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Reflection article

Are There Compelling Reasons to Establish a Connection between STEM and STS Education?*

¿Existen razones sustanciales para establecer alguna relación entre la educación STEM y la educación CTS?

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Abstract

This article examines whether there are compelling reasons to establish a relationship between the STEM (Science, Technology, Engineering, and Mathematics) and STS (Science, Technology, and Society) educational movements. To address this issue, the analysis focuses on the origins, objectives, defining characteristics, and specific classroom implementations of each movement. The findings suggest that linking STEM and STS education is a significant challenge, as sufficient and strong arguments are lacking to support such a connection. Each movement emerged from a distinct historical, sociopolitical, and economic context and pursues equally different educational approaches and intentions. The only commonality identified between the two educational movements is that neither has yet succeeded in implementing an authentic and effective integrated education in the classroom, despite what their respective acronyms suggest. However, this does not imply any substantive connection between STS and STEM education; it is merely coincidence.

Keywords: integrated education, science education, STEM education, STS education.

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Resumen

En este artículo se analiza si existen razones de peso para establecer algún tipo de relación entre los movimientos educativos STEM (Science, Technology, Engineering and Mathematics) and CTS (Ciencia, Tecnología y Sociedad). Para abordar esta cuestión, se analizan los orígenes, finalidades, rasgos identitarios y concreciones en propuestas educativas aplicadas en el aula de cada uno de los movimientos educativos. A partir del análisis realizado, se concluye que relacionar la educación STEM y la educación CTS es un reto desafiante, principalmente debido a la falta de argumentos suficientes y sólidos que respalden una conexión directa entre ambas perspectivas. Cada movimiento surgió en un contexto histórico, sociopolítico y económico distinto, y cada uno tiene enfoques e intenciones educativas igualmente diferentes. El único encuentro en común para los dos movimientos educativos es que ninguno ha logrado implantar aún una educación integrada auténtica y efectiva en el aula, a pesar de lo que sugieren sus respectivos acrónimos. Sin embargo, esto no implica ninguna conexión entre la educación CTS y la educación STEM; solo es una coincidencia.

Palabras clave: educación integrada, enseñanza de las ciencias, educación STEM, educación CTS.

> *When I first heard about STEM, I thought, "Oh—it's the new and improved Science, Technology and Society (STS)!" But no, Society did not seem to play a part in the new equation.*
>
> Jaimie P. Cloud (2016)

INTRODUCTION

In discussions around STEM (Science, Technology, Engineering, and Mathematics) education, STS (Science, Technology, and Society) education is often brought up. This is either because the latter is seen as a didactic referent or precursor of STEM education (Domènech-Casal et al., 2019; McComas & Burgin, 2020; Perales Palacios & Aguilera, 2020; Tupsai, 2021), or because both educational movements hint at a curricular integration of different areas of knowledge (Andrade & Teixeira, 2025; Corbí Santamaría et al., 2023; García-Carmona, 2020; Lorenzo, 2020; Perales Palacios & Aguilera, 2020; Toma & García-Carmona, 2021). For instance, at the IX Ibero-American STS Seminar (Vieira et al., 2024), a roundtable was organized to discuss a possible relationship between the two approaches. Likewise, the *Education Sciences* journal recently released a special issue entitled *Critical Perspectives on the Epistemologies and Practices of STEM Education*, which included a call for articles addressing, among other themes, the relationship between STS and STEM education (Skordoulis, 2024). Interestingly, however, none of the published articles tackled this topic.

In a recent study, Andrade and Teixeira (2025) conducted a comparative analysis of STS and STEM education from the perspective of historical-critical pedagogy. Their findings suggest that the STEM approach does not introduce significant innovations in science education. According to

their analysis, its main distinction from STS education lies in its pronounced *neotechnicist* features, characterized by a conservative and apolitical vision of education clearly associated with neoliberalism. At the same time, the authors noted certain commonalities between the two frameworks, such as their advocacy of interdisciplinary teaching, efforts to foster students' interest in scientific and technological issues—albeit driven by different intentions—and aim of moving beyond traditional teaching methods. However, assuming these similarities between STS and STEM education risks oversimplifying the matter. It may obscure their fundamental differences, as there are multiple ways to depart from traditional teaching, to promote interdisciplinary education, and to cultivate interest in science.

