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Recasting the agreements to re-humanize STEM education

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The purpose of education is to understand and help address local and global problems to better society and the world. A key player in this endeavor should be STEM education, which has the potential to equip learners with the skills and knowledge necessary to address intersectional issues such as climate change, health and income disparities, racism, and political divisions. However, in this article we argue that despite the transformative potential of STEM education, it remains far removed from most people's lived experiences and is detached from the real-world social, political, and economic contexts in which it exists. This detachment not only perpetuates existing inequities by failing to meet the specific needs and reflect the experiences of these communities, but it also hampers STEM education's capacity to address the very local and global problems it is purported to solve. By remaining removed from the tangible, real-world contexts in which it exists, STEM education cannot fully harness its potential to better humanity. To address these issues, we propose humanizing STEM education by intentionally and explicitly grounding all work in the recognition of the inherent worth and dignity of all students, regardless of their background. We begin the article by critically examining the typically unspoken pre-existing assumptions or "agreements" that govern and dictate the norms of teaching and learning within STEM, ways of approaching framing STEM education that we often take for granted as necessary and true. We propose new agreements that expand the ways in which we think about STEM education, in hopes of making STEM education more accessible, inclusive, relevant, responsive, and reparative. Throughout, we deliberate on the notion of being human. We argue that to envision a future of humanistic STEM, one that is intentionally grounded in an ethics of care and equity for all, including the environment, it is necessary to continue to make visible and reimagine the unarticulated assumptions that underlie our current approaches to STEM education and practice.

KEYWORDS

recasting agreements, learning sanctuary, Eurocentric epistemology, humanism in STEM, scarcity, objectivity, pluralistic epistemology, abundance

Introduction

Situated within the special issue's theme, this paper extends beyond the conventional empirical study framework usually presented in Frontiers. Instead, it delves into theoretical exploration, grounded in empirically validated research, to offer a fresh perspective on the paradigms that shape our understanding of Science, Technology, Engineering, and Mathematics (STEM) education. The article explores three interconnected agreements: Eurocentric Ways of

Knowing, Scarcity, and Objectivity, as foundational lenses through which knowledge is approached, valued, and transmitted within STEM.

As the paper unfolds these ideas, readers are invited to engage with this philosophical dialogue, probing into the very roots of how we "know" and "be" within STEM, with a view to facilitating deeper understanding and fostering constructive dialogue within the community of scholars. The article calls for the field to expand its historically Eurocentric values, with its quantitative focus and emphasis on hierarchies, which both limits knowledge and perpetuates disparities, toward a more inclusive and real-world context-oriented approach.

The article is divided into four main sections. We first begin with a discussion about STEM's role in improving the human condition and the notion of humanizing STEM education. We argue that part of the reason STEM education is not reaching its potential of being relevant, responsive, and reparative is because of the current culture of STEM. The second section delves into that culture by examining the underlying assumptions or "agreements" that currently shape STEM education and that we often take for granted as the way in which STEM education and science as a whole have to be. These underlying values, which include the Agreement to Privilege Eurocentric Ways of Knowing, the Agreement of Scarcity, and the Agreement of "Objectivity," not only limit the effectiveness of STEM education—including the identity of students who participate and succeed—but also the practice of science itself and the knowledge it produces. By turning a critical lens onto these unstated agreements, we hope to begin a broader discussion about STEM education, one that empowers educators to cultivate a new narrative that fosters inclusivity, dignity, respect for diversity, social awareness and responsibility, and preparation for a sustainable future. The third section of this article, therefore, proposes new, alternative agreements that expand the current agreements and offer hope for a more effective, equitable, and humanistic approach to STEM. More specifically, we discuss the Agreement of Multiple Ways of Knowing, the Agreement of Abundance & Sustainability, and the Agreement to Center Humanity, Nature, and the World. The fourth and final section of the article ends with a discussion and an invitation to dream of and work toward creating a learning sanctuary.

STEM education and the future of humanity

As a society, we are dealing with overlapping and interrelated challenges–from climate change to health disparities; from profound income inequality to access to good education; from political divisiveness to unrelenting racism; and from mass shootings to mass incarceration. The purpose of education is, in part, to understand and help solve local and global problems in order to better society and the world. Yet higher education, including STEM education, typically remains far removed from most people's lived experiences and is often detached from the real-world social, political, and economic contexts in which it exists. This "sterilized" detachment can result in a narrow and limited view of what counts as "legitimate" knowledge, and can exclude diverse perspectives and approaches to STEM education. Importantly, by operating as a "sterilized entity," STEM higher education may inadvertently perpetuate existing inequities by failing to address the needs and experiences of marginalized and historically excluded groups.[1] These groups may not have access to the same resources and opportunities as those who are economically and educationally advantaged and empowered, perpetuating the disparities in STEM education and beyond. In order to tap into STEM education's transformative potential of being more holistic, inclusive, and socially conscious, we argue that we need to consider, imagine, and enact humanizing STEM education.

Humanizing STEM

What does it mean to center humanism in STEM education and practice? In the scientific world "being human" first and foremost refers to the characteristic of being a member of the species *Homo sapiens*, characterized by traits such as consciousness, rationality, and the ability to communicate and interact with one another. But being human is not merely a biological state–being human also involves social and cultural dimensions. The concept of being human encompasses broader ideas related to the human experience and the human condition, including qualities such as creativity, empathy, imagination, the ability to navigate the ambiguities and the complexities of the world around us, being in community with others, the capacity for self-reflection and self-awareness, and the need for personal growth and self-actualization.

Humanism[2] involves a philosophical and ethical stance that emphasizes the importance of seeing the "whole" person that includes a focus on agency, self-determination, and the inherent goodness, value, and dignity of *all* people. Humanism recognizes our interconnectedness and interdependence—to each other, to nature, and to the world as a whole (Veugelers, 2011).

Importantly, being human, while in large part involves "the possibility of taking responsibility for your own life and your own ideas," is about more than individuality—it requires societal responsibility. Veugelers (2011) writes: "A challenge in humanist thinking and acting is the linking of autonomy and humanity. Autonomy is not isolated individuality but it is the way a person relates to the other. It's the agency of the situatedness of people." Applied to STEM education, being human involves both making STEM education more humane, and also *our* responsibility as STEM educators to our students and to their humanity and success.

To humanize STEM is to intentionally and explicitly ground all of our work in our responsibility to recognize and respect the inherent worth and dignity of *all* of our students, regardless of their

1 Our critique that STEM is "sterile," that is detached from the messiness of the social and political realities of life, aligns closely with the notion of the "absurdity of neutrality" described by McKinney de Royston and Sengupta-Irving (2019) special issue of *Cognition and Instruction*. The authors in the special issue argue against neutrality and detached objectivity, asserting that educators and researchers should take a clear stand ("political clarity") on political and social issues. Political clarity, they contend, is informed by personal experience and ethical commitments, and leads to more human, rigorous, and relevant research.

2 Elfert (2023) contends that: "[T]he term humanism refers to the idea that education should contribute to the fulfillment of individual potential and empowerment – and therefore to the betterment of human lives."

background or field of study.[3] Toward that end, we must recognize the ways in which power dynamics, privilege, and social identities impact the way knowledge is produced and disseminated within academic settings;[4] we must also take steps to create more equitable learning spaces that promote deep and meaningful learning, wellbeing, generative dialogue, collaboration, and mutual respect within the academic community.

To humanize STEM necessitates, in part, that we wrestle with the contemporary, Eurocentric notion of what it means to be "human"–inherently self-centered and economically-driven, an anthropocentric focus that too easily casts aside the world in which we live and the many ecosystems and lifeforms that our planet supports.[5] Accordingly, we believe that in order to envision a future of humanistic STEM, one that is intentionally grounded in equity for all, including the environment, we must first make visible the many unarticulated assumptions that underlie our current approaches to STEM education and research. Those current tacit "agreements" both shape and limit STEM education and research and by extension, the humanity of our students and colleagues.

Our article turns a critical lens on those limiting assumptions that govern teaching and learning within STEM and proposes different "agreements" that not only do not replicate the present, but also set the stage for a more responsive, equitable, and reparative STEM education that will prepare our students to create a more just and sustainable future. By doing so, we can move toward a more transformative and humanizing STEM education system that honors and respects our students' diverse ways of learning, knowing, and being.

What are the "agreements" that shape STEM?

In order to look at these assumptions or "agreements," we will apply and build upon educational theorist Laura Rendón's seminal 2005 article "Recasting Agreements that Govern Teaching and Learning: An Intellectual and Spiritual Framework for Transformation." Rendón argues that higher education institutions have traditionally operated within a framework of agreements that have often been exclusive and inequitable, particularly for students from marginalized and underrepresented groups. Rendón's article aims to "expose the privileged agreements that govern teaching and learning in higher education." By questioning these traditionally accepted "agreements," Rendón (2005) offers the reader suggestions on how to rethink the existing structures that govern our educational system and align them more with our humanity.

Similarly, we argue that within STEM, there are unspoken "agreements" that govern what is valued in STEM, shape how STEM is taught, and influence the ways in which STEM approaches the challenges our society and our world face. Those agreements short-circuit our capacity to humanize STEM education. Following Rendón's framework, we identify and interrogate some of the privileged agreements within STEM and their consequences for both STEM education and how STEM fields create knowledge and operate in the world.

We have identified three such unspoken agreements that currently govern STEM (Figure 1):

1. The Agreement to Privilege Eurocentric Ways of Knowing.
2. The Agreement of Scarcity.
3. The Agreement of "Objectivity."

It is worth noting that these agreements and their accompanying consequences, corollaries, and mindsets build upon each other, intersect, and often overlap–our tripartite structure serves as a heuristic, a structure in which to examine the many ways in which these unspoken agreements play out within STEM education and the practice of STEM disciplines.[6] Similarly, this article is not meant to be a final proclamation about the agreements or values that govern STEM; we hope our work to be the start of a larger conversation about what we should value and prioritize.

Most importantly, while the focus of this article is to critique the often-unarticulated assumptions ("agreements") that underlie STEM education and research, we want to also recognize the beauty, power, and possibilities of these disciplines. We are *not* criticizing educators or scientists themselves. Rather, we are critiquing the field within which we operate with the hope to both expand our understanding of STEM education and research and empower those in STEM to enact a different narrative.

The Agreement to Privilege Eurocentric Ways of Knowing

The ways in which knowledge is produced, organized, and valued shape the way STEM views reality. While science historians regard the Arab Muslim scholar Ibn Al-Haytham (born in 965 in the city of Basra in Southern Iraq) as the inaugural advocate of the contemporary scientific method (Al-Khalili, 2015), STEM's current epistemology was forged during the 18th Century Enlightenment, a period of intellectual and cultural growth in Europe that was characterized by a focus on reason, science, and individualism (Shuttleworth, 2011). Centered on the perspective, values, and experiences of white European men of a certain class,

3 Veugelers (2011) who contends: "A challenge in humanist thinking and acting is the linking of autonomy and humanity. Autonomy is not isolated individuality but it is the way a person relates to the other. It's the agency of the situatedness of people. It implies the possibility of taking responsibility for your own life and your own ideas."

4 Kayumova et al. (2018) emphasize the importance of considering power dynamics when engaging in research. This means questioning who is producing the knowledge, why it matters, what methodologies are being used, and whose perspectives are included or excluded. The authors argue that by considering these "power-sensitive" questions, researchers can uncover often hidden power relationships and socio-political dimensions of learning.

5 For more on this Eurocentric attitude, see work of Wynter (2003). For example, "Unsettling the Coloniality of Being/Power/Truth/Freedom: Toward the Human, After Man, Its Overrepresentation--An Argument."

