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LEARNING FROM THE PAST; THINKING FOR THE FUTURE: REFLECTIONS ON STEM AND ITS INTEGRATION IN EDUCATION

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Abstract:
STEM—science, technology, engineering and mathematics—has evolved from a Cold War workforce initiative into an elastic slogan invoked by educators, policymakers and industry. Drawing on literature and my classroom experience in Spain, Albania and Romania, this paper traces the acronym's little-known 1960s origins, shows how its meaning has fragmented between discipline-focused, interdisciplinary and equity-driven visions, and critiques the tendency to equate STEM with facilities rather than practice. Comparative case studies reveal well-equipped laboratories that sit idle, enthusiastic teachers constrained by centralised curricula, and community projects that thrive only when leaders align resources, assessment and moral purpose. This analysis positions STEM as a flexible object whose flexibility can empower teacher agency—but only if partners negotiate aims, balance disciplines, and embed inclusion as a design criterion. The paper concludes with four recommendations for schools and informal institutions to transform STEM from a buzzword into sustained, context-responsive practice grounded in equity and collaboration.

Keywords: STEM education; interdisciplinary education; formal & informal learning environments; comparative education; educational equity; integrated STEM curriculum

1. Introduction

The term STEM—Science, Technology, Engineering, and Mathematics—has become a powerful symbol of educational reform, representing a shift toward interdisciplinary learning to prepare students for a technology-driven world. However, the history of STEM is complex, its many meanings contested, and the implementation of STEM is uneven. As a STEM educator who has taught and observed STEM practices in England, Spain, Albania, and Romania, I have witnessed its transformative potential and many of its persistent challenges and I have reached the conclusion that STEM is not a unified concept but rather highly dynamic, shaped by economic pressures, pedagogical

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aspirations, and systemic inequities. In this paper, I aim to trace the origins of STEM, explore its fluid meanings, and reflect on its application in three European contexts, drawing on my experiences and literature. In this paper, I also aim to examine opportunities to integrate STEM across formal settings, such as schools focused on curricula and qualifications, and informal settings, like museums and science centres, which offer educational experiences not constrained by assessments (Bevan *et al.*, 2010). I conclude that in order for teachers to realise STEM's promise, it requires clarity of purpose, teacher empowerment, and a commitment to equity, in this way ensuring that STEM does not remain only a buzzword but rather becomes the catalyst for change that I in my teaching experience sought it to be.

2. Historical Origins of STEM Education

STEM education emerged during the Cold War, when global rivalries spurred nations to bolster scientific capabilities. In the United States, the 1957 launch of Sputnik sparked fears that American education lagged behind its competitors, threatening security and economic dominance (Lund & Schenk, 2010). In response, the National Defence Education Act of 1958 aimed to train scientists and engineers, laying the groundwork for integrating science, technology, engineering, and mathematics (Lund & Schenk, 2010). Contrary to claims that Judith Ramaley coined "STEM" in 2001 by reordering SMET (Cavanagh & Trotter, 2008), the term has older roots. In 1962, Dr. Harold Foecke was a specialist for engineering education at the U.S. Office for Education, and by 1964, he was Chief of the Science, Technology, Engineering, and Mathematics Section (*Engineering Education*, 1968, p. 35). This 1968 reference shows STEM is over 50 years old and strongly tied to prosperity and security.

By the late 20th century, STEM became a policy priority with the U.S. National Science Foundation's 2001 directives promoting an integrated curriculum to drive competitiveness (Colucci-Gray, as cited in Burnard *et al.*, 2021), while the U.K.'s 2006 STEM Cohesion Programme unified initiatives to meet labour market needs (Department for Education [DfE], 2006). These efforts reflected a dual rationale: producing skilled workers and fostering public engagement with science (Bybee, 2013; Holman & Finegold, 2010). In 1959, the U.S. President's Science Advisory Committee argued for expanding science to ensure "*all citizens of modern society acquire a reasonable understanding of these subjects and that those with special talents in these fields have the opportunity to develop such talents*" (as cited in Boston, 1965). This vision, reiterated in 1965, outlined three purposes: ensuring scientific literacy, providing specialized education for STEM professionals, and offering science as a cultural endeavour (Boston, 1965), contrasting with today's workforce-focused narratives.

