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Illuminating diversity in STEM: Integrating the cultural meaning of the sun through culturally responsive pedagogies

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Abstract

This article examines how embedding the Sun's cultural and historical meanings within STEM educationfosters more inclusive and engaging learning. Grounded in Culturally Sustaining Pedagogy and Rightful Presence, it challenges the notion of science as culturally neutral by valuing students' lived experiences, traditions, and worldviews. A hands-on solar-oven design activity illustrates this approach: students leverage scientific principles alongside family stories, local practices, and community wisdom about the Sun's role in cooking and energy. Their proposals—for drying staple foods, repurposing everyday materials, or experimenting with novel designs—demonstrate how cultural assets fuel creativity and ownership. Thematic analysis of design artifacts and discussions revealed that when curricula honor diverse backgrounds, students shift from passive observers to active co-creators of knowledge. To sustain this shift, the authors call for systemic reforms in curriculum development, assessment, teacher training, and policy, ensuring that educational frameworks recognize and integrate students' cultural resources. By positioning learners as rightful participants, this culturally responsive model promotes deeper engagement, a stronger sense of belonging, and critical problem-solving skills, ultimately enriching both STEM education and innovation.

Introduction

STEM (Science, Technology, Engineering, Mathematics) education is no longer just about raising student achievement or meeting global employment needs. It increasingly requires a cultural, social and equity perspective that ensures that all learners see themselves, their communities and their knowledge systems reflected in educational processes. Equitable access to STEM goes beyond numerical representation; it must also address the diverse cultural roots, experiences and collective voices that enrich the way scientific concepts are taught and learned. Within this framework, two notable approaches have emerged: "Culturally Sustaining Pedagogy" (Alim, Paris, & Wong, 2020) and "Rightful Presence" (Calabrese Barton & Tan, 2020). Both challenge the prevailing notion that science is a culturally neutral or universally uniform domain, and instead centre students' local knowledge, identities and cultural practices as legitimate foundations for STEM learning.

Focusing on the sun as a unifying theme can illuminate these pedagogical strategies. In many educational settings, the sun is typically discussed only in terms of astronomy, solar energy, photosynthesis, or seasonal change. While these topics are crucial, they rarely integrate the deep cultural and historical meanings that many communities around the world attach to the sun. For indigenous groups, diasporic communities and many ethnic populations, the sun may be linked to myths, religious rituals, communal practices or local ecological knowledge. Moreover, recent comparative studies have shown that integrating CSP principles in STEM classrooms across varied global settings—from community-led energy initiatives in Brazil to indigenous-focused STEM curricula in Aotearoa/New Zealand—has significantly improved both student engagement and scientific reasoning (Whitcomb & Singh, 2021; Alam, 2022). By acknowledging these multiple dimensions, educators can promote learning that not only provides scientific literacy,

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but also honours students' identities and cultural assets. From the perspective of Culturally Sustaining Pedagogy and Rightful Presence, students move beyond being 'invited guests' in a pre-designed curriculum. Instead, they become co-authors of their educational experiences, bringing their cultural and community-based knowledge into the heart of STEM classrooms.

This integration of cultural meaning, especially around a seemingly universal phenomenon such as the sun, requires a shift in the way we conceptualise STEM. Historically, Western-centred approaches have dominated science education, often dismissing local or indigenous knowledge systems (Harding, 1998; Ladson-Billings, 2021). As a result, many students from underrepresented backgrounds feel that STEM does not belong to them - that it is neither relevant to their daily realities nor reflective of their cultural legacies. Yet the academic literature shows that science develops through collective contributions, including those of non-dominant communities and knowledge keepers. This text demonstrates how careful recognition of these contributions can enrich STEM learning. By placing Culturally Sustaining Pedagogy (Alim et al., 2020) and Rightful Presence (Calabrese Barton & Tan, 2020) at the centre, educators can build transformative practices around the unifying theme of the sun that centre students' political, cultural and historical identities within science learning.

In addition to the existing discussion on Culturally Sustaining Pedagogy (CSP) and Rightful Presence (RP), it would be beneficial to include a broader range of interdisciplinary or cross-cultural perspectives (Smith, Avraamidou, & Adams, 2022). By examining how sociocultural factors shape STEM learning in various geographic settings, this expanded literature review can provide a more robust foundation for instructional strategies. Such an approach not only underscores the theoretical strength of CSP and RP but also deepens our understanding of how local and global research findings intersect to inform inclusive educational practices. Incorporating recent scholarship that bridges culturally diverse contexts can offer educators, policymakers, and researchers a clearer roadmap for applying these frameworks in their specific settings. Ultimately, a broader and more up-to-date body of literature will help illustrate the universal relevance and adaptability of the theoretical models proposed in this study.

