Sociocultural Contexts in STEAM Education and Science Communication

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Jesús M. Sáenz[1,2], Karen Y. Castrejón[1]
[1]*Departamento de Física y Matemáticas, Universidad Autónoma de Ciudad Juárez, Av. del Charro No.450. Colonia Partido Romero, CP 32310, Ciudad Juárez, México.*
[2]*Department of Physics, New Mexico State University, MSC 3D 1255 N Horseshoe 88003-8001, Las Cruces, New Mexico, U.S.A.*

E-mail: jessaenz@uacj.mx

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Abstract

This review examines how sociocultural contexts impact the integration of science communication into STEM and STEAM education, particularly in Latin America, where inequities and cultural diversity present distinct challenges. Through a narrative synthesis of examples, case studies, and best practices, the review highlights themes such as science identity, self-efficacy, civic engagement, inclusion, educational technologies, and translanguaging. Findings suggest that culturally responsive approaches enhance motivation and meaningful learning in STEM fields. Achieving this requires collaboration among educators, science communicators, and communities, supported by adequate policies and critical evaluation of educational initiatives and activities.

Keywords: STEM education, Science Communication, Sociocultural Context.

Resumen

Esta revisión examina cómo los contextos socioculturales impactan la integración de la comunicación científica en la educación STEM y STEAM, particularmente en América Latina, donde las inequidades y la diversidad cultural presentan desafíos distintivos. Mediante una síntesis narrativa de ejemplos, estudios de caso y buenas prácticas, la revisión destaca temas como la identidad científica, la autoeficacia, la participación cívica, la inclusión, las tecnologías educativas y el translenguaje. Los hallazgos sugieren que los enfoques culturalmente receptivos mejoran la motivación y el aprendizaje significativo en las áreas STEM. Lograr esto requiere la colaboración entre educadores, comunicadores científicos y comunidades, respaldada por políticas adecuadas y una evaluación crítica de las iniciativas y actividades educativas.

Palabras clave: Educación STEM, Comunicación científica, Contexto sociocultural.

I. INTRODUCTION

In [1], science communication is described as encompassing a wide range of modes that target different audiences, each with specific objectives, all aimed at raising awareness of scientific topics. One traditional approach is the “deficit” or “one-way” model, which assumes a need to fill knowledge gaps. As discussed in [2], this traditional model has been criticized for potentially reinforcing power dynamics. An alternative is the “two-way” model. Llorente [3] presents the three basic models of science communication: dissemination, dialogue, and conversation-participation.

Just as science communication practices must consider audiences’ prior knowledge, values, and perspectives, educational practices in STEM must also acknowledge students’ diverse cultural and social backgrounds.

For example, Vera [4] states that education encompasses various dimensions of student development, including social, cultural, economic, and environmental aspects. Although the study refers specifically to Ecuador, this perspective on education has become increasingly widespread. For example, Benitez [5] discussed the effectiveness of culturally responsible, family-centered STEM interventions among underrepresented groups, such as Latina girls. As noted in [6], there has been rapid growth in STEAM education research – particularly regarding gender- and most of the studies reviewed reveal gender inequality in STEM disciplines. However, many of these studies overlook the social, cultural, and institutional barriers that contribute to gender gaps in representation [6]. This argument supports our advocacy for integrating science communication, sociocultural contexts, and STEAM education.

Following the communicative nature of education, teaching is defined as “a specific form of communication that aims to provide students with the opportunity to learn and construct knowledge” [4, p.2]. The same work asserts that “education should be a liberating process that allows students to reflect on their sociocultural reality” [4, p.8]. Additionally, the work in [7] explains that approaches based on sociocultural theory view learning as “a social process involving cultural tools like language to construct knowledge” [7, p. 1]. As an example, the work presented in [5] explores culturally rooted pedagogy through a case study of STEM teachers at an all-girls STEAM school (predominantly Latina) in the U.S.-Mexico borderlands. These teachers integrate engineering to reinforce core subjects while supporting students' academic and personal growth.