Right from the start, equity was an early concern and going back to 1988, the National Science Foundation (NSF) established programs like 'Career Access Opportunities in Science and Technology for women, minorities, and the disabled' (NSF, 1988b, p. 1). By 1994, the NSF, aimed to "*strengthen and ensure the vitality of undergraduate* *education in science, mathematics, engineering and technology for all students*" with emphasis on underrepresented groups (NSF, 1994a, p. 28). Yet, persistent gaps, particularly for ethnic minority students, highlight the need for further systemic change (Rincón & Lane, 2017).

2.1 Defining STEM: A Contested Concept

STEM functions as a "*boundary object*," malleable and interpreted differently by stakeholders (Colucci-Gray, as cited in Burnard *et al.*, 2021). At present, policymakers view it as a pipeline for skilled workers, while educators see it as a tool for creativity and civic engagement (Wong *et al.*, 2016) and as a result, tension is created between preserving disciplinary knowledge and embracing integrative pedagogies. Two visions coexist: STEM as four distinct disciplines—science, technology, engineering, and mathematics—or as I-STEM, emphasising interdisciplinary projects (McComas & Burgin, 2020). The former allows any subject teacher to claim STEM status, while the latter involves "*the application of technological/engineering design-based approaches to intentionally teach content and practices of science and mathematics concurrently*" (as cited in McComas & Burgin, 2020, p. 5).

This ambiguity in a definition for STEM leads to debates on STEM's purpose. A top-down, economically driven STEM risks reducing education to vocational training, sidelining ecological literacy and critical thinking (Colucci-Gray, as cited in Burnard *et al.*, 2021). On the other hand, reformist perspectives advocate a "*radical democratic character*," integrating arts, ethics, and entrepreneurship (Evagorou *et al.*, 2015). Variants like STEAM (adding arts) and STEAME (adding entrepreneurship) aim to broaden STEM but risk becoming superficial if not thoughtfully implemented (Quigley *et al.*, 2017). Disciplinary imbalances complicate matters. In the U.K., initiatives prioritised physics and mathematics, marginalizing biosciences (Wong, Dillon & King, 2016). Likewise, very often technology and engineering are sidelined, with STEM equated to science and math, undermining its holistic vision (McComas & Burgin, 2020; Williams, 2011).

The fluidity of STEM's meaning challenges collaborations between formal settings (schools) and informal settings (museums, science centres). As Wong, Dillon and King note, "*STEM is viewed differently depending on where you stand*" (Wong, Dillon & King, 2016). In U.K. schools, science and mathematics dominate; in business, technology and engineering are prioritised. Policymakers focus on STEM sector skills, while schools see STEM as interdisciplinary work (Wong, Dillon & King, 2016; Honey *et al.*, 2014).

2.2 STEM in Formal and Informal Settings

Tackling the "*wicked problems*" of our era—climate change chief among them—demands that STEM learning stretch across classrooms, museums, science centres, and other community sites. As Pohl *et al.* (2017) remind us, effective solutions require "*inter-, multi-, and trans-disciplinary approaches*," something no single institution can achieve alone.

The urgency is plain. Disinformation now spreads faster than evidence-based explanations, with tragic results: many people died during the COVID-19 pandemic after rejecting safe vaccines, and public trust in medical science sagged in key groups (Osborne & Pimentel, 2023; Pew Research Centre, 2022). Some observers have gone so far as to claim that science education "*failed*" because it felt disconnected from the messy, multidisciplinary world students inhabit (Dillon, Achiam & Glackin, 2021). Informal science institutions can help repair that gap as they enjoy high public trust (Domenici, 2022), ready access to practising STEM professionals and current research (Alexandre *et al.*, 2022), and the flexibility to craft experiences that cut across subject lines—assets schools rarely possess under high-stakes testing and rigid timetables (Manuel, 2010). Exhibitions on climate, biodiversity or food security routinely weave together biology, engineering and data science in ways visitors can grasp (Dillon, Achiam & Glackin, 2021).