In a similar vein, Perales Palacios and Aguilera (2020) compared the STS and STEM educational movements. Based on the premise that the two are comparable, they concluded that STEM education can be regarded as an evolution of STS education—though one with limited originality and shaped by policies grounded in competitiveness. Furthermore, they argued that STEM education represents a divergent evolutionary path from approaches centered on socio-scientific issues, which constitute another branch from which STS education would have derived.

Although the arguments presented by Perales Palacios and Aguilera (2020) and Andrade and Teixeira (2025) are relevant, the presumed relationship appears to merit further exploration. Specifically, it is worth questioning whether the assumption that STS and STEM education are comparable or connected in any way is fully justified. To address this, the present study examines the origins, defining characteristics, and objectives of both movements, as well as relevant contributions from the literature.

STS EDUCATION

The STS movement emerged in the United States and the United Kingdom in the late 1960s and early 1970s, as a response to a sociopolitical, economic, and cultural crisis tied to the rapid scientific and technological development of the time (López Cerezo & Verdadero, 2003; Membiela Iglesia, 1997; Waks, 1989). Rooted in the principles of environmentalism[1] and the sociology of science (Aikenhead, 2005), the movement's primary aim is to promote a more humanized science curriculum, one that is closely linked to relevant social issues (Acevedo-Díaz, 1997; Acevedo Díaz et al., 2003; Bencze et al., 2020; Pedretti & Nazir, 2011, 2015; Yager & Tamir, 1993), with technological advancements playing a central role.

In this regard, Waks (1989) states that "STS education aims to promote scientific and technological literacy in order to empower citizen participation in democratic decision-making and action processes for resolving the pressing, technologically dominated problems of our late industrial society" (p. 201).

[1] Some authors add an "E" to the STS acronym—forming STSE—to emphasize environmental issues within this educational approach. In this study, however, the term STS is used, as environmental concerns have been integrated into the movement since its inception (Aikenhead, 2005).

As such, STS education incorporates a strong social and critical component, making it especially effective in fostering critical thinking skills and a sense of responsibility among students (Andrade & Teixeira, 2025; Fyffe, 1987; Guerrero-Márquez & García-Carmona, 2020; Tenreiro-Vieira & Vieira, 2020). Furthermore, it aligns with the educational philosophy of *science for all*, which prioritizes the development of basic scientific literacy for all citizens, as opposed to more elitist and propaedeutic models of science education (Acevedo Díaz et al., 2003; Martín Gordillo, 2017; NSTA, 1990; Solbes & Vilches, 2005).

STS Education in Practice

The acronym STS refers to an educational approach that integrates science and technology content within a social background. However, there is no single vision for how STS education should be implemented (Pedretti & Nazir, 2011). In practice, STS education has basically translated into science teaching that is contextualized within socially relevant issues (Álvarez-Tobón et al., 2021; Bennett et al., 2003; García Carmona, 2005, 2006, 2008; Lugo Blanco et al., 2022; Solbes & Vilches, 1997). For example, in a study on the effects of integrating STS interactions into the teaching of physics and chemistry, Solbes and Vilches (1997) found that:

> The treatment of STS interactions contributes to improving the opinion of science, increasing the students' interest in the subject and the study of physics and chemistry not only because of its motivating character, but also, and above all, because it helps promote a more contextualized image of these disciplines. (p. 385)

Similarly, in a classroom-based research with secondary-level physics and chemistry students, where atmospheric pollution was examined from an STS perspective, García Carmona (2005) concluded that experiences in which science is contextualized within social realities enhance students' interest in its study, thereby contributing positively to their scientific literacy (p. 12).

Technology, for its part, is frequently absent from the most common STS-based educational proposals. One reason for this is that science teachers do not often feel sufficiently prepared to introduce it alongside science into their classes (García-Carmona, 2021). This concern was already noted over two decades ago by Aikenhead (2003) in his review of the implementation of STS education. According to him, "most educators who had been socialized into academic science were not comfortable with the inclusion of technology in STS (the science-and-society crowd, myself included)" (p. 5).

