

Beyond acronym expansion: A critical review of STEM, STEAM, and STREAM as models of educational change

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ABSTRACT

STEM, STEAM, and STREAM are widely used in educational discourse, yet the addition of letters does not by itself demonstrate a change in curriculum or pedagogy. This critical narrative review compares the three labels through six analytical dimensions: disciplinary base, problem framing, pedagogical process, learner role, teacher role, and assessment. The synthesis positions these dimensions against established models of disciplinary integration and distinguishes claims made for each approach from the strength of their supporting evidence. Integrated STEM has the most established, though still heterogeneous, evidence base; STEAM is substantial but conceptually contested, particularly regarding creativity and the role of the arts; and STREAM remains comparatively emergent, with stronger evidence for disciplinary literacy than for the acronym as a distinct model. Published robotics and climate-change cases illustrate how the framework can distinguish substantive interdisciplinary change from relabeling. The review argues that acronym expansion is meaningful only when added disciplinary practices alter the design and evidence of learning.

Keywords: STEM education, STEAM education, STREAM education, interdisciplinary learning, arts integration, disciplinary literacy, educational change, teacher education

INTRODUCTION

STEM education has become a central concept in educational reform because science, technology, engineering, and mathematics are closely connected with scientific literacy, technological participation, innovation, and preparation for complex social and economic futures (Bybee, 2013; National Academy of Engineering & National Research Council, 2014). However, STEM education is not simply the teaching of four separate school subjects. In its stronger forms, STEM refers to an integrated approach in which learners use concepts, tools, and practices from more than one STEM discipline to investigate authentic problems, design solutions, test ideas, interpret evidence, and collaborate with others (Kelley & Knowles, 2016; Moore et al., 2014).

Definitions of STEM education nevertheless remain diverse across the literature. STEM has been conceptualized both through its constituent disciplines and through varying degrees of disciplinary integration, making it important to distinguish simple disciplinary coexistence from approaches in which knowledge and practices are meaningfully connected around shared educational problems (Breiner et al., 2012; Hasanah, 2020).

In educational practice and research, STEM is often extended into STEAM and STREAM. STEAM adds the arts to science, technology, engineering, and mathematics, while STREAM adds reading and writing, or literacy more broadly, to STEM or STEAM education (Aguilera & Ortiz-Revilla, 2021; Sun & Zhong, 2024). These extensions are often presented as educational innovations, but the nature of the innovation is not always clearly explained. In some contexts, the acronyms are used carefully to describe specific pedagogical changes. In other contexts, they are used as broad labels for hands-on, creative, or technology-rich classroom activities (Perignat & Katz-Buonincontro, 2019).

This ambiguity creates an important problem for research and practice. If STEM, STEAM, and STREAM are treated as interchangeable terms, educators cannot design coherent curricula, researchers cannot compare findings reliably, and school leaders cannot evaluate whether a program represents genuine educational change (Breiner et al., 2012; Sanders, 2009). A science lesson does not become STEM simply because a digital tool is used. A STEM activity does not become STEAM simply because learners decorate a prototype. A STEAM project does not become STREAM simply because students write a short paragraph at the end. The educational

significance of the acronym depends on whether the added discipline changes the learning process.

In this review, educational change is used primarily at the level of curriculum and pedagogical design rather than to denote whole-system reform. It refers to substantive alterations in what disciplinary knowledge and practices are mobilized, how problems are framed, how teaching and learning are organized, what roles learners and teachers assume, and what forms of evidence are used to assess learning. This distinction is important because adoption of a new program label does not necessarily imply corresponding change in classroom practice. Educational-change scholarship likewise emphasizes that formal adoption of an innovation and change in enacted practice are not equivalent (Fullan, 2016).

This review asks a central question: What actually changes when STEM becomes STEAM or STREAM? Naming a program STEM, STEAM, or STREAM does not by itself demonstrate change in curriculum, instruction, assessment, or learner participation. The analysis examines what each approach adds, the claims associated with it, and the conditions under which those claims are pedagogically credible (Thibaut et al., 2018).

The review is guided by four questions. First, how are STEM, STEAM, and STREAM education defined in the literature? Second, what claims are made for each approach, and how well are those claims supported? Third, where, and with what strength of evidence, do reported STEM, STEAM, and STREAM approaches differ in disciplinary organization, problem framing, pedagogical process, learner activity, teacher practice, and assessment? Fourth, what limitations should educators and researchers consider before adopting these labels?