That said, we are not starting from scratch. Nearly two decades ago, Phillips *et al.* (2007) found that "*more than 70 % of US science museums*" already ran programmes for schools. Bevan *et al.* (2010, p. 11) described these offerings—after-school clubs, summer camps, teacher workshops, even district-wide curriculum projects—as programmes that "*spark curiosity, generate questions, and lead to a depth of understanding … often less possible when the same material is encountered in books or on screens*."

Still, Bevan and colleagues flagged a persistent weakness: "*despite scores of such examples, these collaborations have generally failed to institutionalise in many communities, they come and go with changes in funding or leadership*" (2010, p. 11). Funding gaps, mismatched evaluation tools, and shifting museum priorities all undercut staying power. Their remedy was explicit: partnerships must become "*core activities*" for both schools and informal organisations, with "*intentional and strategic deployments of resources … to meet shared goals*" (p. 11, emphasis in original).

The same report laid out three "*crucial understandings*" that still crystalise why hybrid STEM learning matters (Bevan *et al.*, 2010, p. 12):

1) Scientific literacy goes far beyond memorising facts; it includes conceptual depth, habits of mind, and the capacity to apply knowledge in daily life.
2) Learning unfolds across multiple settings and timescales; no single classroom or field trip is enough.
3) Traditional schooling excludes many learners—particularly women, low-income students and other marginalised groups—from meaningful STEM pathways.

Fifteen years on, these principles remain essential. Building durable school–museum partnerships still calls for the same "*intentional and strategic*" resource use, yet today we must also grapple with STEM's own complexity: competing definitions, uneven disciplinary emphasis, and the growing influence of misinformation. Recognising those layers will be critical if future collaborations are to move from inspiring pilots to lasting systems.

2.3 STEM vs. Traditional Education

STEM contrasts sharply with traditional education's disciplinary vision, which fragment knowledge into isolated subjects prioritising rote memorisation for exams (Barlex *et al.*, 2007a). Integrated STEM applies scientific principles to authentic design tasks, mirroring real-world challenges where disciplines converge (Barlex *et al.*, 2007a). For example, a project combining physics and engineering to build a model bridge fosters problem-solving and collaboration, unlike traditional physics lessons focused on formulas (Barlex *et al.*, 2007a). Robinson's (1994) use of Internet tools for collaborative data-sharing highlights STEM's constructivist roots, enabling students to engage in inquiry rather than passive learning. This approach aligns with the ALLEA report's (2023) advocacy for tackling "*wicked*" problems like climate change through interdisciplinary projects, emphasizing relevance over assessments.

Traditional education's top-down classifications, such as rigid subject timetables, contrast with STEM's fluidity, which allows bottom-up interpretations tailored to local needs (Lund & Schenk, 2010). Anderson *et al.*'s (2021) measurement of STEM tasks reveals a "*periphery STEM workforce*" performing cross-disciplinary roles, underscoring the limitations of siloed education. STEM's emphasis on real-world application—through projects like designing sustainable energy solutions—prepares students for complex challenges, unlike traditional models that prioritize test performance (ALLEA, 2023). However, transitioning to STEM requires overcoming entrenched practices, as teachers accustomed to subject-specific teaching may resist interdisciplinary methods without training (Barlex *et al.*, 2007a). The Odyssey schools in the U.S. and XP East Academy in the U.K. exemplify successful integration, blending subjects to address real-world issues, but such models remain rare due to systemic constraints (Manuel, 2010).

3. Practical Reflections on STEM integration: Spain, Albania, and Romania

My observations begin with Stella Maris College (SMC), a private bilingual catholic school in Madrid. Upon first visiting SMC, I encountered a school that had all the external trappings of an ambitious STEM program: newly built labs in both primary and secondary sections, modern digital resources, and a head of science enthusiastic about project-based inquiry. He had been inspired by a visit to an English school that highlighted computational thinking and cross-curricular exploration. This inspiration compelled SMC's administration to invest in infrastructure—specifically, large specialised labs and licenses for "Science bits," a digital platform that purportedly aligned with the 5E instructional model (Engage, Explore, Explain, Elaborate, Evaluate). In principle, these steps hinted that SMC was poised to become a vanguard of inquiry-based science education in Spain.