6 The three agreements, although distinct, are interconnected and arguably heavily reliant on the first agreement. That is, Eurocentric Ways of Knowing as an agreement sets a foundational worldview and methodology for how knowledge is approached, valued, and transmitted within STEM. As the underlying framework, it directly and indirectly influences the other two agreements.

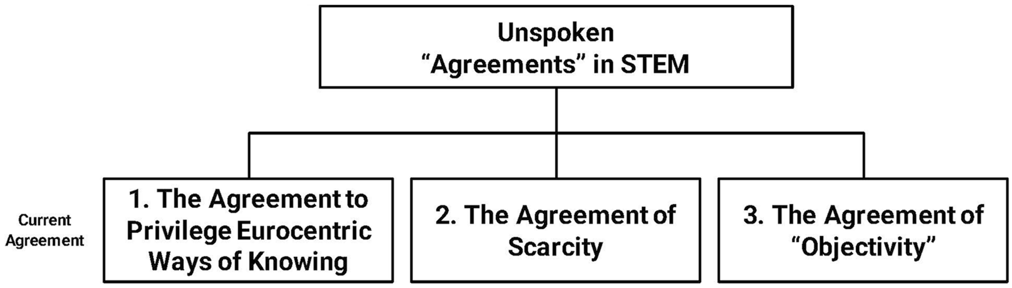

FIGURE 1
Implicit agreements currently governing STEM education and practices.

this Eurocentric epistemology has been dominant in western academic and intellectual circles for centuries, and it has shaped our way of understanding of the world and our place in it, particularly related to science (Mensah and Jackson, 2018). Kayumova and Dou (2022) note that in STEM education and in STEM in general, there is an "inextricable symbiosis between ways of being and ways of knowing." This "onto-epistemology" shapes both the way we teach STEM and the ways in which STEM views (and creates) reality both inside and outside of the classroom.[7] Our views of reality and knowledge in STEM are largely shaped by this historical and cultural context. And while our current scientific epistemology has many advantages, it is also limiting.

Of the three agreements we will discuss, this Eurocentric epistemology is the most significant, and shapes the other two agreements;[8] we therefore take some time to examine how this view shapes our thinking, particularly the approaches to knowing and the ideas it excludes. Philip and Azevedo (2017) argue that "the epistemological and ontological assumptions in science also make scientific knowledge partial and incomplete." Specifically, the Eurocentric mindset, intentionally or unintentionally, tends to marginalize other ways of seeing or knowing; often fails to see or value the diversity and richness of human experiences and cultures; often views other cultures as inferior; and often prioritizes the rights and experiences of the individual over those of the community.

One key limitation of a monocultural, Eurocentric epistemology is that it excludes and marginalizes the knowledge and experiences of people from non-European cultures.[9] For example, indigenous cultures often place a strong emphasis on oral tradition and spiritual connection to the natural world, which may not be recognized or valued within a Western scientific framework (Tuhiwai, 2021).[10] The exclusion of non-Western ways of knowing is often justified on the grounds that such information is "not scientific" or objective enough to be considered valid. However, this view fails to recognize that there are many different ways of seeing and understanding the world, and that different cultures may have their own distinctive ways of approaching knowledge.

By extension, the exclusion of other knowledge can lead to a narrow and incomplete understanding of the world. By prioritizing the knowledge and perspectives of one particular culture, Eurocentric epistemology not only fails to recognize the richness and diversity of human knowledge and experiences, but also is blind to its own limited ways of seeing and understanding reality. For example, Eurocentric epistemology has often failed to recognize the ways in which social and economic power dynamics, including cultural imperialism, have shaped the production and dissemination of knowledge. It can reinforce dominant narratives and perspectives, while marginalizing or silencing alternative voices–related to gender, class, nationality, or cultures, to name but a few–thus perpetuating power imbalances and injustices.

European colonizers often justified their conquest and exploitation of other societies by claiming that they were bringing "civilization" and "enlightenment" to "uncivilized" peoples. This justification was based on a view of the world that saw European culture as superior and rationalized its domination of other cultures, often bolstered by faulty scientific rationalizations (Said, 1978; Wynter, 2003; Fanon, 2008). Since its beginnings modern Western science, in the words of Rohan Deb Roy, has been "inextricably entangled with colonialism… [and] the legacy of that colonialism still pervades science today" (Roy, 2018). Relatedly, a

7 Kayumova and Dou (2022) argue that the dominant onto-epistemologies underlying science are "rooted in a European, White, masculine subject and his logic."

8 For example, The Agreement of "Objectivity" is in many ways a product of Eurocentric ways of knowing (as Kayumova and Dou, 2022, argue) and the Enlightenment, a time during which science writings became widely shared and distributed, and the ideal of "reproducibility" came into being.

9 Much of the "Science Education" literature, geared more toward K-12 classrooms and science learning, have argued compellingly that this Eurocentric focus alienates many science learners, invalidates their experience and contributions, and limits who is thought of as a "scientist" and who is excluded. For example, Kayumova and Dou (2022), citing Rahm and Moore (2016), note that "participation in in science learning requires engagement with dominant cultural, epistemic, and language practices, behavioral norms, and expectations that conflict with lived realities and sociocultural identities of youth from nondominant communities."

10 See Mays et al. (2023) writing about lack of recognition for Black scientists in STEMM. Also, Settles et al. (2020) who write about "Epistemic Exclusion" which "occurs through formal hierarchies that determine how scholarship is valued and the metrics used to assess quality, and through informal processes that further convey to faculty of color that they and their scholarship are devalued." And, Basu (2021) who talks about how monoculturalism reinforces disciplinary boundary.

Eurocentric mindset has historically been associated with the rise of capitalism, and to this day goes hand-in-hand with a decidedly economic approach to looking at the world and the role that humans play within it (Plys, 2013). This capitalistic economic view often sees people, cultures, nature, and the world in general as a means to an end.

This European domination and conquest that extended to the natural world often had its roots in science. In their article on "desettling" STEM education, Bang et al. (2013) assert that "normative descriptions of subject matter operate at what is referred to as the nature-culture divide where they border and define, usually in hierarchical terms, acceptable STEM understandings and practices, including relationships between humans, other organisms, and the environment." This means that traditionally accepted views and practices within STEM fields tend to enforce a division between nature and culture, often placing them in a hierarchical relationship. In turn, Bang et al. argue, that these divides and borders also restricted science itself: "These boundaries function ideologically to (a) restrict the content and form of science knowledge valued and communicated through education and (b) devalue and dismiss boundary-expanding forms of knowledge, experience, and meaning-making with which students approach scientific phenomena." This implies that the rigid adherence to a Eurocentric or Western perspective within STEM can hinder scientific progress itself.

Finally, Eurocentric epistemology typically values the experience and knowledge of the individual over that of the community or society as a whole. Western scientific research often focuses on the individual as the unit of analysis, rather than considering the social and cultural context in which the individual exists (Kimmerer, 2015). Additionally, the emphasis on rationalism values logical, systematic thinking over other forms of knowledge and understanding, such as intuition or emotion. This emphasis on individualism and rationalism can lead to a narrow and reductionist view of the world that fails to consider the complexity and interconnectedness of human experiences. We are not saying that privileging rationalistic, empirical ways of knowing are wrong–only that by limiting our work as scientists to a single Enlightenment epistemology we are limiting our ways of thinking about and understanding our world.

The Agreement to Privilege Eurocentric Ways of Knowing impacts STEM education and STEM research in inculcating three different but related attitudes and mindsets: Fear of Ambiguity, Quantitative Fetishization, and STEM's Superiority to the Humanities. First, this unspoken agreement inculcates a "Fear of Ambiguity" that can stifle creative and innovative thinking by discouraging the exploration of diverse perspectives and epistemologies. Second, it results in the "Quantitative Fetishization," where numbers, data, and statistics are seen as the *sine qua non* for advancing knowledge or making decisions. Third, the fear of ambiguity and the focus on quantitative methods leads to the notion of "STEM's Superiority to the Arts & Humanities," which often prioritize subjective, qualitative, or interpretive approaches, as opposed to STEM's seeming objectivity. These unintended but significant consequences of STEM's monocultural epistemology not only shape STEM education and research, but also limit both how knowledge is created in science and the ways in which science contributes to society (Figure 2).

Fear of ambiguity

Ambiguity and finding comfort within the unknown are critical to scientific inquiry because it allows us to explore diverse ideas, cultural perspectives, and alternative epistemologies. If we do not allow or cultivate in our students a healthy relationship with this lack of certitude, STEM will suffer, in that our scope of inquiry and problem-solving will narrow, ultimately stifling innovation. The fear of ambiguity is, in part, due to the hierarchical nature of Eurocentric ways of knowing and being, which itself is reflected in current STEM education policies and practices. For example, use of high-stakes testing within STEM assesses student's ability in the sciences based on regurgitation of facts, and neglects to assess critical thinking or conceptual understanding (Rucker, 2021). For this, many of our students feel the need to hide what they do not know with what they do know and bury sources of uncertainty.

One of the suggested reasons why students are uncomfortable with ambiguity lies in textbooks. Science and mathematical textbooks present clear-cut information about various principles (Emery et al., 2015). With this presentation of information, our students are given the impression that science is made up of concrete, indisputable ideas. Thus, when given the opportunity to practice on their own, many of our students may struggle accepting ambiguous ideas, as they are under the impression that science should be straightforward.

The quest for tolerance of ambiguity is not an easy one. Throughout the COVID-19 pandemic, it is abundantly clear that the public does not like ambiguity in science, especially in situations of concern and fear. Generally speaking, individuals want concrete answers. When scientists openly admit that their studies are a work in progress, the public often chooses to reject the science, rather than accept the researcher's response (Lissack and Meagher, 2021). Unfortunately, this tendency can encourage scientists to present incomplete or desired results to the public in response to political pressure, public concern, or recognition for finding a solution to a complex societal issue (Lissack and Meagher, 2021). Of course, public response is not to blame for poor science but, rather, when the perceived benefits of producing incomplete science outweigh that of executing good science, the behavior of researchers may be swayed to expedite their work, ignoring ambiguous information.

The problem with not feeling comfortable with ambiguity is not merely that scientists may too quickly jump to "definitive" answers; it is that a fear of ambiguity may cause unease during the scientific process, not allowing students and researchers alike to sit with and learn from that liminal space between not knowing and knowing. Rather than being a place for play and open experimentation, ambiguity can cause anxiety and fear–fear of not getting right, of not knowing, of not moving forward.

Quantitative fetishization

A corollary of this fear of ambiguity is the emphasis on quantitative data in STEM. At the heart of western science methodology is the scientific method, a systematic and structured approach to scientific inquiry and knowledge that involves formulating and testing hypotheses through observation and experimentation. It is this Eurocentric focus on empiricism that often leads to a form of "fetishization" of quantitative data, where measurement and numbers are viewed as the ultimate forms of knowledge and proof. And while quantitative data certainly play an important role in STEM, this focus can be limiting, and devalues the importance of qualitative data, subjective experiences, and intuitive understanding.