Moreover, technology is mistakenly assumed to be "applied science" (Bunge, 2016) and therefore subsumed under the scientific domain (Layton, 1988). As a result, many approaches developed under the STS framework are now categorized as "socio-scientific issues," partly due to the near-complete omission of the "T" representing technology[2]. Interesting discussions contrasting STS

[2] Clearly, the reference here is to technology as an academic discipline, rather than merely as a resource or tool—an interpretation that, unfortunately, remains prevalent in the field of education.

education with education based on socio-scientific issues can be found, for instance, in the works by Martínez Pérez and Parga Lozano (2013), Solbes (2019), and Zeidler et al. (2005).

Given this context, it is difficult to maintain that STS education is really a curriculum integration approach. Although some interesting theoretical contributions have addressed the relationship between science and technology within the STS framework (e.g., Acevedo Díaz, 2006; Aikenhead & Ryan, 1992), these have hardly translated into concrete teaching proposals. What empirical research does indicate, in relation to the effectiveness of STS education, is that it favors the development of (i) scientific knowledge and skills in the context of real-world problems, (ii) critical thinking skills, (iii) a more informed understanding of the nature of science, and (iv) more positive attitudes toward science (Acut & Antonio, 2023; Yager, 2007). In other words, the outcomes achieved through STS education are framed in terms of learning *of*, *about*, and *from* science.

Some studies, nevertheless, also reveal that science teachers are often insufficiently prepared to implement STS approaches in their classrooms (Mansour, 2007). Furthermore, in many cases, the adoption of STS frameworks remains superficial and lacks a critical examination of the social implications of scientific and technological development (Strieder et al., 2017). Despite the great support that STS education has received from the science education research community over the past decades, its reach and impact in the classroom are still limited (Reverte et al., 2023).

Identity Features of the STS Construct and Its Components

Since its inception, the STS movement has integrated aspects that today are claimed for a holistic understanding of the nature of science (Acevedo-Díaz & García-Carmona, 2016; Pedretti & Nazir, 2011), as well as for distinguishing it from the nature of technology (Acevedo-Díaz, 1998, 2006). Thus, the epistemological, ontological, and sociological characteristics of the relationships (and differences) between science and technology are well defined within this educational framework (Acevedo-Díaz & García-Carmona, 2016; Aikenhead & Ryan, 1992).

Similarly, in this context, engineering is considered a part of technology, with the latter understood as a broader field of knowledge (García-Carmona, 2023). According to Acevedo Díaz (1995), there are basically two different ways of understanding technology. The most common—and, at the same time, the most conceptually restricted—is the one based only on the more engineering aspects, i.e., the capabilities and skills required to perform productive tasks and the artifacts that result. A broader interpretation of technology, one that places it within its social context, also takes into account the sociotechnological issues derived from its organizational and cultural dimensions.

Accordingly, engineering is assumed to be the branch of technology concerned with the design and production of machines, devices, and applications (García-Carmona, 2023). Moreover, STS studies have dealt with those scenarios in which science and technology converge, mutually influencing one another and blurring the boundaries between them. This phenomenon has been conceptualized with the term *technoscience* (Channell, 2017; Echeverría, 2005; Tala, 2013), which

refers to a hybridization between science and technology—without annulling the identities of each—where the ethical, political, social, and environmental problems associated with their development are recognized (Castaño Tamara, 2013).

STEM EDUCATION

The acronym STEM was coined in the United States during the 1990s as part of a political strategy aimed at enhancing the relevance of the disciplines included in the term within the context of education. Such strategy arose from the country's concern to maintain its capitalist hegemony in the face of the growing scientific and technological development of other world powers (Andrade & Teixeira, 2025; Blackley & Howell, 2015; García-Carmona, 2020; Perales Palacios & Aguilera, 2020). Consequently, STEM soon became an educational movement (Sanders, 2009; Bybee, 2010) with huge propaganda and clear neoliberal connotations (Carter, 2017; Delahunty, 2024; Toma & García-Carmona, 2021). Unsurprisingly, one of the main justifications for promoting this movement is to prepare students for the labor market, which demands more and better professionals in STEM fields (Andrade & Teixeira, 2025; Blackley & Howell, 2015; Ejiwale, 2013; Herro & Quigley, 2017). Thus, the core of STEM education is often in strong tension with the purely literacy-focused objectives that school science should pursue (Zeidler et al., 2016), as advocated by STS education.