Method

In this qualitative case study, eight middle-school students from diverse cultural backgrounds were recruited through an open call and provided parental consent. Participants engaged in a hands-on solar-oven design workshop, during which they sketched, annotated, and discussed their prototypes without peer influence. Demographic and cultural background data were collected via a brief survey preceding the activity. All design artifacts and discussion transcripts were analyzed thematically to identify how students' cultural knowledge and lived experiences shaped their conceptualizations of solar technology. In addition to thematic coding, students' sketches and annotations were subjected to multimodal analysis to capture the spatial, symbolic, and narrative dimensions of their design reasoning.

Why Culturally Sustaining Pedagogy and Rightful Presence Matter in STEM

Culturally Sustaining Pedagogy (CSP) goes beyond 'including' or 'tolerating' cultural diversity in the classroom; it seeks to sustain and transform it. Rather than treating culture as an add-on or a sporadic reference, CSP weaves students' cultural practices, languages and worldviews into the fabric of curriculum and instruction (Alim et al., 2020). STEM fields, which often pride themselves on their neutrality, have rarely integrated these cultural perspectives in a meaningful or substantive way. Instead, CSP asserts that students' localised knowledge, particularly their experiences with phenomena such as the sun, can be a legitimate lens for scientific inquiry. This fosters a deeper sense of relevance, motivation and intellectual curiosity.

In parallel, the Rightful Presence framework (Calabrese Barton & Tan, 2020) conceptualises learners as having inherent rights in the classroom. In typical 'equity as inclusion' practices, marginalised students are treated as guests in a curriculum designed without them in mind. In contrast, Rightful Presence insists that these students have not only the right to participate in established practices, but also the right to shape what those practices should be. STEM educators using Rightful Presence would encourage students to rethink the processes of scientific knowledge production, to challenge power hierarchies in the classroom, and to shape the definitions of success. Rather than seeing the teacher as a 'host' offering minimal accommodations, Rightful Presence sees teachers and students as co-creators, ensuring that local cultural experiences become part of the academic conversation.

Bringing these two approaches together, the cultural significance of the sun can be used to break down the myth of a purely "universal" or "value-free" science. Indeed, many indigenous peoples, local farming communities or diasporic groups have used centuries-old observational methods involving sunlight, shadows, planting cycles and

cultural ceremonies. These observations combine environmental stewardship, spirituality and practical knowledge - elements that rarely appear in standard textbooks. A culturally sustainable approach highlights these stories, while Rightful Presence ensures that students' social and political realities are recognised as legitimate grounds for building scientific understanding. Together, these frameworks challenge the notion of 'students as mere recipients' and advocate a more dynamic relationship in which students have the power to define the curriculum.

CSP and Rightful Presence frameworks emphasize the integration of social and cultural realities with core scientific principles, aiming for both depth and inclusivity in learning experiences (Chávez-Moreno, 2022). However, explicitly illustrating how these theories play out in classroom practice can greatly enhance the impact of this study. Demonstrating, for example, how traditional solar cooking techniques or community-oriented rituals intersect with scientific inquiry helps to concretize the link between abstract theory and tangible outcomes. By highlighting successful cross-cultural collaborations and interactive lessons, educators and researchers can see firsthand how CSP and Rightful Presence foster not only academic achievement but also personal and communal growth. These frameworks have also informed recent policy-level decisions, such as the U.S. National Science Foundation's INCLUDES initiative and the EU Horizon-funded "STEM for All" programs, which emphasize culturally grounded innovation in science education.

The Cultural Significance of the Sun in STEM Learning

In typical school settings, the Sun is presented mainly as an astronomical entity: a star at the centre of our solar system, essential to life on Earth, studied through concepts such as solar energy, radiation, eclipses, and so on. While such scientific content is crucial, it remains incomplete if taught in isolation from cultural meaning. Anthropological and historical accounts show that countless societies have revered the sun as sacred or incorporated it into agricultural, artistic, and communal rituals (Borrows, 2022; Salimpour, Fitzgerald, & Hollow, 2024). For example, in many First Nations communities in Canada, ceremonial sites serve both spiritual and observational purposes for understanding the cosmos (Hill, 2021). Similarly, in various African indigenous traditions, the sun is more than an object of cosmic significance; it is part of a moral and ecological order that binds the community (Caplan, 2021). These practices do not simply add 'cultural flavour' to science; they speak to broader epistemological assumptions about how knowledge is created and shared.