Numerical data are seen as the most valuable form of information because it is considered "objective," as it offers a form of data representation that supposedly cannot be distorted by researchers. Such quantitative research often uses standardized procedures to collect information, thus suggesting that the data gathered during such research

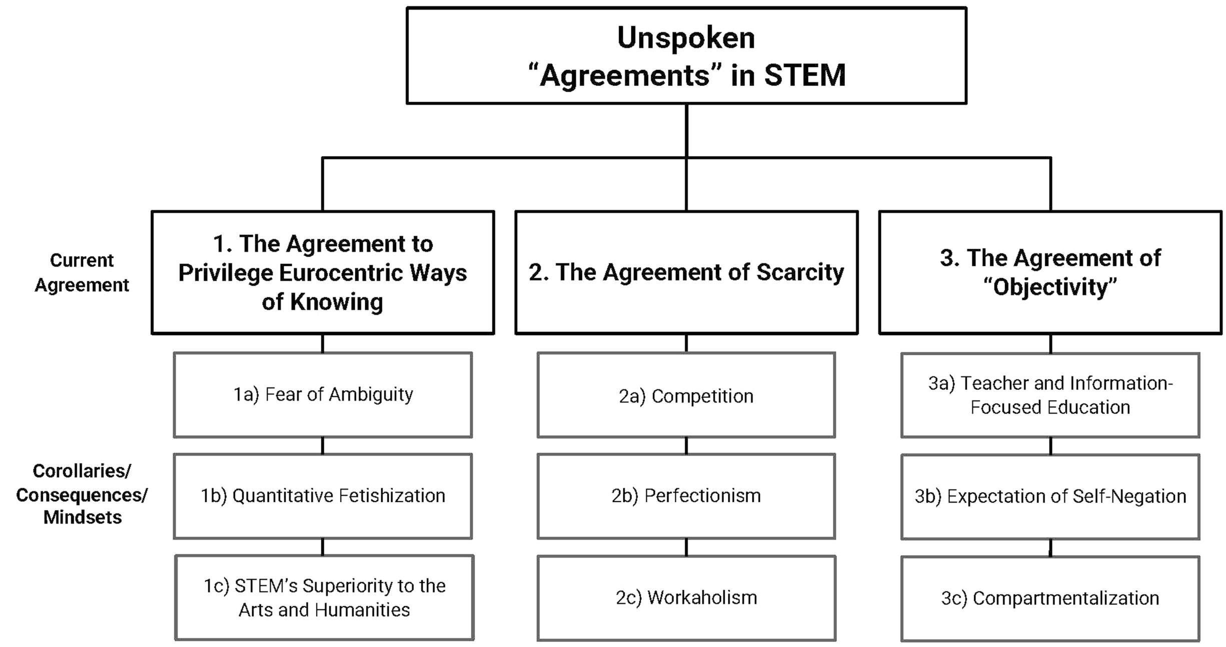

FIGURE 2
Implicit agreements currently governing STEM education and practices and their implicit or explicit consequences.

cannot be influenced by biases (Given, 2008). This notion is expressed in the popular idiom "Numbers do not lie." Only when research is based upon quantitative measures can it be seen as accurate and/or dependable (Given, 2008), and, today, regardless of where STEM fields are practiced, this methodology is how science proceeds.

Although quantitative reasoning is crucial to STEM, on its own, it leaves little to no room for types of evidence arrived at from other sources, such as critical feeling, imagination, philosophy, or the arts. The belief that quantitative data is objective and therefore superior—again, the Eurocentric mindset of hierarchies of ways of knowing--to other types of evidence can devalue qualitative data collection methods and, by association, other types of learning and knowing. By only focusing on the quantitative aspects of STEM knowledge, that which is reproducible with quantified evidence, we may fail to engage in physical, emotional, or spiritual ways of knowing, viewpoints and learning that could make our work and lives richer, helping people involved with STEM education and the sciences in general situate themselves and their work more meaningfully in the world (Hendricks, 1981).

For example, while the STEM curriculum may be embedded with quantitative analysis and problem solving, there is a profound lack of recognition of qualities of hope, endurance, beauty, or ethics (Imad, 2020a). These concepts and ideas, which may seem as if they are the purview of the humanities, are needed in STEM because they help promote a more holistic understanding of the world around us.

A 2018 survey at Pima Community College revealed that although students had practiced exercising critical thinking skills in their humanities courses, they felt unprepared to integrate this knowledge into their STEM courses (Harley and Imad, 2022). Just teaching a skill or concept in humanities courses does not guarantee the transfer or application of skills to other disciplines. Beyond quantitative skills, STEM also needs to teach about critical thinking and logical reasoning, because these skills are essential to the scientific process, from identifying problems to developing hypotheses, and from designing experiments to analyzing and applying data (Imad, 2020a). Without such critical thinking and logic skills, the scientific process can be distorted and is left open to fallacious and conspiratorial thinking.

Further, to ensure the transfer of these critical thinking skills into all aspects of life and education, it is essential that we provide our students with opportunities to exercise different ways of thinking and knowing in every class to teach them ways to apply these skills to a variety of situations, including in STEM courses (Harley and Imad, 2022). Thinking, including critical thinking, does not occur without the involvement of emotions, and it is perilous to ignore the role of emotions in learning and thinking. Our students need to be trained beyond critical thinking; we need to help them cultivate an inner-landscape of holistic critical practices such as critical feeling, critical imagination, and critical being (Harley and Imad, 2022). As STEM teachers and mentors, we also need to help our students understand and appreciate the relevance and utility of those skills.

Otto Loewi, a renowned physician and pharmacologist is known for his discovery of neurotransmitters. More notable, however, was how he came across the experiment design that ultimately led to his discovery and Nobel Prize: through a dream. In 1920, Loewi had a vivid dream of an experimental design to test his theory of chemical transmission using frog hearts. Upon conducting the experiment, his discovery revealed the communication between nerves occurs through chemical signaling, rather than electrical (McCoy and Tan, 2014).

While STEM nowadays prioritizes quantitative and numerical data, without considering other modes of thought, such as dreaming or creativity, scientific discoveries, such as Loewi's may not have come to be. And while we hear stories of scientists who "accept" dreams and intuition as sources of knowledge, we do not normalize it nor discuss it as a potential way of knowing. STEM as we know it tends to exclusively value acquired intelligence and knowledge. While acquired learning can greatly inform scientific practices, recognizing this type of intelligence alone is insufficient when humans all possess a sense of internal and intuitive knowledge from within (Hobson, 2000; Sadler-Smith, 2010).

Again, it is important to note that we are not arguing that the quest for clarity is in itself negative, nor that quantitative data and evidence should not be an important part of scientific inquiry and knowledge–we *are* arguing, simply, for a more expansive approach to knowledge in STEM, one that is open to a variety of ways of knowing, ways which can enhance the (hopefully already) rigorous process of creating knowledge in STEM. Without such openness, we may miss out upon many of the opportunities for growth, the application of new STEM knowledge in ethical and sustainable ways, and utilizing STEM to help solve the complex, "wicked" problems that humanity and the world are currently facing.

STEM's superiority to the arts and humanities

Science, Technology, Engineering, and Mathematics aversion to ambiguity and its emphasis on quantitative data can lead those people in STEM fields to view their education and knowledge as objective (see agreement 3 for more details on this idea). This "objective illusion" leads to the idea that good science is infallible–that the scientific method is superior to other disciplinary methods and so is the knowledge that STEM fields produce. Again, rooted in European notions of the superiority of "rationality" and the hierarchy of ways of knowing and being, the notion of the superiority of STEM to other fields and disciplines can undermine the value of interdisciplinary collaboration and stifle the development of a more comprehensive understanding of the world and its complexities.

This superiority of STEM currently plays itself out in a variety of ways in the western world. The specialization of labor in the United States workforce has promoted this division between different disciplines and approaches to knowledge (Whitehead, 2019), creating a separation between STEM and the humanities. One of the reasons individuals claim that STEM is "better" than the humanities is because of associations between STEM and career salary. Those employed in STEM fields have a higher median earning than those in non-STEM disciplines (National Science Board, 2022). With this information permeating higher education and the American workforce, the idea that STEM is the most valid path for students greatly presents itself in higher education.

Another reason for the often valuing of STEM and devaluing of the arts and humanities is that many people equate STEM with intelligence–a notion related to the idea that STEM quantitative methodology means that it is objective, real, or worthwhile compared to the humanities. Deborah Fitzgerald, the dean of MIT's School of Humanities, Arts, and Social Sciences suggests that within higher education knowing science now represents intelligence, similar to how knowing Shakespeare used to represent the same. Fitzgerald later goes on to say, "It's a placeholder for 'my kid is a smart kid'" (Mullin, 2019).

While studies suggest that students who enter higher education interested in STEM have a higher GPA than those who intend to enter different fields (National Academies of Sciences, Engineering, and Medicine, 2016), it is important to recognize that GPA is not the only measure of success or the only indicator of a student's potential in STEM. What about other factors such as passion, creativity, problem-solving skills, and collaboration which are all abilities crucial for success in STEM fields? Yet, because high school is unspecialized, those individuals who plan to enter STEM and may have higher GPAs than their non-STEM peers may have an internalized feeling of higher intelligence.

The outward and inward expression of STEM being the field of intellect establishes a hierarchy in education where STEM is the most elite discipline, and everything else operates beneath. In turn, this deepens the rift between different modes of thought and distances STEM from the humanities. This deliberate separation has negative implications for education and development of future scientific leaders.

The Agreement to Privilege Eurocentric ways of knowing, and by extension, fear of ambiguity, quantitative fetishization, and the notion of STEM's superiority, impacts our and our students' humanity in a variety of ways. We live in an increasingly complex and nuanced world that is full of uncertainty (Karacaoglu, 2021). To be human is to be able to not merely co-exist with the world around us, but also to interact with and thrive in it. To be human is to be able to experience empathy, compassion, joy, sorrow. To be human is to engage openly with and learn from the variety of human experiences and ways of understanding the world.

The Agreement of Scarcity

Although the discovery and creation associated with science and technology are unlimited, STEM education operates under an Agreement of Scarcity that fosters competition, nurtures fear, and cultivates a zero-sum mentality. We are using the term "scarcity" in as straightforward a manner as possible: the notion that there is not enough to go around, that some people will have and others will go without, that one person having or gaining something means another will go without or lose. In STEM education and research, this agreement is often reflected in the emphasis on high-stakes testing, grades, and rankings in order to create a hierarchy of student learners, which fosters a competitive and individualistic mentality among those students. This, in turn, can lead to a culture of fear and anxiety, where students are more focused on outperforming their peers than on learning and growing. This agreement can, among other things, lead to a focus on short-term goals rather than the broader and long-term goals of sustainability, limit collaboration and the sharing of knowledge, as students and researchers may be hesitant to share their ideas or work with others for fear of losing out on recognition or rewards.

The Agreement of Scarcity[11] is reflected in three mindsets or behaviors that tend to dominate STEM education and STEM: Competition, Perfectionism, and Workaholism. First, there is an often unnecessary and unproductive focus on "Competition" within STEM education and STEM–from getting into sometimes-limited spaces in

11 Over the past year, we have been able to gather preliminary data from undergraduate STEM students at various institutions asking them to examine those agreements and assess which ones(s) show up for them and impact them the most. We've also presented our work at various conferences to STEM educators. In both cases, with students and faculty, the agreement that resonates the most and has the most impact is The Agreement of Scarcity and its subcategories.

key STEM classes, to grading on a curve, from finding positions in labs doing research with a professor to entry into medical school and graduate programs. This mindset is what drives many of our students to focus on outperforming their peers rather than learning and growing together. Second, this competition also leads to "Perfectionism," which can set unrealistic expectations for students and add to the often-debilitating stress we see in many of our students in the STEM disciplines. Third, competition, the fear of failure, and striving to be perfect has led to a culture of "Workaholism," in which unreasonable dedication and hours are taken as the norm for students and professors alike. These unintended but significant consequences of STEM's culture of scarcity and zero-sum mentality not only shape STEM education and research, but are also leading to burnout, mental health challenges, and reduced capacity for creativity and even productivity (Figure 2).