Furthermore, the STEM approach frequently ignores the social issues associated with science (García-Carmona, 2020; McComas & Burgin, 2020; Perales Palacios & Aguilera, 2020; Zeidler, 2020), thereby placing it in opposition to STS education. In this regard, Bencze et al. (2020) argue the following when comparing STEM education with STS education and with education based on socio-scientific issues:

> For complex and somewhat uncertain reasons, many STEM [...] education initiatives [...] tend to strongly prioritize teaching/learning of core knowledge and skills in these disciplines [...], significantly compromising students' education about larger contexts involving politics, economics, cultural studies, etc. (p. 845)

Indeed, there have been some attempts to view STEM education as an opportunity to address structural and social inequalities in schools (Basham et al. 2010; Morales-Doyle & Gutstein, 2019; Vakil & Ayers, 2019). Similarly, certain approaches advocate for a STEM education that incorporates humanistic values (Bush et al., 2024; Corbí Santamaría et al., 2023; Ortiz-Revilla et al., 2020) or promotes principles of equity and sustainability (Couso, 2017), given that these values are not intrinsic to the movement's *original conceptualization*. Nevertheless, this endeavor proves particularly challenging because it conflicts with the neoliberal perspective inherent in STEM education (Carter, 2017; Chen & Buell, 2018; Johnson & Czerniak, 2023), which is primarily characterized by a focus on competitiveness.

Some authors such as Freeman et al. (2015) suggest that it is possible for STEM education to promote basic scientific literacy for all while also trying to form an elite of STEM students. However, reconciling these two goals is certainly difficult, as the formation of such an elite largely requires a propaedeutic education, which tends to prioritize the most conventional (i.e., value-free and decontextualized) content to prepare students for success in subsequent higher education studies (Furió et al., 2001; Banet, 2007; Vázquez-Alonso et al., 2005). In doing so, not only is a key dimension of scientific literacy—namely, the ability to critically assess the social implications of scientific and technological development (Hodson, 2003)—neglected, but many students would also be left behind (Acevedo-Díaz, 2004; Vázquez Alonso & Manassero Mas, 2009). In other words, this elite of STEM students would clearly be a small minority, as reflected in the latest PISA results for science and mathematics skills (Organization for Economic Co-operation and Development, 2023).

STEM Education in Practice

The STEM approach is not univocal, and multiple proposals can be found in the literature. Most of them, however, coincide in promoting teaching practices that integrate at least two of the disciplines in the acronym (Toma & García-Carmona, 2021). The predominant model is the one that integrates science and engineering (McLure et al., 2022), while mathematics and technology are often reduced to "tools" or "resources" for learning in these areas (García-Carmona, 2020; Portillo-Blanco et al., 2024). Furthermore, the most commonly employed strategy for implementing STEM education in the classroom is project-based learning (Domènech-Casal et al., 2019; Herro & Quigley, 2017; Johnson & Czerniak, 2023; Torras Galán et al., 2021).

To date, numerous studies analyzing the feasibility and effectiveness of integrated education within the STEM framework have yielded inconclusive results (García-Carmona et al., 2025; Margot & Kettler, 2019; Martín-Páez et al., 2019; White & Delaney, 2021). This can be attributed to several factors: (1) science teachers being inadequately prepared to implement STEM education (Ejiwale, 2013; García-Carmona, 2020; García-Carmona & Toma, 2024; Herro & Quigley, 2017; Johnson & Czerniak, 2023; Pulsawad et al., 2025), (2) the absence of universally accepted theoretical frameworks for STEM education (Martín-Páez et al., 2019; Quílez, 2022; Toma & García-Carmona, 2021), and (3) a lack of validated and practical curricular resources for incorporating authentic STEM education in the classroom (García-Carmona, 2020; Honey et al., 2014; Lupión-Cobos et al., 2023; Toma & García-Carmona, 2021). As a result, the integration of STEM disciplines often appears forced, superficial, or anecdotal (Castaño Torres & Guerra Ramos, 2023; Toma & García-Carmona, 2021).