In everyday classroom contexts, these insights are often hidden or marginalised. Traditional STEM curricula typically emphasise scientific processes and universal laws, with minimal room for local narratives, socio-historical perspectives or spiritual interpretations. Yet acknowledging such perspectives can profoundly change the way students conceptualise science. A high school class might study solar panels and explore how local communities use solar drying techniques for food or solar heating. Or a middle school might investigate seasonal changes in daylight and link them to rituals practised in the community. This integrates scientific inquiry with students' lived experiences, a key tenet of CSP (Alim et al., 2020). It also aligns with Rightful Presence, as students would not be passive observers, but partners in reshaping the curriculum through their cultural knowledge and family histories.

This approach also holds promise for students who have been historically excluded from STEM due to language barriers, socio-economic constraints, or racially biased structures (Gao & Jones, 2021). By deliberately validating cultural stories or mythological accounts about the sun, educators can invite learners to critique these stories and relate them to scientific explanations, encouraging a form of 'loving critique' (Alim et al., 2020). Students learn, for example, that a solar deity myth may not fit with scientific models of fusion, but that the myth may still offer valuable perspectives on human-environment relationships, community bonding, or seasonal cycles. This process of critical engagement draws on both tradition and science, allowing knowledge to evolve rather than one side being relegated to irrelevance. In other words, science becomes a creative, living discipline shaped by real human concerns and cultural backgrounds.

Toward a Transformative Approach

Although the presentation of student designs is informative, there remains an opportunity to contextualize these findings more thoroughly by linking them to students' cultural, socioeconomic, and familial backgrounds (Morris et al., 2021). Such an exploration would illuminate the unique influences that drive each student's problem-solving process, offering richer insights into how local practices and values shape the outcomes. A deeper discussion that weaves together these distinct social factors could further elucidate the study's broader implications, making the findings more resonant beyond the immediate group of participants. In doing so, the analysis can better highlight the interplay

between individual experiences and systemic realities, thus advancing our understanding of culturally responsive methodologies in STEM.

A transformative approach that actively integrates cultural meanings of the sun into STEM requires more than occasional references to indigenous or local knowledge. It requires a systemic rethinking of curriculum design, teacher preparation, student assessment and education policy. Teachers, for example, often face a rigid system in which standardised tests focus on decontextualised content (Salimpour et al., 2024). Bringing cultural knowledge into the classroom may seem like a diversion from test preparation mandates. However, an expanded definition of 'success' could include students' ability to connect scientific concepts to community-based practices, cultivate a sense of belonging in STEM, and collaboratively solve local challenges related to energy or the environment.

Teacher preparation programmes play an important role in facilitating these changes. Pre-service and in-service training can include workshops where educators learn about different cultural dimensions of the sun and how to integrate this knowledge into science teaching (Brown, Pérez, Ribay, Boda, & Wilsey, 2021). Such programmes would also address personal biases and assumptions about what knowledge is valuable. By working with elders, local leaders or cultural knowledge keepers, teachers can gain richer perspectives on the meaning of the sun and thus develop culturally sustainable materials. Field visits, community interviews or co-teaching arrangements with local cultural experts can help deepen teachers' awareness and confidence in linking science content with students' cultural assets (Abdallah & Alkaabi, 2023). Importantly, these efforts should not be viewed in isolation from broader socio-economic realities. Many marginalized communities face forms of energy poverty, where access to affordable, sustainable power is limited or inconsistent. By linking solar-based STEM education to issues such as equitable energy distribution, housing policies, or historical infrastructural neglect, educators can help students see how science intersects with justice. Projects that invite students to investigate local solar energy use—or lack thereof—can empower them to envision science not just as technical knowledge, but as a tool for advancing collective well-being and socio-political transformation (Howard-Grenville, 2021).