Yet, my conversations with the school director revealed a stark mismatch between the presence of new STEM-labelled labs and their actual usage. The director admitted to being in "*a situation of not knowing*," uncertain about how best to integrate technology without overshadowing handwriting, reading, and the moral and spiritual development so central to the school's ethos. Moreover, teachers themselves—accustomed to more traditional, exam-focused routines—felt ill-prepared to manage open-ended experiments or student-led design tasks. They feared losing valuable instructional time or failing to complete the prescribed curriculum. As a result, instead of daily lab activities or extended projects, teachers defaulted to showing short educational videos or projecting pages from "Science bits", thereby limiting student involvement to a mostly passive experience.

The outcome was that, though SMC's labs were physically well-equipped, they remained largely idle. The head of science lamented that a handful of lessons per year was all these facilities had seen since their inauguration. Despite the superficial label of STEM, the school was not providing the deeper, design-oriented, or hands-on experiences that might truly embody an interdisciplinary approach. This scenario exemplifies a broader pattern in STEM adoption globally: investing in high-tech resources or new buildings without thoroughly preparing teachers or clarifying how these spaces align with broader moral and pedagogical goals (Xhuxhi & Ramirez, 2024)

At around the same time, my work took me to Albania, where I led workshops for a group of about twenty primary and secondary school teachers as part of a program run by the Commission for Catholic Education. Since we faced language limitations, I asked them to "draw STEM" as they personally understood it—annotating their sketches in whatever way they felt appropriate. Many depicted trees or plants, with the letters S, T, E, and M forming the root structure and the trunk symbolizing the growth of learners. Others placed the student at the centre of a Venn diagram, labelling each circle as science, technology, engineering, or mathematics, with arrows symbolizing the flow of "*problems*," "*questions*," or "*projects*." These symbolic representations revealed that Albanian teachers conceptualized STEM as an integrated, problem-solving enterprise. They used terms like "*critical thinking*," "*collaboration*," and "*inquiry*," signalling a genuine aspiration to move beyond rote instruction. However, I also noticed that "Engineering" typically appeared only as a letter among the others, with little tangible sense of how to facilitate design-based or iterative tasks in real classrooms.

As we discussed these drawings, teachers repeatedly mentioned the constraints of a highly centralised curriculum—textbooks mandated by the Ministry of Education, strict pacing guides for standardized exams, and limited autonomy to deviate from conventional lesson structures (Sina *et al.*, 2024). They also noted the scarcity of well-equipped labs or stable internet connections, particularly in smaller towns. While some had attended short workshops on STEM-related methods, they lacked consistent follow-up or robust support networks. Thus, although the impetus for integrated projects was strong, day-to-day practice often remained teacher-centred, reliant on lectures, and geared toward covering official syllabi (Xhuxhi & Ramirez, 2024).

The teacher-exchange program, in which three Spanish primary teachers from SMC spent a week observing three Albanian Catholic schools, reinforced these findings. The Spanish teachers came expecting to see minimal technology usage—correctly so, as many Albanian classrooms still rely heavily on chalkboards and textbooks. Yet they also discovered a highly cooperative classroom culture, rooted in the school's shared Catholic identity that emphasizes mission, faith, and community (Xhuxhi & Ramirez, 2024). This sense of "*educating the whole child*," which resonates with SMC's moral concerns, provided Albanian teachers with a cohesive, values-driven framework for the few collaborative activities they could attempt. Meanwhile, Albanian educators admired the Spanish teachers' relative freedom to adapt lessons, even if the actual practice at SMC was less innovative than the official rhetoric suggested (Xhuxhi & Ramirez, 2024).

My contact with Romanian teachers and scholars layered around similar themes. Romania's educational policies reference STEM as a means of increasing scientific literacy, critical thinking, and alignment with the European labour market (Popa & Ciascai, 2017). Nevertheless, many Romanian secondary schools remain structured around discrete subjects, leaving minimal space for large-scale, cross-curricular projects (Bálint-Svella & Zsoldos-Marchiş, 2022). Teacher training tends to focus on disciplinary mastery rather than interdisciplinary synergy, making it difficult to shift from lecture-based instruction to iterative engineering or design.