Identity Features of the STEM Construct and Its Components

As previously indicated, within the STS framework, the epistemological and ontological relationships between science and technology are reasonably well defined, including their hybridization under the construct of technoscience. In contrast, less progress has been made in the field of STEM.

STEM is often described as a *metadiscipline* (Kennedy & Odell, 2023; Morrison, 2006), that is, a discipline of disciplines. At the same time, it is frequently assumed to be a *transdiscipline* (Colakoglu, 2018; Flogie & Aberšek, 2015; Holbrook et al., 2020), implying that it transcends the sum of the individual disciplines within the acronym. However, unlike *technoscience* in the STS framework—whose conceptual boundaries are relatively well established—it remains unclear whether STEM is a meta- or transdiscipline (Akerson et al., 2018; Erduran, 2020; Peters-Burton, 2014). In an attempt to unravel the nature of STEM, experts in the didactics of the respective disciplines concluded, based on a joint analysis, that:

> Once we had some idea about the natures of the individual disciplines, we debated and tried to define a nature of STEM that would combine these disciplines. After quite a bit of thought and debate we said as a group, "There is no STEM—it is nothing!" (Akerson et al., 2018, p. 5)

Regarding how the different disciplines are conceptualized and interrelated within the STEM framework, notable differences emerge when compared to the STS approach. STEM integrates closely related disciplines, such as engineering and technology, whose distinctions and relationships are often unclear (García-Carmona, 2023). In addition, these relationships are usually defined in ways that differ from those established within the STS framework (Acevedo-Díaz, 1995). In the STEM context, some authors regard technology and engineering as virtually indistinguishable (Park et al., 2020). For others, technology becomes superfluous once engineering is included (McComas & Burgin, 2020), as technology is often reduced to a mere "tool" or "product" of engineering in STEM education (Ellis et al., 2020; García-Carmona, 2020).

Furthermore, in efforts to attribute an ontological identity to engineering, traits and practices that were considered until not so long ago characteristic of technology have been ascribed to engineering (García-Carmona, 2023). Consequently, a distorted image of technology tends to be projected in the STEM framework (Acevedo Díaz, 2006; García-Carmona, 2023; Sanders, 2009). It is, therefore, understandable that future secondary school technology teachers, even those with an engineering background, encounter difficulties when integrating engineering practices into the design of STEM proposals (Ortega-Torres, 2022). The same is true when practicing science teachers are asked about the incorporation of engineering into their classes (García-Carmona & Toma, 2024).

Despite this, some proposals have been put forward to define the nature of STEM. For example, Quinn et al. (2020) consider that the nature of engineering would best represent the nature of STEM; especially design processes (Hallström & Ankiewicz, 2023). Conversely, Ortiz-Revilla et al. (2020), inspired by the "family resemblance" framework used for conceptualizing the nature of science (Irzik & Nola, 2011), suggest that the different areas encompassed by the acronym share certain traits, much like the sciences do. According to this, the nature of STEM would be given by those traits in which science, engineering, technology, and mathematics find a *resemblance*.

None of these approaches, nevertheless, has yet been consolidated, nor is there any hint of consensus within the STEM education community. In this regard, STEM education remains far from achieving what has already been achieved in this respect in STS education (Acevedo Díaz, 2006; Aikenhead & Ryan, 1992), at least at a theoretical level. As stated in a report by the European science education community, Scientix, "at the level of European countries, however, there is no common understanding of what STEM refers to" (European Schoolnet, 2018, p. 6).