Policy decisions are also important. Curriculum guidelines that promote a single, universal approach to science often overlook the potential impact of cultural or community-based methods (Harding, 1998). Educational policy could support local adaptation by allowing teachers to develop place-based modules within broad scientific themes such as solar energy, astronomy or ecology. When policy frameworks recognise that 'achievement' goes beyond standardised test scores, teachers can devote time to more open-ended, participatory and culturally inclusive approaches (Smith, Avraamidou, & Adams, 2022). For example, districts or ministries of education could fund projects in which students design solar-based technologies tailored to the needs of their communities, while exploring cultural narratives about the importance of the sun.

The cultural dimensions of the sun also intersect with broader issues of social and environmental justice. Growing concerns about climate change, drought and sustainable energy are closely linked to how societies use or interpret solar energy. Students learning about solar radiation might, for example, investigate local water shortages or the potential for solar desalination projects (Gong et al., 2021). In a culturally responsive classroom, they learn not just 'facts' about reflection or conduction, but also how different communities around the world understand and manage the sun's energies for collective well-being (Kapayou et al., 2023). This approach fosters a sense of agency and motivation. Students see STEM knowledge as directly relevant to their communities, fostering intergenerational connections and supporting activism or community engagement. However, implementing these strategies can be challenging. Teachers and students may encounter conflict when addressing deeply held beliefs or different interpretations of the sun. In some traditions, the sun may be seen as a sacred presence, while other students may see it as a purely physical phenomenon. Far from shutting down these discussions, culturally responsive approaches welcome them. Through respectful dialogue and 'loving critique', participants can explore how spiritual or mythological views can coexist with scientific explanations, or at least provide a meaningful cultural framework for learning (Barnard & Woodburn, 2024). This kind of negotiation helps students to develop metacognition about knowledge systems, avoiding a strict binary of 'science vs. culture' and instead seeing the complex ways in which these spheres intersect and inform each other.

Student assessment also needs to evolve. Traditional tests tend to ignore whether students have meaningfully engaged with the content or connected it to real-life contexts (Morris et al., 2021). Rather than relying solely on standardised measures, teachers can develop portfolios, reflective journals, group projects or oral presentations that capture the depth of students' interactions with the cultural meanings of the sun. For example, if students collaborate with community members on solar energy projects, their learning outcomes could be measured by how effectively

they integrate scientific data with local cultural knowledge, how well they communicate these insights to peers and family, and how thoroughly they reflect on the process (Weatherton & Schussler, 2021). In this scenario, academic achievement is closely linked to social responsibility and personal growth - in line with the 'rightful presence' idea of education as a shared, ethically grounded space.

Beyond K-12 classrooms, higher education institutions and STEM disciplines can benefit from incorporating the cultural dimensions of the sun. Universities often conduct extensive research on solar physics or renewable energy, but rarely partner with local indigenous or cultural groups to contextualise this research. By working with these communities - hosting joint seminars, co-designing research projects, or implementing solar solutions that respect local customs - universities can advance scientific innovation while honouring mutual learning. This commitment to 'cultural listening' can transform the institution's role from an aloof research centre to an engaged participant in community-based sustainability (Moore, Bryan, Johnson, & Roehrig, 2021). Such partnerships exemplify how scholarship can be both culturally respectful and academically rigorous.

The Case

Eight (8) middle school students from different schools voluntarily participated in this study (Figure 1). Through discussions, they explored solar oven and solar cooker designs, along with considerations about what could be cooked or dried using these devices. The participants joined the study through an open call, and all had obtained parental consent. Upon analyzing the design outcomes and rationales provided by the students, it became evident that individual differences and cultural backgrounds significantly influence solar-focused STEM activities.

Fig. 1. Students participating in the workshop and the working area.

Results

Analysis revealed that students' design choices and proposed applications for solar devices were deeply informed by personal and community practices: local culinary traditions led to suggestions for drying staple foods, recent migration experiences sparked ideas for novel materials, and everyday routines inspired unconventional uses such as hair drying. The thematic review also showed that cultural familiarity increased engagement and sense of ownership, while exposure to exotic food items fostered curiosity. These findings underscore the importance of integrating students' cultural assets into STEM activities to enhance relevance and motivation.

What Can Be Dried?