The work presented in [8] notes that children's emotional understanding is a predictor of psychological well-being and academic achievement. The study emphasizes the importance of addressing individual learning needs, such as learning styles and abilities, to foster inclusive and engaging environments that respect and support each student, regardless of their cultural background.

The reduction of potential exclusionary barriers in implementing advanced pedagogical strategies is discussed in [9]. The work also notes the scarcity of studies that implement digital tools while considering students' sociocultural profiles, particularly among ethnic minorities and underrepresented or vulnerable groups. Science communication is vital in addressing this issue. As shown in [10], individuals from low-income and marginalized backgrounds often have limited exposure to science communication activities. In contrast, science communication training has been shown to increase science identity– which refers to students' self-perceived belonging and competence within scientific disciplines– and self-efficacy – defined as a combination of a student's perceived ability to conduct research, solve problems, and communicate effectively [11]- among STEM students [10].

This review examines how integrating science communication into STEAM education, when informed by sociocultural context, can enhance inclusion, engagement, and effectiveness in diverse learning environments.

II. THEORETICAL FRAMEWORK

To understand how sociocultural learning translates into educational practice, we first define essential terms in STEM and STEAM education. Kotsis [8] defines STEM education as a multipronged approach that integrates science, technology, engineering, and mathematics while fostering creativity alongside scientific and mathematical competencies. The inclusion of the arts in STEM is known as STEAM. Pedrosa [6] argues that incorporating the arts allows students to express creativity and expand their perspectives in traditionally rigid or logical fields. According to [6], the arts help contextualize science and can make STEM subjects more appealing to a broader range of students.

As reported in [12], culturally relevant STEM education focuses on serving students who are culturally, linguistically, and socially diverse. As stated in [7] and [12], Vygotsky's sociocultural theory posits that learning is inherently social and mediated by cultural tools and artifacts, with language serving as the primary mediator. The authors of that work provide a systematic review of the Culturo-Techno-Contextual Approach- an Afrocentric, decolonizing framework in STEAM education that incorporates African cultural knowledge. This approach integrates students' cultural backgrounds, technological tools, and geographical contexts. Oladejo [12] reports that the strategy is effective in STEM learning due to its ability to incorporate student knowledge into cultural practices and daily life, enhance critical thinking, and promote student interest in STEM topics.

Kotsis [8] highlights the difference between general education, which focuses on literacy, mathematics, and social development, and STEM education, which emphasizes the critical and technical skills needed by future professionals. However, as noted in [6], there is no consensus on how STEM education should be implemented. As discussed in [6], there are several approaches for achieving disciplinary integration in STEAM:

- Multidisciplinary: Disciplines remain distinct but are applied together to solve a problem.
- Interdisciplinary: Disciplines are approached separately, then intentionally combined.
- Transdisciplinary: Disciplines are integrated seamlessly to solve problems holistically.

These frameworks provide the conceptual foundation for analyzing how science communication and STEAM education can address the diverse needs of learners.

III. STEAM EDUCATION IN DIVERSE SOCIOCULTURAL CONTEXTS

Certain STEM approaches in education have drawn criticism. Andrade [13] notes that they often lack sociopolitical context, overlooking the social, ethical, political, and environmental dimensions that intersect with science and technology. The work advocates for the Science, Technology, and Society (STS) education framework as a more socially engaged alternative to STEM. However, it does not address the strengths or evolution of STEM education itself. Based on the discussions in this review, it will become evident that STEM education is evolving toward a more critical, inclusive, and socially engaged vision.

Kotsis [8] identifies several barriers to meaningful STEM education: limited resources, insufficient teacher training, and weak support systems. For example, Bhagwati [14] emphasizes the importance of teacher resources, professional training, interdisciplinary curriculum development, and technology integration in supporting effective learning.

Seidel [15] notes that underrepresented communities lack access to high-quality and culturally relevant STEM learning opportunities. Similarly, Bhagwati [14] emphasizes the absence of culturally responsive teaching and the failure to recognize students' prior knowledge as essential challenges.