Competition

Although competition in the classroom is not innately bad, creating intense and unsupportive competitive environments can create an unwelcoming and hostile setting for students (Hughes et al., 2014). One setting familiar to many STEM students that illustrates this kind of unproductive competition is the General Chemistry classroom. "Gen Chem" is often one of the largest classes in colleges and universities, as it is a prerequisite course for many more specific degrees and courses in STEM fields (Arnaud, 2020). Such courses are often very competitive and high-pressure, and also serve as "gateways," not only to higher-level chemistry courses but also as required prerequisites for other STEM majors, from biology to neuroscience to other general health sciences, including medical school.

One of the contributing factors to this fierce competition in chemistry and other gateway courses is the presence of norm-referenced grading, where students are graded against their peers, rather than a predetermined set of standards, using a bell curve-shaped model, rather than grading off of correctness of response (Hughes et al., 2014). Some students will score higher than the mean and some lower, but this grading method ensures that the majority of the class will not earn an A. As students are forced to compete with one another for their grades, they often lose sight of achieving an authentic mastering of content when trying to beat out their peers for the coveted A-grade (Hughes et al., 2014).

This type of approach to grading can discourage many of our students from collaborating because they may feel in competition with their peers over grades. It is important to note that while gateway courses can serve as an important entry point, they also "weed out" poor performers to allow "the cream to rise to the top" (Epstein, 2006), while providing limited resources to support those who may be struggling (Chang et al., 2008). In other words, gateway courses can also act as bottlenecks and create barriers to equity in higher education, especially for minoritized students from historically marginalized and underserved communities.

In addition, competitiveness can be detrimental to many students' learning and success–as well as their wellbeing. In a study of engineering students, those in electrical engineering programs, which are particularly competitive, had a negative correlation with mental health (Deziel et al., 2013). For over three decades we have known that "higher achievement, more positive relationships, and better psychological adjustment result from cooperation than from competitive or individualistic learning" (Johnson et al., 1991). Cooperation has, in fact, long been a basic principle of effective undergraduate education: "Good learning, like good work, is collaborative and social, not competitive and isolated. Working with others often increases involvement in learning. Sharing one's own ideas and responding to others' reactions improves thinking and deepens understanding," write Chickering and Gamson (1989). The use of collaborative teaching methods is known to help promote retention of underrepresented students in STEM (Hughes et al., 2014), and ultimately facilitate a healthy learning environment.

Another major contributor to the competition between students occurs when students plan to apply to medical school or graduate school. When there is a high number of pre-medical students in a class, the classroom competition seems to be amped-up, especially when norm-enforced grading is practiced. This elevated level of competition is fueled by the competitive nature of medical school admissions across the country (Hughes et al., 2014). In the 2022–23 application cycle, the Association of American Medical Colleges reported that there were 55,188 applicants, and 23,810 acceptees, with around 43% of applicants accepted each year (Association of American Medical Colleges, 2022). Students who are highly motivated to attend medical school after completing their bachelor's degree feel that they need to be as accomplished as possible to be seen as a competitive applicant when applying for a medical program. Thus, within STEM classrooms, students not only compete with other potential medical school applicants, they also see themselves in competition against all of their peers, regardless of whether they share similar post-graduate plans. In turn, this situation creates the "pre-med phenomenon," when pre-med students can unintentionally create a negatively competitive environment in the classroom.

Although some pre-med students report that a competitive classroom environment helps them engage with their courses, the majority of students in classes report that the heightened competition has been detrimental to their success (Hughes et al., 2014). While a toxic competitive classroom environment can affect student success across the board, competition has been seen to most highly affect populations historically underrepresented in STEM, where high attrition has consistently been problematic (Dewsbury, 2020). For these individuals, the heightened focus on individual performance can exacerbate the sense of racial isolation, creating an unwelcoming and unsupportive environment (Hughes et al., 2014). The lack of belonging and collaboration that competitive classrooms bring to STEM students makes these fields feel hostile to many students, ultimately preventing the future pursuit of a STEM degree.

Notably, this competition does not just occur between students—it is also seen between scholars. In academia, particularly in research universities, the "publish or perish" sentiment dominates higher education. The publish or perish principle states that for an academic to continue receiving employment by their respective institutions, they need to publish rapidly and consistently (Moosa, 2018). This creates competition between academics to publish quickly, even at the expense of quality and content of work produced.

Although having some form of pressure to publish and contribute to one's field can be valuable to one's career advancement, professors can have difficulty balancing research with their other responsibilities. In an institutional culture where scholarly achievement is the *sine qua non*, there may be little merit granted for activities beyond research, such as teaching and mentoring students, particularly of undergraduates. Such a system places a greater reward upon

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producing groundbreaking research than for exceptional teaching, placing emphasis on the professor as a researcher, rather than the professor as an educator (Rawat and Meena, 2014). With the applied pressure, time, and effort required for faculty members to produce work, students at institutions may suffer the consequences, as they are forced to compete for their professor's attention. Under this framework, research and teaching are needlessly put in direct competition to each other, and the students may take second place to the professor's work (Moosa, 2018).

Perfectionism

In the process of developing the lightbulb, Thomas Edison said, "I have not failed. I've just found 10,000 ways that will not work." STEM is built upon the foundation of learning from failure; however, Edison's conception of learning and failure has faded within institutions over time. In many ways a result of the needlessly competitive nature of STEM, the perfectionist tendencies in STEM can be attributed to both the type of students who are encouraged to study STEM disciplines, as well as the growth of the importance of standardized tests in secondary education. Unfortunately, for many students studying STEM, the competition for grades, the fear of being compared poorly to their peers, and the need to compete for limited internships and places in graduate school, make failure not an essential part of the learning process—and the scientific method—but feel as if it is possibly a career-ending event. Indeed, there are some things in STEM that are scarce, that students and STEM faculty do have to compete for. And, our STEM community contributes to the intense competition and fear of failure in the field by allocating those scarce resources, like internships or funding, based on measures that reward perfection, such as high GPAs and test scores, or affiliation with prestigious institutions. The notion of the scarcity of STEM opportunities and ways to succeed means that the quest for perfectionism may feel like the only way forward for many students entering STEM.

The role of perfectionism in academic success among students in STEM fields is well documented and, although much of it is beyond the scope of this discussion, impacts different students in different ways, especially related to their social identities. Rice et al. (2013a) showed that female students tend to experience more perfectionism than male students and compared to their female counterparts, the perfectionism trait in men did not notably influence their academic performance or their confidence in their academic abilities. In addition, female students who exhibit maladaptive perfectionism[12] tend to perform worse in their STEM courses while those who exhibit adaptive perfectionism tend to perform well academically in their STEM courses (Rice et al., 2013a). STEM students with strong perfectionistic tendencies have a more difficult time coping in academic settings when stereotypes related to their gender, race, or ethnicity are emphasized or made apparent (Rice et al., 2013b). Female maladaptive perfectionists, in comparison to their male counterparts, have a higher likelihood of experiencing significant levels of stress (Rice et al., 2015; Lin and Deemer, 2019).

The body of psychological research on perfectionism underscores the nuanced role it plays in academic outcomes, in this case, in the context of gender and STEM fields. It highlights the differential impact of adaptive and maladaptive perfectionism on female students' academic performance. Furthermore, the studies illustrate the intersecting influences of perfectionism and stereotype threats, emphasizing how societal pressures can exacerbate the challenges faced by perfectionistic students, especially those who are from marginalized groups.

A recent book by Thomas Curran, an expert on the psychology of perfectionism, links perfectionism to the pressure to succeed, noting that "Perfectionism is not a personal obsession—it's a decidedly cultural one" (Curran, 2023a). In an interview with Sarah McCammon (Curran, 2023b), Curran links "the pressure to be perfect" to growing inequality. Talking about his working-class background and growing up in a consumerist culture where he felt shame about not having "stuff," he says of his own perfectionist tendencies: "I was overcompensating for that upbringing all the way through my young adult years where I was constantly trying to lift myself above other people, trying as hard as I can not to let that background define me and try to, I guess, elevate myself out of that. And, of course, that meant a lot of pressure." Curran's research singles out two key characteristics of perfectionists that can make it *difficult* for them to succeed—both of which relate to the culture of STEM: first, perfectionists "work unsustainably hard" (see below, "Workaholism"); and, second, they are "world-class self-sabotages." His research shows that when met with a difficult task, non-perfectionists who fail the task upon their first try continued with the same amount of effort, or even tried harder, on their second try; highly perfectionist people, however, "did the opposite." That is, "[t]heir effort fell off a cliff because what they were doing is they were trying to preserve their sense of self-esteem by withdrawing themselves from the activity," states Curran, "knowing that the anticipated guilt, shame and embarrassment of that initial failure was so fierce that they simply did not want to experience it again."[13] Curran's research perfectionism as a cultural phenomenon has implications for STEM: rather than viewing perfectionism as a personality trait or personal obsession, the current competitive culture of science education itself may be creating a feedback loop of overwork and failure. Understanding the complexities of failure and success can help educators create more inclusive learning environments that better support mental well-being, promote equity, and foster resilience among all students, especially those from diverse backgrounds.

A contributor to this change in attitudes about failure from the time of Edison is due to the No Child Left Behind (NCLB) Act, the

12 Perfectionism can be divided into two distinct categories: adaptive and maladaptive (neurotic) perfectionism (Hamachek, 1978). Adaptive perfectionists have a tendency to strive for flawlessness without impinging on their self-esteem, and they find satisfaction in their tireless efforts (Stoeber and Otto, 2006). On the other hand, maladaptive perfectionists harbor a tendency to seek unattainable objectives and exhibit dissatisfaction when these are not accomplished (Blatt, 1995).

13 Curran (2023b) continues: "And in their minds, you cannot fail at something you did not try. And you see this in all sorts of self-sabotaging behaviors, not just complete withdrawal, but also things like procrastination and avoidance, where perfectionists are pulling themselves away from doing these really difficult tasks because they are managing, essentially, their anxiety of falling short." In the interview Curran also notes of consumerist culture and income inequality the pressure to succeed in fields that give people access to a comfortable way of life, singling out "tech, medicine, law, finance."

federal government's initiative to "improve" educational achievement across the country (DasGupta, 2015). This act created a series of rigorous standards for schools to meet in reading and mathematics—failure to meet these standards could result in school closures and/or job losses for educators, placing a great deal of pressure on both teachers and their students to succeed on these high-stakes exams (DasGupta, 2015). These changes ultimately led to the shift from teaching-to-learn practices to test-based education. Although this policy was well intentioned, it has left profound impacts on education across the nation, particularly for the sciences. In this case, educators often teach to test, and science curriculum takes the back burner to classes heavily emphasized on these high-stakes exams, namely reading and math (Griffith and Scharmann, 2008).

Nowhere is this correlation between testing well and pursuing a STEM degree more apparent than on the ACT, one of the predominant national standardized tests taken by students when applying to college. The ACT claims to assess students' comprehension of English language, reading comprehension, mathematics, and scientific reasoning. In each of these various areas they offer "benchmark" scores that correlate with the chances of a first-year college student receiving a certain grade in the corresponding college course. For example, if a student receives a benchmark score of 18 on the English portion of the ACT that means that they have a 50% chance of receiving a grade of "B" or higher in their college English composition course. These benchmark scores vary, with the ACT Mathematics (which predicts minimum grade in college algebra) and ACT Science (college biology) benchmark scores being 22 and 23, respectively (ACT Inc., 2018). However, on the ACT STEM questions, a benchmark score of 26 is required to meet the same level of the probability of a "B" or higher in college classes such as calculus, chemistry, biology, physics, and engineering. The ACT claims that its STEM scores can help predict not only student success in first-year STEM courses, but also student persistence in STEM fields, their GPAs, and whether or not a student ultimately graduates with a degree in STEM (Radunzel et al., 2015).