Review Approach and Literature Selection

This article uses a critical narrative review approach because the purpose is conceptual clarification, critical comparison, and theoretical synthesis across heterogeneous research traditions rather than exhaustive study enumeration or statistical meta-analysis (Green et al., 2006). The conduct and reporting of the review were additionally informed by the scale for the assessment of narrative review articles (SANRA) (Baethge et al., 2019). SANRA was used as a quality-assurance and reporting guide rather than as a numerical scoring instrument. Its principles were addressed by establishing the importance of the review topic, stating explicit review questions, describing the literature-search strategy and source-selection logic, referencing central claims to relevant literature, and maintaining explicit scientific reasoning throughout the comparative synthesis. In particular, empirical findings, conceptual propositions, and broader advocacy claims were distinguished rather than treated as equivalent forms of evidence. The review also addressed SANRA's emphasis on appropriate presentation of relevant evidence by comparing the maturity, consistency, and limitations of the evidence available for STEM, STEAM, and STREAM rather than assuming that the three labels have equivalent empirical support.

The literature base was assembled through iterative purposive searching and citation chaining. To update and test the breadth of coverage, supplementary searches were conducted in August 2026 using ERIC and targeted searches of

journal and publisher websites. Search terms combined the focal labels with concepts central to the review, including disciplinary integration, arts integration, disciplinary literacy, reading and writing, argumentation, educational robotics, climate change, and environmental education. Searches focused mainly on work published from 2000 through August 2026, while earlier foundational sources were retained where they were needed to establish the conceptual history of curriculum integration, learning theory, literacy, assessment, or educational change. Reference lists of major reviews and conceptual papers were also followed to identify influential sources.

Sources were retained when they contributed directly to at least one of four purposes: defining STEM, STEAM, or STREAM; characterizing forms of disciplinary integration; reporting or evaluating pedagogical or learner outcomes; or providing a conceptual basis for analysing interdisciplinary curriculum and pedagogy. Conceptual frameworks, systematic and integrative reviews, theoretical studies, and selected empirical studies were therefore eligible. Sources were not retained merely because they used a STEM-related acronym; the reported educational design, evidence, or conceptual argument had to inform the questions addressed in this review.

Because the review is critical and narrative rather than systematic, the included literature was not subjected to meta-analytic aggregation or a formal risk-of-bias procedure. Instead, the synthesis distinguished among definitional claims, theoretical propositions, empirical findings, and broader advocacy claims. Particular attention was given to areas in which evidence is contested or uneven, including claims concerning creativity and transfer in STEAM and the status of STREAM as a distinct educational model.

Analytical Framework

The six dimensions used in this review are treated as a second-order analytical synthesis rather than as a competing classification of disciplinary integration. Existing frameworks have primarily addressed how disciplines are connected, including distinctions among multidisciplinary, interdisciplinary, and transdisciplinary integration and models identifying characteristics or conditions of integrated STEM learning (Drake & Burns, 2004; National Academy of Engineering & National Research Council, 2014; Roehrig et al., 2012; Vasquez et al., 2013).

The six dimensions were developed through a comparative synthesis of recurring sites of educational change across the reviewed STEM, STEAM, STREAM, and disciplinary-integration literature. They were informed by existing integration frameworks rather than adopted from any single pre-existing typology. Accordingly, the present framework asks a different question: where must an added disciplinary component produce observable change before expansion of an acronym can reasonably be interpreted as expansion of the educational model? Six recurring sites of change are examined: disciplinary base, problem framing, pedagogical process, learner role, teacher role, and assessment. These dimensions capture respectively, what forms of knowledge and practice enter the task, how the problem itself is constituted, how learning activity is organized, what learners are required

to do, what forms of teacher expertise and orchestration are required, and what counts as evidence of learning.

Within this framework, the six dimensions function as diagnostic sites of educational change. They make it possible to examine whether arts or literacy alter the design of learning rather than simply the label attached to it. An acronym extension is substantively consequential when the added component alters one or more central dimensions and those alterations are visible in enacted pedagogy, learner activity, or assessment.

Contribution of This Review

The contribution of this review is a comparative analytical framework that connects established integration scholarship with observable changes in problem framing, pedagogical process, participation, teacher practice, and assessment across STEM, STEAM, and STREAM.

Taken together, the framework treats STEM, STEAM, and STREAM as claims about educational design rather than as self-evident categories. The important issue is whether an added discipline changes the intellectual work of the task, the forms of participation it invites, or the evidence used to judge learning. This makes it possible to distinguish substantive interdisciplinary change from a change in terminology alone.