Several educators in Romania described how hackathons, robotics clubs, or extracurricular STEM competitions had garnered student interest (Lazarou *et al.*, 2024). Yet these remained optional programs, often targeting high-achieving students who already exhibited strong math or science aptitudes. As a result, mainstream classrooms did not widely adopt the more interactive, integrated approaches that official policy documents extol. Once again, the tension between exam preparation, teachers' comfort zones, and limited time for "*non-essentials*" constrained widespread adoption of hands-on STEM (Chiriacescu *et al.*, 2023). Furthermore, a frequently encountered misconception equates "STEM" with technology usage alone. Teachers or administrators might point to a new set of computers or digital presentations to illustrate progress, but rarely do they mention the deeper engineering design processes or genuine inquiry that might engage students in real-world problem-solving (Xhuxhi & Ramirez, 2024).

Across Spain, Albania, and Romania, the "Engineering" dimension tends to be the most neglected. In each place, I saw references to science labs, digital tools, or mathematics practice. Yet rarely did I encounter structured design-based tasks where students learn by building and iterating, facing uncertainty, and applying knowledge from multiple disciplines (Sina *et al.*, 2024). In some cases, teachers cited resource limitations: no budget for materials, no specialized software, or no training in how to manage a messy engineering project. In others, the reluctance stemmed from fear that open-ended tasks would derail coverage of required academic content (Xhuxhi & Ramirez, 2024). Either way, the repeated focus on "*labs plus computers*" overshadowed the potential synergy that integrated engineering can offer, bridging theoretical concepts with tangible, student-driven exploration (Xhuxhi & Ramirez, 2024).

A final thread that unites these contexts is moral or cultural ambivalence about technology. At SMC, the director worried that students might lose core literacy skills and humanistic values if labs and computers became too dominant. This echoed certain Albanian teachers' concerns that technology access outside the classroom might be unequal, or that parents might disapprove of too much screen time. In Romania, some parents have also voiced scepticism of new digital resources, worried about over-reliance on internet-based activities (Popa & Ciascai, 2017). In Catholic or faith-based schools, these concerns often intertwine with spiritual missions, emphasizing that education must remain humane, ethically grounded, and child-centred (Sina *et al.*, 2024).

Nonetheless, these moral and ethical stances do not inherently oppose STEM. Indeed, one could argue that a robust STEM program, if thoughtfully implemented, can dovetail with moral goals by engaging students in socially relevant or community-based projects—like environmental stewardship, public health, or resource conservation (Pashaj & Gjika, 2023). When teachers integrate ethical reflection into science or engineering tasks, the technology ceases to be an end in itself; it becomes a means for responsible action and collaborative problem-solving. The challenge is to ensure that, rather than overshadowing these values, STEM initiatives incorporate them in ways that make scientific inquiry and technological design more purposeful.

Teachers in all three settings repeatedly mentioned that major transformations hinge on supportive leadership, consistent training, and structural accommodations. If exam demands leave no room for multi-week design challenges, or if administrators remain ambivalent about project-based learning, then STEM will remain superficial (Xhuxhi & Ramirez, 2024). Conversely, where leadership clearly articulates the rationale for inquiry-based tasks, invests in teacher development, and rethinks how to assess students, labs might come alive with genuine activity. A good example emerged in a short pilot program at an Albanian Catholic school, where teachers spent two months developing a cross-curricular unit on local ecology, culminating in a simple yet meaningful engineering task—designing homemade sensors to measure humidity in nearby farmland. Though modest, this venture reportedly ignited student enthusiasm, illustrating how integrated problem-solving can be done on a small budget (Xhuxhi & Ramirez, 2024)