When students were asked, *"What can be dried using solar ovens?"*, their responses (Figure 2) provided the following insights:

- One student suggested drying *goose meat*, which is a staple food in the local region. During our discussion, they mentioned that their family already dries goose meat but traditionally by hanging it on a line without using a solar oven.
- Another student proposed drying *rose petals*, even though roses are not commonly grown in the region. When asked about the origin of this idea, they explained that their father had recently moved to the area for work but previously lived in a city renowned for its roses.
- A third student provided an unconventional response, suggesting the use of a solar oven for *drying hair*. When asked for their reasoning, they pointed to their long hair, explaining that they wash and comb it daily, which is time-consuming, and they were looking for an easier alternative.
- While most students suggested drying common fruits such as bananas, apples, and oranges, one student uniquely proposed *dragon fruit*. When asked why, they said they had never tasted it before but had seen it on television and were curious to try it.
- Another student suggested drying *marshmallows*. Their reasoning was that they had roasted them at a campfire before and wanted to experiment with drying them to see how the texture and taste would change.
- One student proposed drying *cheese* and justified this by expressing an interest in accelerating the production of cheddar cheese (a traditional cheese well-known in the region).

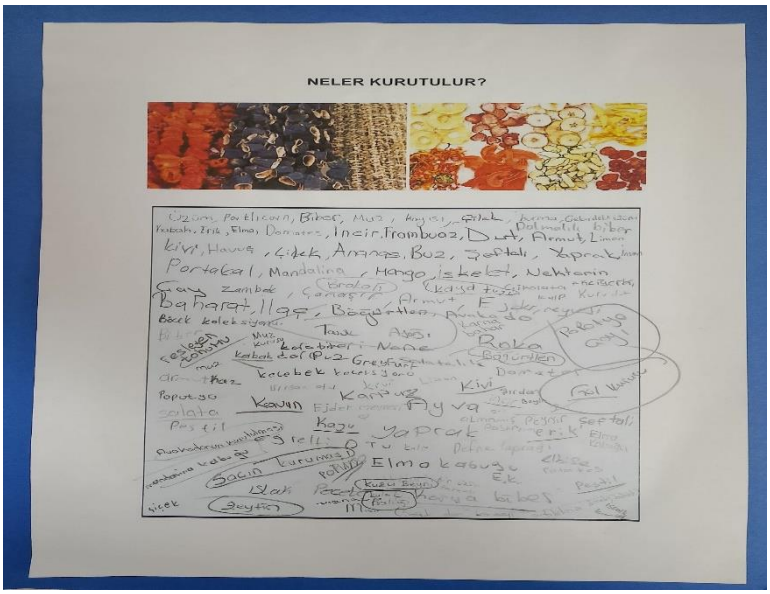

Fig. 2. Students' suggestions for drying various materials.

The students' responses reveal that their suggestions were deeply influenced by their daily experiences and cultural familiarity. Foods that are locally significant were the first to come to mind, as students were particularly curious about whether these familiar foods could successfully be dried. Based on these findings, it can be concluded that when selecting food items for STEM activities, they should either be culturally significant and widely recognized within the local community or exotic foods that introduce new cultural experiences. This approach fosters curiosity and increases students' sense of ownership and engagement in the activity.

In interpreting the findings from these eight participants, it is important to emphasize that this study is grounded in a qualitative tradition, where the goal is not to produce broad generalizations but to uncover context-rich insights (Hernandez, 2022). In qualitative research, smaller, purposeful samples are often used to capture depth rather than breadth, enabling a more nuanced understanding of participants' lived experiences and cultural practices (Beckett et al., 2022). Although some might suggest expanding the sample for stronger statistical power, such an approach would shift the emphasis from in-depth exploration toward more generalized claims. Here, the intention is to illuminate how personal, family, and community contexts shape students' engagement with solar-based STEM activities. By closely examining a limited number of participants, we gained a clearer window into how cultural norms, everyday routines, and individual motivations converge to inform learners' designs and perceptions.

Furthermore, the localized and culturally embedded nature of this study supports the decision to work with a smaller number of learners. Each participant brought a distinct socio-cultural background—ranging from valley life to recent migration—which offered rich examples of how diverse life experiences intersect with scientific and technological problem-solving (Guo-Brennan & Guo-Brennan, 2021). Larger samples could dilute such specific narratives, risking a loss of detail about how and why participants conceive of certain solar innovations. By prioritizing depth over breadth, we highlight unique, individualized insights that can be transferred to similar contexts rather than universally generalized. As a result, this tailored, context-sensitive lens supports the spirit of both Culturally Sustaining Pedagogy and Rightful Presence, ensuring that each student's voice is explored on its own terms rather than subsumed in a broader, homogenized set of data.