STEM EDUCATION: INTEGRATION, INQUIRY, AND TECHNICAL PROBLEM-SOLVING

STEM education refers to science, technology, engineering, and mathematics, but integration is the defining issue. A curriculum that places these subjects beside one another is not necessarily integrated in STEM. Integrated STEM requires meaningful connections among disciplines through a shared problem, phenomenon, project, or design challenge (Roehrig et al., 2012; Vasquez et al., 2013). This distinction matters because the educational value claimed for STEM depends on students using knowledge across disciplinary boundaries, not simply encountering different subjects in the same timetable.

The main pedagogical features associated with STEM include authentic problem contexts, inquiry, engineering design, mathematical modeling, technological application, experimentation, collaboration, and iterative improvement (English, 2016; Stohlmann et al., 2012). These features shift learning from passive reception toward active knowledge use. Students are expected to ask questions, test ideas, model relationships, design solutions, revise prototypes, and justify decisions. In this sense, STEM education is not only about content coverage. It is also about participation in scientific, mathematical, technological, and engineering practices.

Research commonly associates STEM education with problem-solving, scientific literacy, technological literacy, collaboration, design thinking, and interest in STEM-related pathways (Li et al., 2020; Margot & Kettler, 2019). These claims are connected to both civic and economic purposes. Learners need scientific and technological understanding to interpret evidence, evaluate public claims, respond to

environmental and health issues, and participate in societies shaped by digital systems and technological innovation.

However, STEM education also faces limitations. One limitation is conceptual looseness. STEM may refer to separate subject teaching, multidisciplinary connection, interdisciplinary integration, or transdisciplinary problem-solving, depending on the context (Çorlu et al., 2014). Another limitation is that STEM can be framed too narrowly around labor-market preparation, which may reduce attention to ethics, creativity, culture, communication, and citizenship (Zeidler, 2016). These limitations help explain why some educators and researchers argued for broader forms of interdisciplinary learning.

Implementation nevertheless depends on more than the formal combination of subject areas. Integrated STEM requires coordination across disciplinary knowledge, instructional design, classroom organization, and assessment, while teachers frequently identify time, curricular structures, resources, collaboration, and confidence as implementation constraints (Margot & Kettler, 2019; National Academy of Engineering & National Research Council, 2014). Work on the effective STEM educator similarly emphasizes pedagogical literacy, collaboration, self-efficacy, and the capacity to coordinate these demands in practice (Gavrilas & Kotsis, 2025a). The presence of several STEM subjects is therefore insufficient if their interaction does not materially alter the learning task.

STEAM EDUCATION: MORE THAN ADDING ART

STEAM education adds the arts to STEM. The addition appears simple, but the meaning of arts is complex. In the literature, the arts may include visual art, music, drama, dance, design, architecture, media, creative writing, humanities, or broader creative practices. This definitional variety makes STEAM flexible, but it also creates ambiguity for researchers and educators (Liao, 2016; Perignat & Katz-Buonincontro, 2019).

The strongest interpretation of STEAM is not that art should be added after STEM work is complete. STEAM is meaningful when artistic practices shape inquiry, design, representation, communication, critique, and interpretation. In weak versions of STEAM, students may simply decorate a model, design a poster, or make a final product visually attractive. In stronger versions, students use artistic and design practices to imagine alternatives, represent complex systems, communicate with audiences, interpret human experience, and evaluate the social and aesthetic dimensions of solutions (Henriksen, 2014; Quigley & Herro, 2016). This integrative role of design is also evident in design-education research. Kawakita (2025), for example, demonstrates how structured design activity can connect creative development with analytical decision-making, illustrating how design may function as a bridge between creative and systematic forms of thinking rather than merely as an aesthetic addition to technical work.

The movement from STEM to STEAM changes the problem frame. STEM problems are often framed as technical, scientific, mathematical, or engineering challenges. STEAM expands the frame by asking how a solution is experienced, represented, communicated, and situated in human contexts (Wynn & Harris, 2012). For example, a STEM project on water filtration may focus on materials, efficiency, testing, and measurement. A STEAM version may also require learners to design visual explanations, consider user needs, produce public communication materials, or explore how communities understand water quality and environmental responsibility.