Kotsis [8] highlights the persistent gender gap in STEM, with girls and women remaining underrepresented in the field. The study notes that although girls often show early interest in STEM, that interest tends to decline throughout their educational journey. In this context, Zhou [16] addressed the multifaceted decline in interest in STEM careers. Factors such as gender, ethnicity, self-motivation (including interest, enjoyment, and social utility), social persuasion, self-efficacy, personal utility (e.g., job stability), and positive STEM experiences are identified as primary influences on STEM career choices. The roles of social utility and persuasion underscore the importance of sociocultural context in STEAM education, mainly as students increasingly express concerns about environmental and social issues [16].

Kotsis [8] also attributes the gender gap to the influence of social groups and cultural expectations. Similarly, Benedito [17] reports that societal biases around gendered behaviors and skills reinforce stereotypes from early childhood. The study encompasses an in-depth review of Latin American public policies addressing gender inequality in STEM fields. In contrast, Dou [18] emphasizes the positive role of family context in shaping children's STEM identity, including interest, recognition, and self-perception of performance, through everyday conversations about STEM and related topics. These positive outcomes suggest opportunities for science communication to engage families by incorporating cultural, emotional, and narrative forms that stimulate discussion.

Science identity refers to how students perceive themselves as capable and actual participants in science communities. As mentioned in [11] and [19], undergraduate science identity can predict engagement in STEM communities but does not necessarily correlate with self-efficacy or communication skills. Furthermore, these studies reveal a disconnect between science identity and civic engagement, which refers to the application of scientific knowledge and skills to promote public welfare, influence policy, and participate in community-based problem-solving, suggesting that science training does not always prepare students to become social leaders or promote equity. These findings underscore the importance of science communication in shaping students' identities.

Regarding educational design, such as with metaverses—3D immersive virtual environments used for interactive learning—Avendaño [9] recommends beginning with an understanding of how factors like ethnicity, socioeconomic status, gender, and functional diversity influence student engagement and experience. Science literacy is essential for making informed decisions, understanding diverse perspectives, and constructing evidence-based arguments, which are core elements of effective science communication. Benedito [17] also finds that public policies supporting gender balance in science education can encourage interest and motivation, especially when introduced from early childhood.

To guide culturally responsive instruction, Ganesan [7] offers several strategies, which include:

- Leveraging linguistic resources: Translanguaging draws on the full range of students' languages, allowing them to use their home languages alongside academic and scientific terms to construct meaning and deepen understanding.
- Culturally responsive pedagogy: Linking science content to students' cultural experiences.
- Integrating scientific content and language instruction: Emphasizing concurrent learning of scientific content and language for multilingual students.
- Technology-enhanced learning: Using tools like digital storytelling to engage learners.
- 5E Instructional Model: Engage (connect to prior and cultural knowledge), Explore (hands-on collaboration), Explain (student-led understanding), Elaborate (apply concepts to new situations), Evaluate (assess understanding with multiple modes).

Ganesan [7] emphasizes that the success of culturally sustainable approaches relies on designing learning experiences that are responsive to diverse cultural contexts.

Together, the findings so far presented in the review reveal that without attention to sociocultural context, STEAM education risks perpetuating existing inequalities. The following section explores how science communication may help address this challenge.

IV. SCIENCE COMMUNICATION AS AN EDUCATION TOOL

According to [1], science communication, through its various modes, serves to raise awareness of science topics among specific target audiences. When the audience consists of students, science communication serves as an educational tool. The authors propose that science communication and science education are "two sides of the same coin" [1, p. 6].

One major challenge in science communication is the lack of consistent evaluation criteria across activities, which creates uncertainty about their success [3]. Ziegler [20] outlines three critical challenges in evaluating science communication: (1) vague definitions of objectives and target audiences, (2) relying on self-reporting rather than scientifically valid evaluations, and (3) viewing evaluation as a final step instead of an ongoing learning process in the activity design and implementation. These limitations should be addressed when using science communication as an educational tool.

The literature review presented in [16] highlights the importance of improving STEAM education while noting the limitations of science communication: "…classroom interventions such as museum visits and involvement in citizen science projects … do not have a very strong influence on STEM career choice but seem to enhance rather than influence aspirations outright" [16, p. 18].