The ACT organization explains that the difference in benchmark scores is because it creates a higher standard "because the first-year college courses popular among STEM majors tend to be more difficult, as a result, higher ACT scores are needed to have a reasonable chance of success in those courses" (ACT Inc., 2018). Those who meet or exceed the ACT's set benchmark of 26 in STEM are considered "more likely than those who do not succeed in a variety of STEM-related college outcomes" (Allen and Radunzel, 2017), which proves to be true even after considering student's interest in STEM or high school coursework (Radunzel et al., 2015). With high stakes exams, such as the ACT, reporting that students' success in STEM fields is dependent upon test scores, students can become discouraged from pursuing a STEM major, as they are set up to believe that they will not be able to do well or succeed in the field (Rucker, 2021). Consequently, the emphasis on test scores can disproportionately affect underrepresented student populations in STEM, including women, racial minorities, and those of lower socioeconomic status, as these groups tend to score lower on the SAT or ACT exams, which can further perpetuate the narrative that these individuals do not belong in STEM fields (Rucker, 2021).

While standardized testing is a significant factor, they are not entirely to blame for perfectionistic tendencies in STEM. Previous work suggests that science courses systematically assign lower grades to students compared to that in humanities fields (Epstein, 2006). For students who are driven by achieving high grades, the bluntest form of tangible academic success–and one, we admit, that can carry a great deal of weight in many contexts–STEM's emphasis on "tough" grading standards can discourage many students from pursuing degrees in the sciences.

It is important to note that perfectionism is not exclusively a bad trait. Previous work suggests that perfectionism can be positively associated with psychological wellbeing (Geranmayepour and Besharat, 2010) and allows individuals to derive pleasure from completing difficult tasks (Schweitzer and Hamilton, 2002). However, perfectionism is problematic when it is neurotic perfectionism—a type of perfectionism associated with profound concerns about making mistakes or fear of judgment from others, among other characteristics (Geranmayepour and Besharat, 2010). Research with a group of university students in Australia revealed that those with neurotic perfectionism (also known as maladaptive perfectionism) are prone to experiencing symptoms of depression, anxiety, and stress, likely as a result of internalized self-criticism (Schweitzer and Hamilton, 2002). Previous research on perfectionism shows that there are a series of pathological consequences associated with perfectionism, including mood disorders, eating disorders, anxiety disorders, personality disorders (Geranmayepour and Besharat, 2010), as well as depression (Schweitzer and Hamilton, 2002). Rice et al. (2015) showed that STEM students have higher levels of maladaptive perfectionism, which is associated with higher levels of mental distress, which can lead to attrition, isolation, and even suicide (Lipson et al., 2016; Daker et al., 2021; Kalkbrenner et al., 2022).

The emphasis on "getting it right" on high-stakes testing, both before students enter college and after in STEM gateway courses, as well as the often-unproductive perfectionism of many students interested in or studying STEM, shapes not only who chooses to pursue STEM degrees, but also the wellbeing of those who do. In many ways the competitive mindset (scarcity of opportunity, grades are key, testing is competitive, only the best make it) and the perfectionist mindset (high grades and test scores matter, achievement is key, learning is high stakes, failing is not acceptable) form a vicious cycle, where they feed into and reinforce each other, creating a hamster wheel of STEM education from which students cannot escape.

Workaholism

In article of Beardslee and O'Dowd (1961), "The College-Student Image of the Scientist," they write: "There emerges a picture of the scientist as a highly intelligent individual devoted to his studies and research at the expense of interest in arts, friends, and even family." Has this view of scientists as "workaholic"–and the expectations that accompany it–really changed in the 60-plus years since that article was published? Corollary to the mindsets of competition and perfectionism, workaholism seems to be one of the ways those striving to succeed in STEM address and embody the fear of scarcity—under the belief that there is never enough time and too much to do, students in STEM may find themselves working constantly to stay ahead.

"In addition to the usual work-day schedule, I expect all of the members of the group to work evenings and weekends. You will find that this is the norm here at Caltech" wrote Professor Erick Carreria, Professor of Chemistry at California Institute of Technology (Caltech) to his postdoc in a now infamous 1996 letter (Carreria, 1996). Carreria then proceeds to emphasize that a lack of a demonstrated work-ethic will lead to termination of the recipient's position: "I receive at least one post-doctoral application each day from the United States and around the world. If you are unable to meet the expected work-schedule, I am sure that I can find someone else as an appropriate replacement" (Carreria, 1996). Although Carreria has publicly stated his own growth and evolution as a mentor and a scientist and has distanced himself from his younger self who wrote and sent that letter, the letter continues to hold a light to the type of work culture promoted in STEM fields, especially in elite postdoc programs, such as that at Caltech.

Similarly, in another letter by P.G. Gassman in 1988, sent to the members of his research group, he states, "I feel that anyone desiring to become a good organic chemist should be putting in a minimum of 60 h per week in improving their knowledge and ability spent in the area of organic chemistry" (Gassman, 1988). In STEM fields, students and academics are expected to demonstrate a high level of commitment to their field, not only to earn their position, but also to maintain their academic standing. Although these letters may seem to articulate rather extreme perspectives, the notion of dedication and beyond-typical expectations for time spent working, especially for graduate students and postdocs, is common. And while the Carreria controversy may be over 2 decades old, the debate about work expectations and hours continues today.

A common stereotype of a scientist is a man working through the night, thinking, not feeling, relentlessly pursuing his work, creates a damaging narrative that suggests that scientists prioritize their work over everything else (Limas et al., 2022). In academia, it is often thought that working overtime is the only effective way to demonstrate passion and commitment to your work (Limas et al., 2022). This image of the "workaholic" affects who enters STEM as well as who is viewed as successful. For students hoping to earn a degree in a STEM discipline, the academic culture ingrained in these disciplines tells students that "not everybody is good enough to cut it" (Epstein, 2006). This competitive mentality pushes students to either put all of their energy into their education, or leave STEM disciplines altogether.

The Agreement of Scarcity with its zero-sum mentality, and by extension, competition, perfectionism, and workaholism can impact our and students' humanity in a variety of ways. When we unknowingly embrace this attitude, we can set an example for our students that can devalue empathy, ethical considerations, personal wellbeing, and mental health. When the culture of STEM education normalizes competition and workaholics, we inadvertently lead our students to neglect their personal identity and self-worth. If their entire identity is based on their work and productivity, it can be challenging for them to see their value outside of their academic achievements. Prioritizing competition and achievement over cooperation and wellbeing can lead students to feel inadequate, low self-esteem, and a lack of fulfillment in life–all of which will necessarily impact their humanity.

The Agreement of "Objectivity"

The Agreement of "Objectivity," is an idea that permeates STEM education and influences what is valued in STEM and as well as how STEM fields are taught. Kayumova and Tippins (2016) reassess traditional approaches to science education, particularly those that adhere to strict dualistic conceptions such as mind/body and reason/emotion, perpetuating a view of science as an entirely objective, bias-free endeavor devoid of personal subjectivity or emotion.[14,15,16] Thus this agreement presents STEM fields as being impartial and therefore neutral fields that exist independently of social and cultural influences, and is intimately connected to the Agreement to Privilege European Ways of Knowing and reinforced by the notion that quantitative methods are the gold standard for knowledge production ["quantitative fetishization" (1b)]. Although closely related to European, hierarchical ways of valuing knowledge, because the notion that STEM fields are "objective" operates in such powerful ways within science disciplines themselves and in the academy as a whole (not to mention the world at large), we are examining it as its own separate agreement. STEM's emphasis on "objective" empirical data can be powerful but also problematic: STEM methodology often disregards the ways in which social and cultural factors shape scientific research and knowledge production. Knowledge is not created in a vacuum but is always shaped by the interest, values, and perspectives of those who conduct research and interpret data. Additionally, the methods we use to collect and analyze data are themselves often influenced by social and cultural factors. Feminist philosopher Sandra Harding's seminal work interrogating objectivity emphasizes that knowledge is inherently shaped by the social situation of the researchers. She criticizes the concept of neutral objectivity and refers to it as the "God-trick," an attempt to observe the universe with complete impartiality. She acknowledges traditional science's ability to eliminate social values across cultures but argues that it cannot identify the shared social concerns and interests of all observers. It is noteworthy to mention that for Harding marginalized groups, such as women and feminists, have an advantage in spotting biases within the scientific community. As such, For Harding (1993), incorporating the standpoint of marginalized groups is essential to maximize objectivity in research.

The Agreement of "Objectivity" impacts STEM and STEM education in three different but related ways, encouraging: a Teacher- and Information-Focused Education, Expectations of Self-Negation, and Compartmentalization. First, STEM's "Teacher- and Information-Focused Education" prioritizes teachers and their disciplinary

14 The authors invite us to consider the work of Zembylas (2003), who encourages a departure from such dichotomies and promotes the understanding of emotions and affect as being entwined with the cultural, historical, and epistemological contexts of education. Importantly, these contexts are portrayed as areas of both control and resistance.

15 By drawing attention to the dualistic thinking endorsed in traditional scientific methodology, particularly the separation of mind/body and reason/emotion, Kayumova and Tippins (2016) asks us to examine the Eurocentric roots of these ideas. Dualistic thinking has its roots in European Enlightenment thought. This period was characterized by a shift toward scientific rationalism and empirical evidence, and the idea of an objective reality that could be discovered through reason and observation became a cornerstone of Western scientific thinking. In this context, objectivity was seen as a critical quality that allowed for unbiased observations and conclusions. Science was considered a neutral process of discovery, free from the personal beliefs, emotions, or cultural contexts of the observer. This idea of objectivity is an aspect of Eurocentric ways of knowing because it was heavily influenced by European philosophical and cultural values of the time.

16 See also Hodson (1993), Walls (2014), and Sheth (2018).

knowledge over learners and their lived experiences. Second, the ideal of "objectivity" fosters "Expectations of Self-Negation Self-Negation" leads to the depersonalization of STEM for students, undermining their individuality and their ability to make personal connections with the material. Third and finally, the idea that science is always "objective" encourages "Compartmentalization" of knowledge and the practice of science, removing it from the lived experiences of those students and practitioners, prioritizing the final product over process and discovery, including student self-discovery and personal development. The result of the Agreement of "Objectivity" not only makes STEM education less effective than it could be, but also leads STEM ethos to focus more on short-term goals rather than long-term sustainability and holistic development (Figure 2).

Teacher- and information-focused education

The traditional STEM education puts the teacher at the center of the learning process, which makes typical STEM courses information- rather than learner-focused. The professor too often becomes the focus of STEM information and "learning," both literally, during lectures, and metaphorically, as the arbiter of knowledge and learning (Mensah and Jackson, 2018). As a result, this approach can create a one-sided and passive learning environment, where students are expected to absorb and regurgitate information rather than actively engage with and apply it. By placing an emphasis on objectivity, STEM education often positions teachers and authoritative sources of information as the ultimate arbiters of knowledge and truth. This approach can inadvertently devalue the importance of our students' personal experiences and cultural backgrounds. Students may feel excluded if their experiences and perspectives do not fit into the traditional STEM framework.

We are not arguing the importance of learning information; we do believe, however, that given the most recent information about teaching and effective learning that much of STEM education could do better.