In Romania, there have been parallel efforts to pilot interdisciplinary units in mathematics and science, sometimes in partnership with NGOs or external sponsors (Lazarou *et al.*, 2024). Teachers who participated in such efforts described them as highly beneficial for student engagement, yet they lamented that these were exceptions, not the norm. Meanwhile, in Spain, certain private schools beyond SMC have adopted more progressive STEM methods—like robotics courses that culminate in a design competition or engineering modules that teach coding through microcontroller projects. Yet these successes often occur in schools with more liberal policies around curriculum adaptation (Bálint-Svella & Zsoldos-Marchiş, 2022)

Reflecting on these experiences, I see a consistent need for policy-level reforms to embed project-based or inquiry-based standards into national curricula or exam formats (Bálint-Svella & Zsoldos-Marchiş, 2022). Without formal recognition that open-ended, multi-disciplinary tasks are legitimate ways to assess learning, teachers often feel they must revert to memorization-based methods to prepare for conventional tests. Another common requirement is teacher collaboration—scheduling time for science, math, and technology instructors to co-plan integrated lessons, share reflections, and refine approaches. Currently, many schools do not afford teachers such time.

At Stella Maris College, for instance, the biology teacher and the math teacher rarely planned lessons together, even though an integrated approach might have turned routine lab exercises into deeper engineering or design explorations. In Albania, the

Catholic schools I visited often had strong internal solidarity but lacked official channels or systemic incentives for cross-subject collaboration. Similarly, Romanian educators attested that multi-subject projects require negotiation of time and resources, which is not always feasible given rigid class schedules and overstuffed curricula (Chiriacescu *et al.*, 2023).

Despite these barriers, I observed that teachers shared moral commitment—whether tied to Catholic identity, as in Spain and Albania, or to broader principles of nurturing critical thinkers, as in Romania—could serve as a unifying driver. Indeed, the teacher-exchange program between Spain and Albania hinted that a sense of shared mission helped educators embrace new activities more openly, at least for the duration of that short visit (Xhuxhi & Ramirez, 2024). Both sets of teachers valued holistic child development, so the Spanish educators demonstrated some group-based, inquiry-driven exercises, while the Albanian hosts enthusiastically tried them, though uncertain whether they could sustain such methods once the visitors left.

This moral dimension can help quell the concern that technology alone might overshadow deeper humanistic values. In fact, teachers can harness digital tools to investigate ethical questions or to engage in collaborative service projects, aligning STEM tasks with the overarching ethos of caring for the planet, serving the community, or mastering new literacies in a mindful way. The tension arises when administrators or directors, like the one at SMC, vacillate between approving large budgets for STEM labs and simultaneously worrying about a "*technological invasion*." That ambivalence sends mixed signals to teachers, who then hesitate to diverge from standard textbook routines. Considering the entirety—SMC's underutilized labs, Albanian teachers' symbolic "STEM trees," and Romania's competing realities of official policy statements vs. teacher-centred traditions—it becomes clear that superimposing "STEM" onto an existing system does not suffice. True STEM integration involves carefully articulated leadership, teacher agency, consistent training, moral clarity, and flexible curricula that accommodate extended, iterative explorations. When one or more of these elements is missing, we see the phenomenon of well-appointed labs gathering dust, or teachers playing short videos under the STEM banner, or extracurricular clubs serving only a small fraction of students. Therefore, the potential solution is multifaceted. First, a school's leadership must formulate a clear, context-sensitive strategy for STEM, ensuring that all educators understand how labs, digital tools, and project-based units align with the institution's deeper values and missions. Second, teachers require ongoing professional development that goes beyond single workshops—offering them collaborative planning time, practical modelling of inquiry-based lessons, and supportive follow-up (Chiriacescu *et al.*, 2023). Third, policies need to become more flexible about content coverage and assessment modalities, allowing teachers to devote time to design processes and real-world problem-solving, instead of rushing through chapters or drilling for standardised tests (Thanasi & Beqiri, 2024). Fourth, the moral and cultural concerns about technology could be reframed as an impetus to incorporate ethically oriented engineering tasks or social applications of science, thus binding technology usage to tangible ethical engagement.