Claims for STEAM commonly concern creativity, engagement, motivation, communication, conceptual learning, and broader participation, but these outcomes should not be treated as intrinsic consequences of adding the arts. The empirical evidence is heterogeneous because studies vary substantially in how they define STEAM, how deeply the arts are integrated, which outcomes are measured, and how those outcomes are assessed. Aguilera and Ortiz-Revilla (2021), for example, identified positive tendencies concerning creativity but emphasized limitations in the available evidence. The broader arts-education literature likewise cautions against assuming automatic transfer from participation in the arts to general creativity or achievement in unrelated domains (Winner et al., 2013). Creativity and engagement are therefore treated here as empirical claims requiring evidence rather than as defining outcomes of STEAM.

A further difficulty concerns the position assigned to the arts themselves. Mejias et al. (2021) show that STEAM is used in conceptually ambiguous and sometimes contradictory ways, including approaches in which the arts function instrumentally in support of STEM priorities. This critique complicates the assumption that adding artistic activity necessarily broadens the epistemic structure of STEM. A stronger STEAM interpretation therefore requires evidence that artistic practices contribute to problem framing, representation, interpretation, critique, or design reasoning rather than functioning mainly as decoration, motivation, or presentation.

The learner role also changes in STEAM. STEM often positions learners as investigators, designers, builders, coders, modelers, and problem-solvers. STEAM adds the roles of creator, communicator, interpreter, and designer of meaning (Yakman & Lee, 2012). This broadened role can help learners see scientific and technological work as connected to culture, design, communication, and human needs. It may also support students who do not initially identify with mathematics or science but who can enter interdisciplinary learning through representation, design, storytelling, or artistic expression.

The teacher role also becomes more complex. Teachers may need to coordinate disciplinary goals while supporting creativity, critique, aesthetic judgment, audience awareness, and communication. This often requires collaboration across subject boundaries and greater attention to how artistic practices are integrated into inquiry and design rather than appended after technical work is complete (Quigley & Herro, 2016; Wynn & Harris, 2012). This broader role is consistent with accounts of STEM teachers as facilitators and innovators

who adapt pedagogy and learning environments rather than simply transmit subject content (Gavrilas & Kotsis, 2025c).

STEAM has several risks. The first is superficial implementation. The arts may be treated as decoration rather than as a way of knowing. The second is conceptual vagueness. If STEAM means any creative activity, the term loses precision. The third is assessment misalignment. If STEAM claims to develop creativity and communication, then assessment must examine creative process, representation, design reasoning, and communication rather than only technical function or final appearance (Conradty & Bogner, 2020). These risks show that STEAM represents real change only when the arts transform the learning process.

STREAM EDUCATION: AN EMERGING AND CONTESTED EXTENSION

In this review, STREAM refers to the integration of reading and writing with STEM or STEAM education. The acronym is not fully standardized: in some educational contexts, the R has also been used to denote religion (Mubarak et al., 2020). This variation makes it important to state explicitly what the R represents in any particular study or program. Here, STREAM is treated as an emerging literacy-explicit extension rather than as a settled third stage in a STEM-STEAM-STREAM progression.

The strongest rationale for a reading/writing interpretation of STREAM is not the acronym itself but the established literature on disciplinary literacy. Scientific, technological, engineering, artistic, and mathematical knowledge are produced and communicated through texts, diagrams, models, reports, specifications, explanations, data displays, and arguments. Students therefore need to learn how language functions within disciplinary and interdisciplinary work (Norris & Phillips, 2003; Shanahan & Shanahan, 2008). This distinction matters because evidence that disciplinary literacy supports learning is not equivalent to evidence that STREAM is a distinct educational model.

Reading can deepen interdisciplinary learning by providing background knowledge, multiple perspectives, evidence sources, technical information, and social context. In a STREAM unit on renewable energy, for example, students may read scientific explanations, public policy documents, technical diagrams, community narratives, and media reports before designing or evaluating a solution. Reading in this context is not an isolated language exercise. It becomes part of problem definition and evidence gathering (Pearson et al., 2010).

Writing can support reasoning and metacognition because it requires students to organize ideas, connect evidence to claims, explain procedures, compare alternatives, and reflect on revision. In STREAM learning, students may write design briefs, research summaries, engineering notebooks, laboratory reports, reflective journals, peer feedback, public explanations, or argumentative essays (Hand et al., 2004; Keys, 1999). These forms of writing make learning processes visible and help teachers assess not only what students produce but how they think.