In the STEM curriculum, especially in introductory science classes at colleges and universities, many professors continue to heavily utilize lecture-based learning, a method often used because it allows professors to present a high volume of content to a large number of students (Rucker, 2021). By placing heavy emphasis on the quantity of content taught, students are limited in their ability to ask questions and engage meaningfully with the material (Petersen et al., 2020). This passive approach to learning places on the students the responsibility of gaining a conceptual understanding of the material and to integrate the knowledge needed to succeed without the benefit of actively engaging with the concepts and materials (Rucker, 2021). Although students are typically encouraged to attend office hours, the professor's role in teaching often seems to end outside of class time.

When there is only one person responsible for the spread of knowledge in the classroom, in this case, the professor, only a single line of reasoning can flourish (Tompkins, 1990). This approach to teaching has long been critiqued because it creates an imbalanced dynamic between students and educators where teachers have all the answers and students ask the questions (Hendricks, 1981). Brazilian educator Paulo Freire describes this teaching method as the banking model of education, where knowledge is seen as a gift bestowed upon the student by the educator, i.e., the possessor of knowledge (Freire, 1968).

In this form of banking education, students are too often treated as passive receivers of knowledge (Schorr et al., 2004). Ultimately, this type of teaching suppresses the opportunity for creativity within students and stifles the development of critical consciousness (Freire, 1968). One study in which researchers observed the teaching in science classes found that in almost half of the classes, students were found to talk directly with the teacher and not with other students about the material, showing how teachers often serve as the center of academic learning (Schorr et al., 2004). Most students who choose to leave STEM cite uninspiring and ineffective classroom instruction and environment as their reason for leaving (National Academies of Sciences, Engineering, and Medicine, 2016).

Part of the high attrition rate in STEM fields is likely the result of a profound lack of active learning strategies typically used in teacher-centered classrooms. Studies suggest that regardless of STEM discipline, active learning strategies can help raise students grades by half a letter and improve retention by 55% compared to lecture-based instruction (Freeman et al., 2014), showing how allowing students to have a stronger role in their education can improve learning and performance outcomes. Active learning in STEM courses can not only increase student learning in general, it can also narrow the achievement gap in our courses experienced by traditionally underrepresented and excluded students (Theobald et al., 2020; Sandrone et al., 2021).

Effective educational experiences also help students build and nurture relationships with their peers (Felten and Lambert, 2020)—something not easily done in a teacher- and information-centric lecture hall. To move away from packing students with facts and instead, fostering a dialogue in the classroom, it is critical to listen to student voices both in and outside of the academic setting (Dewsbury, 2020). Ultimately, as Dewsbury (2020) and others contend that STEM education is not about teaching STEM and pushing tons of content on students; it is about teaching students how to learn, how to think critically and holistically, and how to problem-solve efficiently and ethically. By prioritizing these skills, students are better equipped to navigate the complexities of the world and make informed decisions that positively impact their communities. Additionally, these skills help promote lifelong learning and empower students to continue growing and adapting as new challenges arise.

Science, Technology, Engineering, and Mathematics is a naturally active discipline–not mostly about reading and writing, like many disciplines, but about doing, about active experimentation and engagement. STEM courses thus call for an active approach, namely through hands-on or lab-based learning. Previous research suggests that to foster a productive learning environment for students, labs should include realistic task situations, implement various academic disciplines, and feature social interaction (see, for example, Sandrone et al., 2021). By integrating these skills into coursework, higher education can better prepare students for a career in STEM (Admiraal et al., 2019). While both reading and writing skills are needed, at its core, STEM requires active experimentation and engaging in the course material, whether one works in the medical field, in a lab, or anywhere in between. STEM is all about practice–doing STEM, actively–whether in a lab or in a medical field–so focusing on the learner makes the most sense.

Expectation of self-negation

Self-negation is the act of denying or suppressing one's own thoughts, feelings, and experiences in favor of an external standard or expectation. Given the teacher- and information-centric learning process typical in many STEM classes, the unwritten agreement of objectivity can also contribute to a culture of self-negation and depersonalization within STEM, where students are encouraged to divorce themselves from their own experiences, values, and perspectives in the pursuit of objective knowledge. This can result in students feeling detached from their work, less motivated to learn, and less likely to see themselves as an integral part of the scientific process.

Effective educational experiences also help students build and nurture relationships with their peers, which in turn helps them develop a healthy sense of self (Felten and Lambert, 2020)—something not easily done in a teacher- and information-centric lecture hall where students are asked to bring their brains and little else.

The result is that we often expect students to leave the world behind them when they enter the classroom and concentrate solely on the course material (Imad, 2020a). This unspoken expectation of self-negation results in the undermining of students' individuality and their ability to make personal connections with the materials and others around them. Our depersonalized approach to STEM education can lead to a sense of disconnection and disengagement from STEM among students who do not see themselves reflected in the traditional STEM canon or who feel that their experiences and perspectives are not valued. This can lead to feelings of isolation, anxiety, and a lack of belonging, which can negatively impact student mental health and academic success.

When our students suppress their emotions and experiences in order to conform to STEM's standards of stoicism, it can lead to feelings of inadequacy, low self-esteem, and even, a lack of meaning and purpose. This suppression and isolation can foster a misconception for both faculty and other students that all students are self-sufficient and without hidden struggles, such as mental health issues. Expecting students to hide their emotions and internal struggles can contribute to the development or worsening of anxiety, depression, and even suicidal thoughts.

And research shows that even when we have mental health interventions in STEM education, they typically focus on what students can do to help themselves, not what the institution can do to support students (Limas et al., 2022). In order to make learning as meaningful and effective as possible for our students in STEM, as well as foster their sense of wellbeing, we need to invite students' whole selves into our classrooms and our labs. Being human is relational and so is learning. Learning is a deeply relational process that involves not only the acquisition of new information but also the integration of that information into our existing knowledge, values, and experiences. To do so, we must necessarily be able to connect with ourselves so we may connect new information to what we know, who we are, what we value, and to the larger community and the world (Schwartz, 2019).

Compartmentalization

Taking the focus off the learner along with the resultant expectation that "the self" is negated during both the educational process and for reasons of "objectivity," can result in an unhealthy compartmentalization in both students learning STEM and the practitioners in STEM fields. One result of this compartmentalization is that we try to separate STEM as a field of knowledge and the lives of those individuals learning and practicing STEM. This compartmentalization can also lead to a focus on obtaining specific results, with less emphasis on the learning process and the journey of growth and self-discovery. This approach can discourage our students from taking risks, asking questions, or exploring alternative ways of solving problems. By prioritizing the final product, not on the process nor the people actually learning and doing STEM, STEM education may inadvertently discourage creativity, critical thinking, and interdisciplinary learning.

When we focus on achieving specific outcomes and products rather than developing a more holistic integrated understanding of STEM. For example, STEM education often focuses on training students in specific skills necessary for specific jobs rather than also fostering in them a deeper understanding and appreciation of the role of STEM in society.

This compartmentalization has also exacerbated the mental health crisis because students may experience increased stress, anxiety, and burnout due to the pressure to produce results and conform to expectations. In other words, the separation of personal and professional identities can contribute to feelings of isolation and a lack of support, as students may struggle to find balance and meaning in their lives beyond their work. Indeed, a high proportion of students in graduate school in general report mental health struggles–some figures report that graduate students are about six times more likely than the general population to have depression–and scholars have recognized that there is a "mental health crisis" plaguing students in graduate STEM programs specifically (Wilkins-Yel et al., 2022).

The agreement of objectivity, and by extension, being information-focused, requiring some form of self-negation, and asking students and practitioners alike to compartmentalize their lives, impacts our and our students' humanity in a variety of ways, decentralizing the human beings and the humanity that are and should be at the center of STEM. This false objectivity and its consequences lead to a culture of separation which necessarily dehumanizes our students by focusing on their ability to memorize and reproduce information, rather than on their unique perspectives, experiences, and personal growth. Furthermore, the agreement of objectivity and its associated compartmentalization of knowledge and individual experiences, reduces our students' ability to see the interconnectedness of different areas of knowledge and the impact of STEM fields on society and the environment.

Recasting the agreements that govern STEM education and practices

As stated earlier, these agreements have far-reaching impacts on our individual and collective humanity. For example, Eurocentric ways of knowing, if universally applied, can inadvertently diminish the validity of diverse cultural perspectives and knowledge systems. The scarcity mindset promotes a competitive environment, which can affect interpersonal relationships and societal structures. And, the prioritization of objectivity can lead to an undervaluing of personal and subjective experiences, emotions, and creativity.

It is not sufficient to merely recognize the shortcomings within STEM education—it is critical to find ways to engage the challenges STEM faces in order to help make these fields more inclusive and productive. At the beginning of this article, we stated that while our central objective is to examine the implicit assumptions that underpin STEM education and their unintended consequences, we also acknowledge the inherent value, potential, power, and magnificence of these disciplines. We want to reiterate that our aim is not to denigrate or disparage educators or scientists themselves, but rather to critically evaluate the prevailing paradigms and conventions of the fields of STEM. By doing so, we hope to broaden and deepen our comprehension of STEM education and empower those involved in STEM to effectuate a much needed transformative, humane, and inclusive narrative.

We want to make clear that STEM's unstated agreements and the myriad ways they play out in STEM education and the practice of STEM are not in themselves essentially flawed or invalid—they are simply limiting. There is great value in European epistemologies and methodologies; *sometimes* scarcity can be real and an effective driving force for excellence and innovation; and "objectivity" can be an important, often aspirational and powerful approach to knowledge in our very polarized world. We are not proposing that we get rid of the scientific method or quantification. *Rather, we are asking that we recognize that these unstated agreements, and their resulting mindsets and corollaries, often carry with them unintended consequences related to how STEM is taught, who succeeds and who fails within STEM, how STEM creates knowledge, and what impact STEM has on the world.*

In her article, Rendón (2005) suggests that it is important to "recast" the agreements in higher education by fundamentally rethinking and restructuring the way that institutions operate and interact with their students, faculty, and communities. One key aspect of recasting agreements in higher education is the need to prioritize equity and inclusion and meaningful participation in all aspects of the institution's operations. Within STEM education, it is important both to recognize and to reframe these agreements so we can move from an intervention approach to a prevention approach to best serve STEM students and the pressing, wicked problems that the world faces.

We posit that recasting the current, unwritten agreements in STEM will humanize STEM education by: (1) asking STEM to incorporate a diverse and more nuanced human experience and world view, allowing STEM education and fields the opportunities to explore the full range of what it means to be human; (2) challenging those of us in STEM to not be in hierarchical competition with one another, but rather to work together--a collaboration that is important for human cohesion and the overall wellbeing of society; and (3) emphasizing the real-world implications and ethical dimensions of scientific and technological developments. With that, we propose that STEM education needs to consciously create new "Agreements."

To start off the process, we offer three such "recasted" agreements and how they might potentially improve not only STEM education but also the practice of STEM as a whole. It is important to note that our suggested new agreements are corollary to but do not necessarily address point-to-point or replace directly the three current agreements we identify above.

We believe that STEM education and STEM practices would be improved by three new, explicitly stated "Agreements" (Figure 3):

1. The Agreement of the Power of Multiple Ways of Knowing: Personal, Disciplinary, Historical, and Cultural.
2. The Agreement of Abundance, Multiplicity, and Sustainability.
3. The Agreement to Center Humanity, Nature, and the World.

These agreements not only would help transform STEM education, making it more equitable and just, they also would eventually influence the ways in which STEM exists in the world: the identities of the people in STEM fields, the prime concerns and values of the practitioners of STEM, and the approaches and priorities of the ways in which STEM operates in communities and the world. Rather than STEM education for the privileged few who meet certain criteria,[17] and many of the benefits of science extending mostly to those already advantaged, rethinking these agreements will help transform both STEM education and the ways in which science operates in the world. Such changes means that the ways in which science is practiced and the knowledge it creates can be more textured and complex, better reflecting, supporting, and sustaining its diverse inhabitants, both human and beyond. These new agreements have the potential not only to humanize STEM education the science in general, but also to transform science in a way that it can better address many of humanity's most complex challenges and problems: access to food, clean water, and health care; global warming and the depletion of our planet's resources; even out of control consumption, consumerism, and inequality.