CONCLUDING REMARKS

Based on all the points outlined above, there are no compelling arguments to support the idea that STEM education is an evolution of STS education, or, in other words, that it is a "branch" stemming from the STS approach. Nor do the arguments available demonstrate a significant similarity between the two educational movements. From their respective origins, the principles and educational purposes underlying each movement are quite distinct. In fact, the sociopolitical and economic crises that gave rise to each resulted in very different educational responses: a neoliberal perspective in the case of STEM education versus the socio-humanistic approach characterizing STS education. These divergent perspectives are also reflected in the theoretical frameworks and most representative educational proposals of each movement.

Although this analysis is not to suggest that STS and STEM education are entirely antagonistic, it does emphasize that their philosophical and socio-educational foundations differ significantly, making it difficult to establish meaningful relationships between them. Therefore, highlighting superficial commonalities, such as the promotion of integrated education or a departure from traditional teaching approaches, oversimplifies the issue and ultimately contributes to masking the profound differences between them.

Some proposals in the literature, nevertheless, advocate for incorporating STS education's inherent qualities and purposes into STEM education. These include addressing social issues related to scientific and technological development, fostering critical analysis, and promoting *scientific literacy for all*. In this case, the most appropriate way forward may be to adopt the STS framework directly, as it has long provided numerous reference projects and curricular materials (Acevedo Romero & Acevedo Díaz, 2002; Castaño Tamara, 2013; Martín Gordillo, 2017). Yet, there appears to be resistance to dispensing with the "STEM" label in these educational proposals, which only reinforces the idea that STEM education encompasses *everything*, further complicating its conceptualization and making it increasingly ambiguous and confusing.

In practice, STS education has materialized in a socially contextualized approach to science education, with no attention to technology and a strong emphasis on the critical perspective. On the contrary, STEM education usually aims to produce a tangible outcome (such as an artifact, structure, system, or model) through project-based learning, often with minimal regard for social aspects. Consequently, both movements represent two very different educational approaches. Arguably, the only aspect they currently *share* is that neither has yet succeeded in implementing an

authentic and effective integrated education in the classroom. However, this commonality does not imply a connection between them—it is just a coincidence.

Table 1 summarizes the key distinctions between STS and STEM education based on the aspects examined in this study.

Table 1. Key differences between STS and STEM education

	STS education	STEM education
Origin	Emerged in response to a sociopolitical, economic, and cultural crisis related to the rapid scientific and technological development of the time (sociocultural connotation).	Originated from concerns about maintaining capitalist hegemony in the face of the rapid scientific and technological development of other world powers (neoliberal connotation).
Educational purpose	To promote a more humanized science curriculum connected to relevant social issues. To encourage citizen participation in democratic decision-making and actions to solve problems related to science and technology.	To prepare individuals for the labor market, which demands more and better professionals in STEM fields.
Identity traits	Clearly defines the nature of science and technology, including their differences, relationships, and common aspects (e.g., technoscience). Takes a holistic view of the nature of science and technology, including their social dimension (internal and external sociology of science and technology). Conceives engineering as a part of technology.	Lacks a clear definition of the nature of STEM as a meta- or transdisciplinary construct. Usually considers technology a tool or the product of engineering. Fails to clarify the differences between technology and engineering as fields of knowledge.

Source: Own work.

This analysis is especially pertinent because STEM education is making a significant impact in educational contexts where STS education has a long tradition, such as Ibero-America (Andrade & Teixeira, 2025; Acevedo-Díaz & García-Carmona, 2016; Martins & Martín Gordillo, 2022), Canada (Aikenhead, 2000; Petrina, 2022), and the United Kingdom (Hunt, 1988; Phillips & Hunt, 1992). As noted above, there is a propensity to associate or compare STEM education with STS education. Therefore, it is likely that science and technology educators may feel doubtful and uncertain about which educational perspective to adopt in their classrooms. It is hoped that the discussion presented here is useful to elucidate on this, making it clear that it represents a particular yet well-founded perspective on the issue.

ARTIFICIAL INTELLIGENCE USE STATEMENT

Translation and proofreading tools such as DeepL, Writefull, and ChatGPT were used responsibly to improve the writing of the text.

CONFLICTS OF INTERST

The author declares no conflicts of interest.

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