Intersectional Influences on Design Choices

Moreover, applying an intersectional lens revealed that students' cultural, geographic, and socio-economic positions intricately shaped their solar-oven design reasoning. For instance, participants with recent migration backgrounds emphasized portability and resourcefulness in their prototypes, whereas those from agrarian communities foregrounded local material use and seasonal considerations. Similarly, gendered experiences influenced engagement: female students often highlighted communal and collaborative aspects in their sketches, while male students more frequently explored technical modifications to enhance efficiency. These patterns underscore how overlapping identities—not just single cultural factors—inform learners' problem-solving approaches in culturally responsive STEM activities.

What Should We Cook with?

Students were introduced to a solar oven, a solar cooker, and other small solar-powered devices, which they had the opportunity to use. They were then asked to design their own devices using specially prepared sheets where they could both sketch and describe their ideas. Importantly, they were instructed not to look at each other's work. After completing their designs, they engaged in discussions about the feasibility of their proposals. The following observations were recorded:

- One student, who comes from a village located in a valley, suggested utilizing this topographical feature to solve winter heating issues. This idea was based on their firsthand experience of rural life.
- Another student proposed making jewelry items, such as necklaces, rings, and bracelets, out of glass, incorporating built-in drying compartments. Their interest in jewelry was a driving factor, and they believed that drying their own fruit slices in these accessories would ensure better taste and safety.
- One student suggested attaching jars to an airplane's wings to dry food while in flight. Upon further discussion, it was revealed that the student had recently taken their first airplane trip and had been deeply inspired by the experience.

While many students explored design ideas involving mirrors and lenses, the study demonstrated that their prior experiences and personal interests played a crucial role in shaping their proposals. This finding underscores that family and societal structures not only transmit cultural knowledge to children but also influence how they think and approach problem-solving.

A key finding is that the cultural significance of the sun is not limited to indigenous or specifically local communities. Migrant and refugee populations, as well as urban youth from diverse socio-economic backgrounds, also bring unique perspectives. For example, a student from a subtropical region who has recently moved to a northern city may notice dramatic differences in seasonal sunlight, which can spark reflections on climate, social structures and personal identity (Guo-Brennan & Guo-Brennan, 2021). A teacher using a culturally sustaining lens would encourage these observations by prompting an inquiry: "What does sunlight represent in your original home culture? How might that compare to local practices here?" This simple invitation can lead to deeper engagement with weather patterns, earth-sun geometry, cultural adaptation and the emotional significance of seasonal change. Students learn that their past experiences are not a barrier to success in STEM, but a source of ideas.

In many cases, local traditions related to the sun have scientific value, even if they are not codified in mainstream textbooks. A farming community's methods of using sun angles to determine planting times could illustrate advanced observational techniques. A fishing community's understanding of tides and sunlight could combine traditional ecological knowledge with oceanography. When these experiences are recognised as valid and integrated into the curriculum, they not only enhance the authenticity of STEM education, but also empower students to see their home

cultures as sites of knowledge production (Izam, Itam, Sing, & Syamsir, 2022). This empowerment aligns closely with rightful presence, which grants learners the right to reshape the academic narrative based on their lived realities.

Despite these benefits, there are often structural barriers to such practices. Teachers may worry about time constraints, institutional policies, or a perceived incompatibility between local knowledge and the standardised curriculum. However, if we look at STEM not as a one-size-fits-all approach, but as a malleable field open to multiple perspectives, these fears recede. STEM has historically been shaped by many cultures, from the mathematical contributions of Arab scholars to the navigational expertise of Polynesian communities. Highlighting the cultural roots of scientific ideas is a powerful way to legitimise the participation of all students in shaping the future of science (Ladson-Billings, 2021). Indeed, placing the sun at the centre can be a powerful illustration of how even universal scientific concepts come to life differently in different local contexts.

Community-based events or interdisciplinary projects offer opportunities for broader engagement. For example, a public "solar festival" can invite families, local artisans, and cultural practitioners to collaborate with students on solar-based demonstrations or performances (Rotar, 2022). This fosters intergenerational knowledge sharing and a sense that learning is not confined to the classroom but is a collective endeavour. Students who actively witness older community members sharing stories about shading, heat waves, or seasonal transitions gain a deeper appreciation for the living legacy of cultural knowledge. Such contexts also challenge any notion that STEM is an elite or exclusive domain, instead framing it as an open forum for everyone's perspectives.