Below we briefly elaborate on the "recasted" agreements, and follow them with suggestions on their potential implications for STEM, as well as specific practices that model and support the new kind of thinking that each agreement represents.

The Agreement of the Power of Multiple Ways of Knowing: Personal, Disciplinary, Historical, and Cultural

First, we argue that STEM education and STEM disciplines can greatly benefit from engaging with other ways of knowing, including personal, disciplinary, historical, and cultural. Similar to Kayumova and Dou (2022), who call for STEM education "to engage in different ways of being, knowing, and relating to our shared world," we propose a shift in focus from privileging Eurocentric ways of knowing to recognizing and embracing the value and power of diverse perspectives and knowledge. "What we currently understand as scientific practices," write Kayumova & Dou, "remains embedded in science-related institutions, advantaging … white ways of being, knowing, and relating to the world." We posit that by recognizing the importance of different disciplinary, cultural, social, and historical contexts, we can improve STEM education, diversify STEM epistemologies, and gain a deeper understanding of complex issues and challenges facing our world.

Multiple ways of knowing might include disciplinary knowledge beyond STEM, the idea of different intelligences (see Harley and Imad, 2022), as well as ways of knowing from non-European cultures and non-Western peoples or historically minoritized or marginalized groups. To enact the Agreement of the Power of Multiple Ways of Knowing, and in order to expand STEM's conception of what it is to know and what counts as evidence, we invite STEM educators to explicitly (Figure 4).

17 For example, science educational researchers, Kayumova and Dou (2022), whose work in part focuses on the subjectivity of the youth science learner, argue that the "humanization" of science and science education begins with turning to racialized youth with multiple, insurgent identities, who human(ess) and dignities have been oppressed, ridiculed, erased, and/or deemed illegitimate."

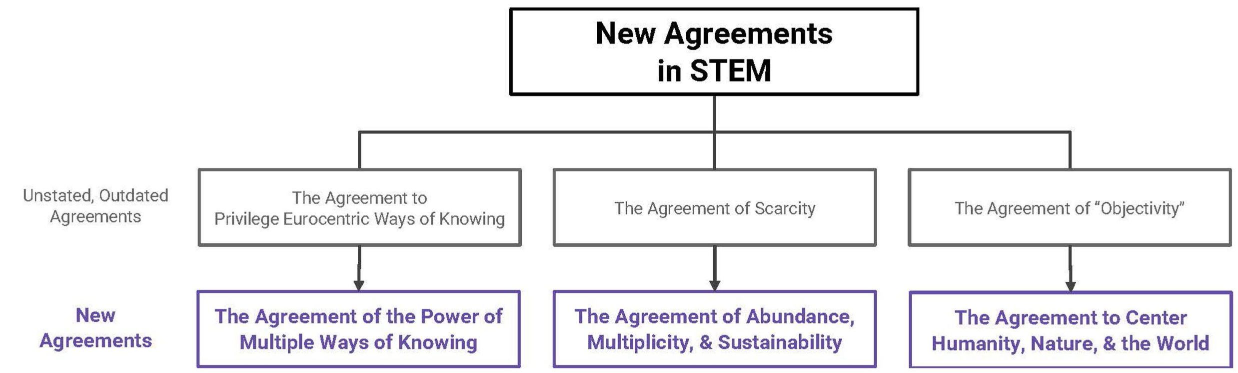

FIGURE 3
Recasting the old agreements in order to enact a culture of STEM that is grounded in pluralistic epistemology, community and abundance, and the symbiocene.

1a. *Be open to other types of evidence and ways of knowing, especially approaches that challenge STEM's established norms and values.* Nasir et al. (2021) argue that "Too often, classrooms reflect a commitment to hierarchies where diverse ways of being, knowing, and doing are viewed as deviant and necessarily inferior.[18] We can model this openness for our students by incorporating diverse perspectives and alternative ways of knowing into the curriculum and creating a learning environment that fosters curiosity, broad-mindedness, and acceptance. For example, ask students to consider what they are learning in some of their non-STEM classes and how that might apply to what they are discussing or doing in your STEM course. Or consider assigning a reading from *Braiding Sweetgrass*, where botanist Dr. Robin Wall Kimmerer beautifully shares with us glimpses of the wisdom of Indigenous epistemology and methodology. Or invite your students to co-create an assignment based on the work of Montgomery (2021)'s Lessons from Plants and how we can learn from plans about resilience, adaptability, and diversity.

1b. *Recognize and prioritize the ethical and historical implications of STEM education and research, particularly in relation to social justice issues and marginalized communities.* We can model this ethical and historical mindset for our students by examining the social and cultural contexts in which scientific research is conducted, and by centering ethical considerations in STEM education. For example, when discussing the concept of cell line consider assigning an article about the history and ethical consideration of HeLa cell line.

1c. *Acknowledge the subjective nature, fallibility, and human influence on scientific inquiry and those involved in STEM.* We can model the importance of our individual and collective humanity for our students by promoting critical reflection and self-awareness, and by recognizing the role that personal values and biases can play in scientific inquiry. For example, consider offering a case study that examines and problematizes the quickness with which health practitioners make assumptions about correlation between race and hypertension.

18 See also Annamma and Booker (2020) and Spencer et al. (2020).

This recasted Agreement of the Power of Multiple Ways of Knowing is crucial for STEM education and disciplines because it will cultivate an inclusive, receptive, and expansive approach to understanding the world around us and how we produce and apply knowledge. Such expansiveness can help us better address the complex challenges facing humanity and our world and develop more holistic, nuanced, and sustainable solutions to local and global problems.

The Agreement of Abundance, Multiplicity, and Sustainability

Second, we argue that both STEM education and STEM disciplines are enhanced by an attitude of abundance as well as a focus on making both the educational and scientific process sustainable. We propose a shift in focus from privileging scarcity and zero-sum mentality toward a focus on collaboration, iteration, available resources. An abundance mindset encourages students to focus on what they have rather than what they lack. This can encourage generosity and a willingness to share resources with classmates, which can strengthen community and create a sense of interconnectedness. We posit that by embracing abundance, we can foster a more humane, collaborative, and sustainable approach to STEM education and knowledge production.

To embody the Agreement of Abundance, Multiplicity, and Sustainability, we invite STEM educators to explicitly (Figure 4):

2a. *Focus on community and collaboration, by fostering a sense of cooperation and support among STEM learners and practitioners.* We can model community and collaboration for our students by articulating to them why learning is relational, social, and emotional and by cultivating peer-to-peer learning. For example, consider reducing some of the contents in your course and designing group poster assignments where students work together to present (and co-learn) on materials that you did not cover in class.

2b. *Appreciate that learning is an iterative process that involves making mistakes, persisting through challenges and setbacks.* We can model learning as a process for our students by creating a learning environment that encourages experimentation and risk-taking, and by valuing the process of learning over the end product. For example, consider assigning a sticky problem for your students where you ask them to not so much give you the correct answer, but rather to consider all the ways students may struggle to solve the problem. In other words, focus on the mistakes students make; in doing so you are modeling how mistakes can help us learn.

2c. *Recognize that learning takes time, and there are optimal conditions for deep and sustained learning that we need to support as much as possible.* We can model effective and sustainable learning for our students by working with your students to co-create a learning environment that meets and supports individual needs, including providing resources and support to promote deep learning. For a straightforward example of this type of co-creation, consider creating an anonymous google form where you ask students what support they need to empower themselves to learn *and* also what support they will bring to help their classmates continue to learn. A more complex and sustained example of such co-creation is the "Being Human in STEM" course created by a group of Amherst students that sparked a national movement to rethink aspects of STEM education.[19]

This recasted Agreement of Abundance, Multiplicity, & Sustainability is crucial for STEM education and disciplines because it promotes a more collaborative, generative, inclusive, and sustainable approach to how we interact with the world around us and how we generate and apply knowledge. A culture of multiplicity recognizes and celebrates diversity in all its forms, including diversity of opinions, experiences, and identities—key changes to making STEM more humane. Such a culture can foster greater understanding and empathy by asking students to learn to see things from and appreciate different perspectives, which can lead to more creative solutions and a deeper understanding of complex issues. By embracing abundance and focusing on available resources, we can foster a more equitable and supportive learning environment that values the process of learning and growing.

The Agreement to Center Humanity, Nature, and the World

Third and finally, we argue that STEM education and STEM disciplines need to *explicitly* center humanity, nature, and the world.[20] We propose a shift in focus from privileging objectivity, compartmentalization, and product to encouraging students to bring their authentic selves into our classrooms and our labs. By valuing students' unique experiences and perspectives, we can create a more inclusive and empowering learning environment. We posit that by centering humanity and by cultivating intellectual empathy and ethical reasoning, we can foster a more responsible and accountable approach to STEM education and knowledge production–one that

19 For more information about the Being Human in STEM Initiative, please see Bunnell et al. (2021, 2023) and visit https://www.beinghumaninstem.com.

20 Shifting from the Anthropocene to the Symbiocene echoed by Albrecht (2015) and Mead et al. (2023).

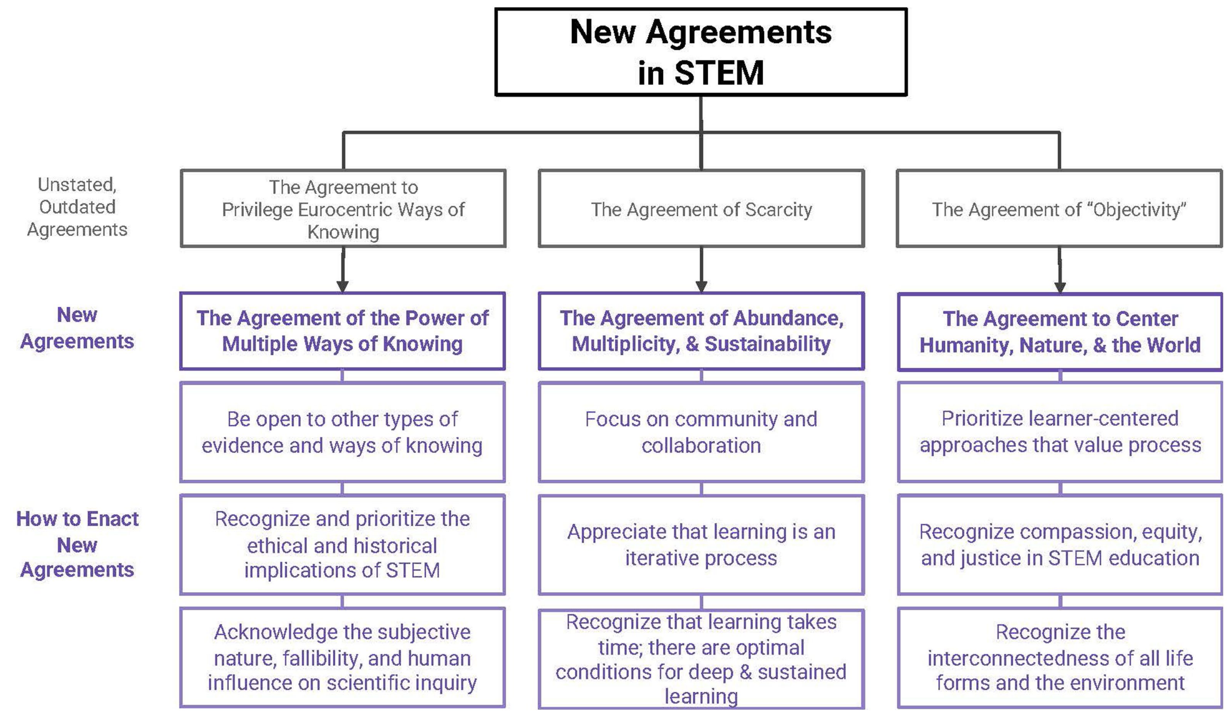

FIGURE 4
Suggested ways to enact the new recasted agreements.

intentionally and explicitly considers the implications of STEM priorities and policies for individuals, groups, nature, and the world.[21]

To embody the Agreement of Centering Humanity, Nature, and the World, we invite STEM educators to explicitly (Figure 4):

3a. *Prioritize learner-centered approaches that value process and experience over results and products.* We can model this learner-centered approach for our students by creating a learning environment that values the individual experiences and perspectives of STEM learners, and by emphasizing the process of learning over the end product. For example, consider using language like co-creation of knowledge and ask your students to use stories from their own experiences and backgrounds to offer analogies or applications for the content and skills they are learning in your class.