4. Equity and Collaboration Challenges in STEM

Equity themes infuse every contemporary STEM strategy, yet numerical parity remains elusive. Despite thirty years of scholarship programmes and diversity task forces, women occupy only 16 percent of Europe's digital-technology workforce (European Commission, 2022). Latino and Black scientists remain under-represented in tenure-track positions across North America. The IJSTEME review notes that equity language appeared in policy as early as 1988, when the NSF funded "Career Access Opportunities" for women, minorities and disabled students. Why, then, is progress so slow?

One reason, documented by Rincón and Lane (2017), is that broad demographic categories mask intersectional dynamics. Equity strategies cannot assume that a scholarship alone offsets stereotype threat or cultural isolation. Another reason, highlighted by Anderson *et al.* (2021), is measurement error. Occupational codes that determine who counts as STEM exclude large pools of technical labour—machinists, solar-panel installers, medical technologists—jobs often held by first-generation college graduates or vocational-track students. When those workers disappear from data dashboards, policy overlooks their upskilling needs.

A third factor is curricular imagery. Williams (2011) points out that technology education, with its blend of craft and innovation, potentially attracts learners who disengage from abstract science, yet underfunding and exam timetables restrict those hands-on experiences. Without visible vocational pathways, students from non-dominant communities may see STEM as culturally alien. Informal institutions attempt to fill the gap. The U.K. programme Operation Earth builds on environmental stewardship values already present in families, thereby reframing science as conservation rather than test preparation. Yet museum reach is patchy; rural or low-income families often face admission fees and travel costs.

Finally, some scholars warn that equity rhetoric can operate as assimilation (Lane, 2017). A pipeline that delivers a few more women to boardrooms, they argue, does not challenge exploitative business models or the ecological damage wrought by unchecked tech growth (Lane, 2017). Equity measured only by demographic representation may blind us to systemic injustices—who owns patents, who bears environmental costs, whose data are commodified—issues only peripherally addressed in traditional STEM syllabi.

None of these critiques suggests that equity is a hopeless cause. They do imply that metrics must extend beyond admission quotas to include retention, leadership participation and culturally grounded curriculum design. In partnerships, an early consensus on what kind of equity is sought—numerical, participatory, epistemic—helps partners avoid token gestures.

5. Reflection

STEM has a tangled history, and there is a contested purpose of the term. The lack of clarity on the details of the origins of STEM and the reasons of its creation, makes one think that if the field's practitioners cannot agree on when or why the word was invented, can we ever be confident we all share a common agenda for STEM today? I question whether we need to share a common detailed agenda on the meaning of STEM for STEM to serve a purpose. As practitioners we need clarity of the core values of STEM, and through this section its clear what those core values are, but my experience teaching science and technology in England, Spain, Albania and Romania has led me to value the lack of clarity on the detailed meaning of STEM that emerges from the uncertainty in its origins does not impede teachers from using STEM in the classroom, but rather should empower teacher agency in the classroom. For me, it has meant that as a teacher of Science and Technology, I have been able to adapt STEM because of this flexibility to the needs of the school and students, while holding to its core foundational values.

The fascination of authors such as Justin Dillon (Millar, Park and Dillon, 2025) and agencies as the U.S. federal agencies on exposing STEM acronym's semantic slipperiness, goes beyond my comprehension. The need to know what counts as Science, Maths, Engineering, and Technology is bewildering. Why not allow the classroom teacher to make that decision? Why the need to dictate where the focus should be? In doing so, conflicts of interest arise- in England, for example, we have seen successive initiatives have channelled resources towards physics and mathematics while marginalising the biosciences because biology is already *"popular"* and supposedly less vital to economic growth. Do technology and engineering need to be part of the school timetable for STEM to be taught? I don't think so. As a STEM teacher technology and engineering are taught along Science and Maths and likewise even if Science and Maths are to be absent from the school timetable by having Engineering and Technology in the timetable you would teach Maths and Science, one could argue therefore that the acronym STEM operates less as a precise taxonomic label and more as a pliable slogan that different schools and teachers in different areas should bend not to their own priorities nor to the priorities of passing governments but to the priorities of the community they serve. Pressures from governments to lean toward the pipeline narrative of STEM that measures success by the number of graduates entering technical careers or pressures to frame STEM as cultivating lifelong curiosity and civic engagement without explicit discussion about the directions the community, collaborations that badge themselves "STEM" may in fact be pulling in opposite directions, defending incompatible success metrics and evaluation tools.