For teachers, designing lessons around the sun can highlight key physics or astronomy content - such as solar radiation, photosynthesis, angles of incidence, or climate patterns - while exploring how different communities track sunlight or use solar energy for local survival and celebration. Students might interview family members about culturally significant solar rituals, document them in a digital format, and then compare their findings with scientific measurements of solar angles or daylength variations (Kim & Li, 2021). Such activities, which bridge personal and academic life, encourage students to co-create knowledge. They practise data collection, analysis, reflection and discourse, while drawing on intangible cultural values. In the face of these opportunities, certain tensions remain. Teachers and students may struggle with conflicting worldviews or fear the tokenisation of certain cultural practices (Mensah, 2021). The strategies offered by CSP and Rightful Presence emphasise reciprocity, empathy and collaboration in these discussions. Educators model how to hold multiple truths in productive tension, while acknowledging that not all cultural practices necessarily align with current scientific models. The essential shift is to approach these practices with respect for their social and historical meanings, rather than dismissing them outright or forcing them to conform to rigid scientific dogma. This approach encourages critical thinking: Students learn to question how science is socially constructed, who holds authoritative knowledge, and how new knowledge can emerge from cross-cultural contact and introspection (Beckett, Lu, & Sabati, 2022).

Assessing this kind of learning requires expanded metrics that go beyond discrete test items. Non-numerical indicators - such as the quality of class discussions, the depth of community engagement, or the creativity shown in linking cultural narratives with scientific theory - provide a more complete picture (Morris et al., 2021). Schools could include e-portfolios, reflective essays or group presentations that show how students integrate local knowledge, scientific concepts and creative problem solving. Teachers could look for evidence of developing mindsets: Has a student gained the confidence to challenge dominant narratives? Are they using their cultural background to generate new hypotheses about environmental sustainability or solar technology? If so, this indicates a successful alignment with the principles of Rightful Presence and CSP.

Global collaboration can also strengthen these efforts. Classrooms around the world can share observations of sunlight intensity, local myths, or historical sun-watching monuments through digital platforms (Shadiev, Wang, Wu, & Huang, 2021). By sharing data and stories, students gain cross-cultural awareness and collectively see the sun as more than a scientific topic. It becomes a symbol of intercultural dialogue, bridging languages, regions and identities. This fosters a sense of global citizenship in which scientific inquiry is combined with mutual respect and cultural preservation (Lippa et al., 2022). Whether students are comparing the desert sun of the southwestern United States with the more temperate sunlight of northern Europe, or exploring how the sun is understood in big cities versus rural communities, they realise that no single narrative can fully encompass the sun's significance.

Such inclusive work also links to current global concerns such as climate change, energy transitions and environmental justice (Lent, 2021). The sun is a powerful source of renewable energy, but solar technologies often raise questions about equitable distribution and local acceptance. Projects that invite students to investigate the use of solar panels in low-income neighbourhoods can address how cultural attitudes towards technology, historical

energy policies, or property issues influence the adoption of solar solutions (Caplan, 2021; Kapayou et al., 2023). CSP encourages them to analyse these complexities with empathy, and Rightful Presence invites them to propose new forms of ownership or community-led solar initiatives that better suit local contexts.

Challenges inevitably arise when trying to implement these ideals in real classrooms. Educators need time, resources, administrative support, and possibly professional development to deal effectively with the layered cultural and scientific content (Hernandez, 2022). Students, too, may need guidance on how to articulate or defend cultural perspectives, especially if they have previously been discouraged from bringing such perspectives into STEM spaces. Nevertheless, the ultimate promise of centering the cultural meaning of the sun is that it allows educators and students to co-construct a more inclusive, vibrant and purposeful form of STEM learning. Teachers become facilitators, inviting each student to explore how their unique histories and worldviews interact with fundamental scientific questions. Students realise that their cultural voices are legitimate in science, forging personal and communal agency (Sun, Wang, Wegerif, & Peng, 2022). In this sense, the sun is no longer just a star or an abstract source of energy, but a vehicle for connecting knowledge systems, bridging historical narratives, and igniting social imagination (Salimpour et al., 2024). From a Rightful Presence perspective, students do not simply conform to the existing boundaries of science; they extend or redefine these boundaries. As co-creators, they claim space for their cultural experiences and forge new meanings that speak to both local heritage and global science. Meanwhile, from a culturally sustainable perspective, these experiences are continuously supported, validated and woven into the curriculum - never reduced to a token 'multicultural day' or an anecdotal example.