3b. *Prioritize compassion, equity, and justice in STEM education by centering and teaching students about the heart and love.* We can model a more compassionate, equitable, and just approach to STEM education for our students by intentionally imparting intellectual empathy, humility, and ethical considerations into your STEM curriculum. By emphasizing the importance of social justice issues in STEM research and development, we increase the chances of STEM making a positive impact on the world not only for a select few, but for humanity as a whole. For example, consider discussing with your students the history of Descartes's "I think, therefore, I am," and his dualistic philosophy (mind versus body) upon which so much of our western science rests upon. Then share with your students the emerging evidence about the heart and the role it plays in thinking and decision-making. Importantly, our current Western understanding of the role of the heart in the human experience echoes that of Indigenous teaching.

3c. *Recognize the interconnectedness of all life forms and the environment and that science without humanity will be humanity's, and our world's, downfall.* We can model this interconnectedness for our students by promoting a more critical view of scientific advances that carefully considers the implications for new substances and technologies. The world is full of examples where science has contributed products, additives, and technology that may fit well into our late capitalist economic models but have done unintended but immeasurable damage to human health, animal habitats (including our own), and the planet as a whole. STEM education and STEM leaders cannot leave the ethics of the knowledge, processes, and things we help create to other people–we must take responsibility to think globally and sustainably about what we contribute to society. To share such global thinking with your students, choose something that science helped create–such as plastic–and ask them to trace its history: why it was so appealing, the disposable convenience it embodied, how its proliferation fit into our economic system, and what we are now dealing with environmentally as a result. Have them consider how plastic could have been rethought, using science, from the beginning, to be less of a threat to our planet's wellbeing.

This recasted Agreement of Centering Humanity, Nature, and the World is crucial for STEM education and disciplines because it can promote a more responsible and accountable approach to STEM education and knowledge production and application. By centering humanity and promoting intellectual empathy, we can create a more inclusive and empowering learning environment. By centering the ecosystem and ethical reasoning, we can help create scientists who value the interconnectedness of all life forms and the environment, promoting a more sustainable and responsible approach to STEM knowledge production.

Rethinking STEM education and practice

Inspired by the scholarship of Rendón (2005, 2014), we hope that these recasted STEM agreements can help guide STEM education and practice so we may begin to place humanism and care[22] at the core of what we do as educators, scientists, and practitioners.

By questioning and challenging the implicit assumptions and values that underlie the way we currently teach and practice STEM, we hope that this article will help start a variety of conversations within and across many STEM departments and disciplines. Our thoughts are preliminary, and we are aware of the limits of our critique of the current unarticulated agreements that dictate STEM education and STEM; our analysis may contain overstatements or errors, and our thinking, without a doubt, is incomplete.[23] Of one thing we are certain–that, articulated or tacit, these agreements have consequences, both intended and unintended, that need to be carefully considered in order for

21 While the Agreement of the Power of Multiple Ways of Knowing might include ways of knowing from Indigenous, non-European cultures, or non-Western peoples or cultures that center nature, such alternative approaches to knowing are necessarily environmentally or holistically focused. The Agreement to Center Humanity, Nature, and the World, however, is about moving beyond the hierarchical, anthropocentric lens to a more holistic, symbiotic approach toward both humans, nature, and the world. While the some of the knowledges in the former agreement may take that more holistic, symbiotic, interdependent approach toward nature, not all do; we believe that the focus on humanity and nature deserves its own agreement and analysis, not only given science's major failings in the past in terms of holistic thinking and prioritizing nature (e.g.,: atomic weapons, forever chemicals, plastics, etc.…), but also because of the critical tipping point we have reached in earth's and humanity's history, with climate change, the general destruction of nature, and unbridled production and consumption.

22 The term ethic of care as it relates to education was first coined by Noddings (2003).

23 There are other agreements currently governing STEM teaching and learning that we did not address in this article. For example, the agreement of ableism is a deeply ingrained assumption that governs not just STEM education, but the broader educational landscape as well. The assumption that students who appear to have no visible disabilities are entirely able perpetuates inequities and injustice.

STEM education and the practice of STEM to evolve and change, in order to make STEM as a field more relevant, responsive, reparative, and sustainable.

We wrote this article because we believe we can do better. In their article "Matters of participation: notes on the study of dignity and learning," Espinoza and colleagues beckon us to consider education as a human right that is intimately connected to human dignity. "Across eras and cultures, the persistence of the argument that education is a fundamental right relies on the human capacity to learn to dream again, to compose, out of sorrows unspeakable, a thrumming song," they write (2020). We wrote this article to underscore the urgency of transforming STEM education and to extend an invitation for you to join us so we may collectively compose and sing a new song for STEM, one that upholds the dignity of everyone and honors the environment.

We also know that our proposed "recasted" agreements are just a starting point. We wrote this article because we are inspired by things implicit or explicit that we care about, things that make us human that perhaps we cannot measure but are some of the most important things in our lives, such as empathy, kindness, connection, tenderness, friendship, and love. The things that help make us human.

We invite and encourage you to think critically about the ideas we have presented, and to critique, to revise, and to add your own ideas. In order to help provoke critical self-reflection and conversations, we have included a series of questions in Appendix A as well as a class activity in Appendix B.

Creating a learning sanctuary: a space that fits being human in STEM

We believe that the current agreements which govern STEM and higher education do harm to our students by stifling their learning, growth, and ability to thrive in our complex world. Recasting those agreements enables students *and* educators to work together to cultivate transformative "learning sanctuaries" where "students are empowered to co-create meaning, purpose, and knowledge" (Imad, 2020b) – a space of being human, of radical hospitality, one that supports growth and healing, and promotes wellbeing and welldoing.

Similar to the practice of science, being human is a practice that involves actively engaging with and participating in the world around us, rather than simply passively existing in it. Jamaican educator Sylvia Wynter argues that being human is not a fixed or static state but rather an ongoing process of constructing ourselves as human subjects through our daily experiences and interactions with others. This view of being human is aligned with the notion of praxis, which is our ability to actively and reflectively engage in the process of creating and changing our social world through our actions (McKittrick, 2015). Being human is about learning and growing and like learning, being human is relational–to other people, to our material surroundings, and to the ideas with which we engage. We use our thoughts, emotions, and actions to engage with others and the world around us in meaningful and ethical ways in order to make meaning, to learn and grow, to make a positive difference in the world and to create a more just and equitable society.

A sanctuary is a place where students find refuge from all the uncertainties and distractions of the world and join a community of learners where we lose ourselves *and* find ourselves in learning (Merton, 2005). Such a space welcomes learners as their authentic selves, in all of their potential messiness, and provides the support and challenge to learn, grow, co-create, and flourish. This sanctuary recognizes the dignity and values the unique experiences, perspectives, and contributions of each student. It fosters an atmosphere of mutual respect, understanding, and empathy, where all students feel safe to express their thoughts, ask questions, and *make mistakes*. We, teachers and students, learn to trust the process of learning and not shy away from ambiguity; learn to sit in that transitional discomfort, because in that liminal space we can also find ourselves and each other. A learning sanctuary is about being in community and solidarity with other seekers and co-learning to resist settling, to resist the status quo, and to resist the normalization of compartmentalization. Importantly, this learning sanctuary is not just helping students but can also serve as a place of what bell hooks calls "liberating mutuality," where both the professor and their students are co-liberated (Hooks, 1994).

A learning sanctuary investigates and honors what it means to be human where learning and knowledge production is understood to be a deeply human activity, and for that to happen, we need to take intentional and purposeful steps to create an environment in which all members of the academic community can meaningfully participate and contribute (Espinoza et al., 2020). In this space, we shift our focus from grades and test scores to the holistic development of each individual. We recognize that every one of our students has unique talents and gifts, and we strive to help them discover and cultivate these strengths. We understand that learning is not a one-size-fits-all process, and we tailor our approaches to meet the needs of each student.

The philosopher and educator Paulo Freire argues that education plays an essential role in empowering individuals to actively engage with and transform their own lives and communities. In his book *Pedagogy of the Oppressed*, Freire argues that true education should involve more than just the transmission of knowledge, but should also involve the development of critical thinking skills and the ability to take action to change the world. By extension, a learning sanctuary is a place where we, who are in a position of power, necessarily realize that harm has been committed by our institutions (for example, historical exclusion from or ongoing marginalization in education). And while we as individuals may not have caused these inequities and exclusions, we inherited them, and unless we actively challenge them, we are contributing to their perpetuation.

In *The Pedagogy of the Distressed*, English professor Jane Tompkins tells us that what we do in the classroom is our politics (Tompkins, 1990). A Learning Sanctuary model adopts this notion, and fiercely designs and advocates for the "rightful presence," meaningful participation, and the wholeness of every student (Barton and Tan, 2019; Espinoza et al., 2020). We each have the power to make meaningful change within the systems of STEM higher education. We recognize that systems may seem daunting and difficult to change. Nonetheless, systems are ultimately created and *sustained* by individuals, all of us. In other words, while we recognize that change can be incremental and require sustained effort, we also want to highlight the potential impact of our collective individual actions in creating a larger shift toward equity and inclusion leading to the creation of new systems.

By rethinking and expanding the agreements that shape STEM education, we invite you not only to dream of creating a learning sanctuary, but also to help in our collective work toward realizing such a space of open abundance, of critical thinking and feeling, of meaningful participation, and of "bestow[ing] a sense of worth on others in ways that were not possible before" as noted by South African scholar Gobodo-Madikizela (2016).[24] This learning sanctuary is a place of growth and transformation, where we all have the opportunity to learn from one another and flourish together. It is a place where we can challenge ourselves and our beliefs, and where we can create a brighter future for our students and ourselves. By rethinking the values that shape our current approach to STEM education, we can create learning spaces that truly support all of our students and their ability to use science to make the world a more just, equitable, and humane place.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material; further inquiries can be directed to the corresponding author.

Author contributions

MI came up with the concept of identifying and recasting agreements in STEM education and practices (inspired by Laura Rendón's work). MRe and MRo helped to develop the concept, research the agreements (old and recasted), and write the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2023.1193477/full#supplementary-material

SUPPLEMENTARY APPENDIX A
Discussion Questions (Table 1).

SUPPLEMENTARY APPENDIX B
Suggested In-Class Activity (Table 2).

24 Gobodo-Madikizela calls for "moral spaces that would allow the imagining of relationships" that imparts this newfound sense of value to others in ways previously absent.

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