Lorke [21] proposes that science communication activities be classified by their objectives: increasing access to science, influencing audience response, encouraging action, promoting dialogue with the scientific community, or fostering participation in science.

Science communication is increasingly adopting organizational structures. For example, Krebs [22] suggests that defining participant roles, audience types, and objectives can optimize science communication efforts. Such structures may also be applied in the classroom by aligning educational goals with science communication objectives. These experiences can extend into informal STEM education, which includes activities centered on STEM engagement outside the formal classroom [23]. Examples include after-school programs, presentations, science festivals, museum and planetarium visits, social media, popular books, games, and films [23].

Moving on to science communication channels that can be used with students or general audiences, del Cerro-Sánchez [24] identifies gamification, utilizing digital and board games, role-playing, and simulations, as an effective science communication tool to promote science literacy, facilitate interactive discussions, and support hands-on experimentation. The authors argue that success requires planning, clearly defined objectives, effective use of technology, and opportunities for collaboration and feedback. These elements reflect core principles of strategic science communication. In this approach, games are viewed as tools that educators and science communicators can utilize in both formal and informal settings to introduce STEM concepts.

Andrade [13] notes the increasing dissemination of STEM approaches through various channels, including events, academic journals, educational websites, articles, dissertations, and theses. These are just a few of the many communication channels (e.g., blogs, social media, influencers, videos) used in science communication, although they can be considered professional channels.

Dou [18] observes that socialization in both formal and informal learning contexts shapes stereotypes and archetypes of STEM professionals, often in contrast with students' perceptions of their own STEM identities. In this context, science communication is increasingly seen as an interdisciplinary collaboration among educators, pedagogues, public engagement professionals, and STEM experts to create supportive learning environments [2, 25].

Seidel [15] highlights digital storytelling, used in both formal and informal settings, as a valuable educational tool for enhancing student engagement, achievement, and motivation. Digital storytelling is defined as the use of video and digital media to communicate science through short, research-based narratives.

Ulbrich [26] argues that technologies such as 3D modeling and printing can enhance creativity, critical thinking, collaboration, and communication in STEAM education, thereby helping to bridge gender gaps. This underscores the teacher's role as a science communicator, who is required to explain content using innovative digital tools.

Table I shows initiatives that illustrate how science communication strategies have been applied in public-facing physics education:

TABLE I. Summary table of example science communication initiatives in physics.

Initiative	*Key Features*
ATLAS Collaboration [27]	Outreach activities, multilingual materials, virtual visits, high-energy physics tutorials.
CERN Science Gateway [28]	Collaborative outreach center with scientists, educators, designers, and multimedia experts.
Stanford Underground Research Facility [29]	Educational programs, teacher training, Artist in Residence program focused on neutrino and astroparticle physics.
Italian Institute of Nuclear Physics [30, 31]	Narrative storytelling, social media, and workshops for children on atomic structure and cosmology.
MAGIC Collaboration [32]	Social media recognition of young scientists, public lectures, masterclasses, and telescope site tours.
Educational YouTube Channels [33]	Topics include energy, electricity, sustainability; accessible digital format.
Webb Outreach Through Art [34]	Artistic interpretation of James Webb telescope images to engage the public.
Do You Speak Quantum? [35]	Interactive exhibition to raise public and policymaker awareness of quantum physics and computing.

Together, these approaches underscore that science communication—when designed to engage and include—can enhance formal education, potentially increasing participation in STEM fields.

V. INTERSECTION OF STEAM EDUCATION, SCIENCE COMMUNICATION, AND SOCIOCULTURAL CONTEXT

This section synthesizes the theoretical and empirical insights discussed above to show how science communication, STEAM, and sociocultural context, featuring intersect in practice.

The work presented in [13] highlights a tension in curricula proposals aimed at fostering citizenship, social participation, and transformation, "contrasted with the pragmatic, economistic, and market-oriented perspective typical of STEM projects" [13, p. 1]. STEM's original purpose, introduced in the United States three decades ago, was "to promote a skilled workforce in the areas of Science, Technology, Engineering and Mathematics" [6, p.188]. The review does not adopt this dichotomy. Instead, it presents ample evidence that STEM education and science communication can be implemented with attention to sociocultural context. However, more research is needed to critically assess the effectiveness of STEM approaches compared to traditional teaching methods.