Ultimately, the cultural significance of the sun can reshape how we perceive STEM at its core. Rather than a static discipline based on perceived neutrality, STEM emerges as a dynamic tapestry of human experiences, values and creative expressions. Educational leaders, policymakers, teachers and students can work together to embed local solar narratives, mythologies and practical knowledge into science education, ensuring that learning is not only academically rigorous but also personally and culturally resonant. This promotes a powerful message: Science belongs to all of us, and every learner has a rightful place at the table.

To enhance the readability and coherence of the text, it may be beneficial to introduce clearer subheadings or summary statements that bridge the theoretical sections with practical examples (Simanjuntak et al., 2022). Strengthening these transitions can help readers navigate the argument more easily while seeing precisely how concepts such as Culturally Sustaining Pedagogy and Rightful Presence manifest in real-world classroom scenarios. Maintaining a seamless flow between empirical evidence, theoretical discussions, and policy considerations ensures that the main messages remain both accessible and impactful to a diverse readership.

Conclusion

By integrating the cultural significance of the sun into STEM education, we create a compelling demonstration of how science can be more inclusive, reflective and transformative. The interplay of Culturally Sustaining Pedagogy (Alim et al., 2020) and Rightful Presence (Calabrese Barton & Tan, 2020) ensures that students' backgrounds, experiences and cultural practices become inseparable from scientific inquiry. The sun is no longer just an astronomical entity to be memorised; it becomes a shared medium through which students can observe their environment, reconnect with family and community narratives, and imagine new possibilities for scientific inquiry and community well-being.

Such an approach disrupts deeply ingrained notions of who has valid knowledge in STEM and challenges the idea that Western scientific perspectives occupy the only legitimate space in the classroom. By acknowledging diverse cultural practices - whether from indigenous, African diasporic or immigrant communities - educators foster a sense of belonging in science. Students learn that the knowledge passed down by elders or the spiritual meanings attached to cosmic events can sit alongside scientific explanations of solar physics, each contributing to a richer understanding of the world. But this model requires more than a superficial nod to cultural diversity: it requires structural changes in policy, teacher training and classroom assessment that position students as active participants with the right to reshape what science can look like. The ultimate goal is not simply to increase enrolments or test scores, but to raise a generation capable of combining cultural awareness with scientific rigour. When students see themselves as rightful contributors to STEM, they become protagonists in solving problems such as climate change, energy inequality and local sustainability. Their own stories, anchored in the universal relevance of the sun, empower them to see STEM as a tool for justice, identity building and community flourishing.

Beyond immediate classroom strategies, the implications of this study extend to policymaking and broader educational reform efforts. For instance, local and regional authorities can incentivize community-based solar projects that align with culturally significant practices, thereby fostering engagement and interest in STEM from a young age (Izam et al., 2022). Likewise, teacher education programs could integrate culturally relevant pedagogical modules, equipping educators with the skills to adapt curricula and assessments to diverse student backgrounds. Such structural support ensures that the inclusive methods highlighted here become a sustainable part of the educational landscape rather than a one-off initiative.

Far from being a mere academic ideal, the vision of "Illuminating Diversity in STEM" is a pragmatic necessity in an era of global uncertainty. The sun's universal light can be harnessed to strengthen cross-cultural dialogue, redefine scientific literacy and promote an ethical framework rooted in mutual respect. Through thoughtful, culturally responsive and rights-affirming pedagogical design, educators and learners can work hand in hand to make STEM education more inclusive and meaningful. In this sense, the sun is not just a celestial body, but a beacon guiding us towards a future where the culture, identity and aspirations of every learner shine equally bright. Future research could build on the foundations of this study by exploring how culturally embedded solar-themed STEM education operates across different age groups, geographic regions, and institutional settings. Longitudinal studies that track how students' perceptions of science evolve over time in culturally responsive classrooms would provide deeper insights into the lasting impact of these approaches. Additionally, comparative research between urban and rural contexts, or among students from different diasporic communities, could reveal valuable patterns about how place-based solar knowledge shapes STEM engagement. Mixed-methods investigations combining quantitative measures (such as science self-efficacy) with qualitative data (like student narratives) may offer a more holistic understanding of learning outcomes. By expanding the methodological and contextual scope, scholars can help solidify the position of culturally sustaining STEM education within mainstream educational reform efforts.

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