedagogical strategies, evaluating the impact of curriculum changes, and investigating the intersectionality of issues related to race, ethnicity, and gender in science education. Such research endeavours can provide valuable insights into refining and advancing the goals of a socially just and inclusive physics curriculum.

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