The effective implementation of STEAM education and science communication depends mainly on educators. As Kotsis [8] notes, educators function not only as instructors but also as mentors and role models. This expanded role requires awareness of students' diverse needs and backgrounds, often addressed through strategies like differentiated instruction—tailoring content, teaching methods, and assessments to individual strengths and contexts.

As discussed, del Cerro-Sánchez [24] offers an example of the intersection of STEM education, science communication, and sociocultural awareness: an outreach program in rural Latin American communities that incorporates local dialects and cultural contexts. Science communication about STEM concepts, including microbiology and climate, was enacted through talks, inquiry-based activities, and hands-on experiences to enhance reasoning, critical thinking, and collaborative learning, promoting civic awareness and science literacy by relating the topics in a culturally relevant manner.

As mentioned, Kotsis [8] emphasizes the importance of an inclusive learning environment and highlights the benefits of differentiated instruction. Similarly, Vera [4] argues that social inclusion in education requires new approaches to communication and teaching that accommodate students' individual needs, including sensory and spatial considerations.

Kotsis [8] views technology as an educational and communication tool—not a replacement for traditional teaching practices—that can boost student engagement, motivation, and academic achievement. The work cites examples such as interactive software, multimedia materials, and online platforms.

Regarding technology integration, Avendaño [9] examines the use of metaverses—three-dimensional immersive virtual environments—as innovative pedagogical tools.

As Ganesan [7] suggests, further research is needed to evaluate long-term impacts on students, improve teacher training in designing and implementing learning experiences, integrate science communication tools into STEAM education, and explore the intersectionality between science communication and sociocultural contexts.

VI. CASE STUDIES AND BEST PRACTICES

This section presents some concrete strategies and case studies that exemplify how the intersection of STEAM education, science communication, and societal awareness can be enacted.

From the gamified science communication approach in [24], the following best practices can be identified: engaging diverse learners, designing culturally meaningful materials, centering underrepresented communities, combining science communication models, and ensuring visibility and representation. However, Rillero [36, p.7] asserts that "[c]ultural relevance in STEM education extends beyond mere inclusion of diverse examples to encompass a deeper understanding and validation of students' cultural identities, experiences, and ways of knowing." According to the authors, STEAM education should recognize and build upon students' cultural and linguistic resources while addressing inequitable practices.

Additional best practices recommended by Rillero [36] include implementing family-centered, project-based learning, recognizing students' aspirational, familial, and linguistic capital to inform instruction and identity-building activities, and promoting intergenerational science communication.

Seidel [15] emphasizes the value of science communication through video storytelling as an educational tool. This approach expands learning opportunities for underrepresented student communities, enabling them to explore cultural connections to food systems, plants, and animals and to share their knowledge.

Kotsis [8] outlines the important qualities of effective STEM educators, including a strong background in STEM, a solid understanding of its concepts and trends, effective problem-solving and communication skills, and a passion for interdisciplinary learning. In this context, integrating technology and science communication into STEAM lessons can support students' unique learning needs while fostering curiosity and a desire for experimentation in inclusive classrooms. Avendaño [9] notes that Latin America faces challenges in adopting emerging technologies in education, including budget constraints and limitations in connectivity and infrastructure.

Kotsis [8] also emphasizes the importance of collaboration between engineering faculty and STEM educators in hands-on learning activities that foster creativity and enhance student engagement. The study adds that collaboration between educators and industry professionals provides enriching experiences that benefit both students and instructors.

Regarding gender disparities in STEM, Kotsis [8] argues that early STEM education plays a crucial role in building inclusive and supportive learning environments.

Avendaño [9] reports on the implementation of an educational metaverse that includes materials on analytic geometry calculus, linear algebra, probability, statistics, and formative assessment. The 3D immersive environment improved learning outcomes in these subjects and increased motivation and engagement among Maya-Tzeltal students from rural communities in Chiapas, Mexico. This example illustrates how immersive technologies can be culturally responsive when designed for specific linguistic and regional communities.