Equity, as we have seen, offers another window onto the acronym's conceptual instability. As early as 1988, the National Science Foundation funded programmes explicitly aimed at widening participation for women, minoritised groups and disabled learners , yet decades later those participation gaps remain unchanged. STEM's continual rebranding is distracting attention from structural inequities: adding yet another initiative under the same banner risks masking the absence of systemic change. For hybrid projects to be more than short-term exhibitions of virtue, partners must treat equity not as an optional extra but as the criterion against which definitions and outcomes are judged.

The most pragmatic section of the paper examines why ostensibly promising partnerships between schools and informal venues so often collapse. The 2010 CAISE inquiry had already catalogued the educational value of "*hybrid*" endeavours and chronicled their fragility when grants ended or leadership shifted. Beneath funding cycles lurks a deeper cause: stakeholders walk into joint ventures presuming mutual understanding of STEM's aims when, in reality, each operates with an unspoken and sometimes contradictory definition. A museum may regard an engineer-themed exhibition as a route to public dialogue on climate resilience, while its school partner may see the same event as a vehicle for improving test scores in algebra. Because neither side has articulated those assumptions, misaligned goals go unnoticed until the project stumbles over assessment, staffing or curriculum constraints.

From the cumulative effect of these historical and contemporary analyses its possible to frame four recommendations that read less like administrative checklists and more like invitations to intellectual honesty. First, any publication or proposal should declare explicitly which definition of STEM it is adopting and justify the choice. Second, collaborators must scrutinise disciplinary balance: whose expertise is foregrounded, who's sidelined, and why. Third, partners need to negotiate the underlying rationale—whether workforce preparation, civic literacy or tackling wicked problems such as climate change—and design evaluation criteria that match. Finally, equity must move from rhetorical preamble to operational backbone, with measurable strategies for inclusion built into budget lines and governance structures.

6. Closing words

STEM's half-century journey from an obscure office title to global refrain demonstrates that slogans endure when they can absorb shifting priorities—Cold-War defence, neoliberal competitiveness, climate resilience, and social justice. The danger is that unexamined elasticity fosters cycles of hype followed by disappointment. The opportunity is that the same elasticity invites creative renegotiation of education's purposes. If schools, museums, industries and communities approach STEM as a living conversation rather than a settled blueprint, they can co-construct programmes that honour both local context and global imperatives.

Doing so requires humility—the acknowledgment that no single definition will serve all contexts—and courage to expose hidden assumptions. It demands evidence that matches plural aims and assessments that credit complex learning. Most of all, it insists that equity be treated not as a peripheral quota but as a central design criterion. Only then can the acronym move from slogan to substance, from fundraising hook to transformative practice, from moving target to shared horizon.

Conflict of Interest Statement

The author declares no conflicts of interest.

About the Author

Joseph Xhuxhi graduated from Imperial College London with a degree in Biology specializing in Neuroscience- he has a Postgraduate Certificate in Education (PGCE) in Science Education from the Institute of Education in London as well as a PGCE in Leading Innovation and Change in Education from the University of Saint Mary's in London. Joseph completed a Master degree in Science Education at the University College London. Currently Joseph is a Doctoral student in Education with the Universidad Autónoma de Madrid - with a focus on STEM education and students of Special Educational Needs including students identified as Able, Gifted and Talented. Joseph has and maintains significant international Science teaching experience in secondary and primary state as well as private schools employing the Spanish, British and American curriculums. He is a member of the Research Group "Active Methodologies and Mastery Learning" at UNIR and a lecturer of Innovative teaching in Undergraduate degrees at UNIR as well as a lecturer of New Teaching Methodologies and New Technologies Applied to the Teaching of a Bilingual Environment in the Master's in International Education and Bilingualism at Universidad Camilo Jose Cela. Joseph also maintains a strong interest in Initial Teacher Training as well as ongoing Teacher Professional Development, especially in the Balkan countries.

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