Taking into account students' sociocultural realities, Vera [4] recommends implementing collaborative activities, inclusive teaching materials, and culturally responsive strategies such as community dialogues and cultural fairs. This work strongly advocates for making cultural diversity a core element of education.

Building on these strategies, one notable feature of integrating cultural, technological, and contextual elements into STEM education is the adaptability of approaches such as the Culturo-Techno-Contextual Approach, which can be tailored to different cultures using culturally relevant strategies and materials [12]. One example of such adaptation is the inclusion of culturally relevant storytelling, as mentioned in this review.

Table II summarizes a set of strategies and notable cases that illustrate how the intersection of STEAM education, science communication, and sociocultural sensitivity can translate into effective educational practices. These evidence-based experiences, implemented in diverse contexts, offer replicable paths for educators, science communicators, and curriculum designers committed to more inclusive and contextualized teaching.

TABLE II. Best practices in STEAM education and science communication with sociocultural awareness.

Strategy or Practice	*Educational and Sociocultural Applications*
Gamification and Cultural Narratives [24]	Use of games, simulations, and role-playing to promote scientific literacy and culturally meaningful discussions.
Family-Centered Project-Based Learning [36]	Recognition of family and linguistic capital; intergenerational participation in STEAM activities.
Science Video Storytelling [15]	Promotes connections between science and culture in marginalized communities through digital narratives.

Immersive Education (Metaverses) [9]	Improved learning and motivation in rural communities (e.g., Maya-Tzeltal students) through tailored 3D environments.
Collaboration Between Teachers and Professionals [8]	Enhancing STEAM learning through joint work between educators and industry or science communication professionals.
Culturally Aware Technology Integration [4]	Use of digital tools with attention to students' functional, linguistic, and cultural diversity.
Culturo-Techno-Contextual Approach [Oladejo]	STEAM curriculum design that integrates local knowledge, technological tools, and geographical context.

The synthesis of case studies and practices presented in Table II offers a framework that can guide the design of inclusive, culturally grounded, and communication-enhanced STEAM education initiatives.

Altogether, the practices exposed above suggest that inclusive STEAM education requires more than just curriculum design —it must integrate cultural knowledge, community collaboration, and adaptive communication strategies.

VII. CONCLUSIONS

This review presents multiple examples, such as the use of metaverses, digital storytelling, and gamification, demonstrating how science communication can be meaningfully integrated into STEAM education when informed by sociocultural contexts. Three key dimensions emerge at the intersection of STEAM education, science communication, and sociocultural sensitivity: students' science identity, self-efficacy, and civic engagement.

The review also acknowledges the tension between traditional teaching methodologies and the need for cultural relevance in education. While the examples discussed provide valuable guidance, a more critical perspective is needed to assess their effectiveness, especially considering the lack of consensus on implementation practices across varied audiences and local institutional settings. Best practices suggest that these models should not only be replicated but also systematically documented at every stage—from design to evaluation.

An important insight derived from this review is the expanded role of teachers and educators, who also serve as mentors, role models, and science communicators. This highlights the need for adequate training in educational strategies that address cultural and technological diversity, as well as in the use of culturally responsive curricula and science communication tools.

To fully harness the benefits of science communication as an educational strategy, science communicators must collaborate with educators in tailoring their approach to specific audiences while aligning it with educational objectives.

Policymakers and institutions should actively support initiatives, such as interdisciplinary programs, teacher training, and infrastructure, that integrate STEAM education, scientific knowledge, and cultural diversity. There is also a growing need for interdisciplinary collaboration involving educators, communicators, technologists, artists, and local communities.

For future research and practice, a critical evaluation is needed to understand better the impact of science communication on students' science identity, self-efficacy, and civic engagement, using both qualitative and quantitative methods. Additionally, educational strategies such as translanguaging should incorporate prior knowledge and local cultural perspectives into STEM curricula, where applicable.

Although challenges persist globally in STEM education and science communication, they are particularly pressing in Latin America, where structural inequalities, linguistic and cultural diversity, and institutional barriers must be addressed through context-sensitive, inclusive, and innovative approaches.

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