Table 1. Comparative analytical framework for STEM, STEAM, and STREAM

Dimension	STEM	STEAM	STREAM
Disciplinary base	Science, technology, engineering, and mathematics (Kelley & Knowles, 2016; National Academy of Engineering & National Research Council, 2014)	STEM plus arts (Perignat & Katz-Buonincontro, 2019)	STEM/STEAM plus reading and writing (Sun & Zhong, 2024)
Problem framing	Authentic scientific, technological, engineering, or mathematical problems requiring meaningful connections across STEM disciplines (Roehrig et al., 2012; Vasquez et al., 2013)	STEM problems broadened through human experience, representation, aesthetics, communication, culture, or user needs (Wynn & Harris, 2012)	Problems approached through disciplinary texts and evidence, with reading and writing contributing to problem definition and evidence gathering (Pearson et al., 2010; Sun & Zhong, 2024)
Pedagogical process	Inquiry, engineering design, modeling, experimentation, collaboration, and iterative improvement (English, 2016; Thibaut et al., 2018)	Artistic and design practices shape inquiry, representation, interpretation, critique, and communication (Henriksen, 2014; Quigley & Herro, 2016)	Reading and writing are embedded throughout inquiry and design to gather evidence, document reasoning, revise claims, and communicate conclusions (Hand et al., 2004; Sun & Zhong, 2024)
Learner role	Investigator, designer, builder, modeler, and problem-solver (Kelley & Knowles, 2016; Thibaut et al., 2018)	Investigator, designer, creator, communicator, and interpreter (Yakman & Lee, 2012)	Investigator, creator, reader, writer, critic, and reflective practitioner (Norris & Phillips, 2003; Sun & Zhong, 2024)
Teacher role	Integrator, inquiry facilitator, and design guide (Stohlmann et al., 2012; Margot & Kettler, 2019)	Creative facilitator, interdisciplinary designer, and critique guide (Quigley & Herro, 2016; Wynn & Harris, 2012)	Literacy scaffold, discourse facilitator, and reflective mentor (Moje, 2008; Sun & Zhong, 2024)
Assessment	STEM concepts, design performance, prototypes, problem-solving, and collaborative processes (National Academy of Engineering & National Research Council, 2014)	STEM outcomes plus creativity, communication, representation, and design process (Aguilera & Ortiz-Revilla, 2021)	STEM/STEAM outcomes plus reading, writing, evidence use, argumentation, and reflection (Hand et al., 2004; Osborne, 2010)
Main risk	Fragmented subjects or narrow technical framing	Arts as decoration (Mejias et al., 2021)	Literacy as worksheet or final report (Sun & Zhong, 2024)
Real change occurs when	Disciplines are integrated around authentic problems	Arts shape inquiry, design, representation, and communication	Reading and writing shape reasoning, evidence use, and reflection

A literacy-explicit interpretation of STREAM foregrounds argumentation. Students may be required to justify claims with evidence, critique sources, evaluate explanations, and communicate reasoning to different audiences. Argumentation has long been recognized as central to science education because scientific knowledge is built through claims, evidence, warrants, critique, and revision (Erduran & Jiménez-Aleixandre, 2008; Osborne, 2010). The relevant contribution of STREAM, where it is substantively implemented, is therefore to make these literacy-mediated practices explicit across interdisciplinary learning rather than to introduce argumentation as a wholly new practice.

Making literacy demands explicit may support more equitable participation when appropriate scaffolding is provided. In STEM and STEAM classrooms, students may be expected to read technical information, understand specialized vocabulary, explain design decisions, and present arguments without direct instruction in those practices (Moje, 2008). However, greater textual and linguistic demands can also create additional barriers for learners developing proficiency in the language of instruction, students with literacy difficulties, and students unfamiliar with specialized disciplinary genres. Literacy-rich interdisciplinary design therefore requires explicit vocabulary support, multimodal representation, structured writing guidance, and opportunities for oral rehearsal; inclusion cannot be inferred from the STREAM label itself.

STREAM can also be implemented superficially. A project does not become STREAM because students complete a worksheet or submit a final report. Reading and writing should

be embedded throughout the learning cycle: reading to understand a problem, writing to plan inquiry, documenting observations, explaining design decisions, revising claims, and communicating conclusions (Sun & Zhong, 2024). When literacy is used only at the end of a project, it becomes reporting rather than knowledge construction.

COMPARATIVE ANALYTICAL SYNTHESIS

The comparison reveals a more complicated relationship than a progressive STEM-STEAM-STREAM sequence. The literature is comparatively mature for integrated STEM, substantial but heterogeneous and contested for STEAM, and considerably thinner for STREAM as a named model. The analytical value of the acronyms therefore depends less on the number of represented disciplines than on whether additional disciplinary practices become consequential to the design and evidence of learning. These design-level distinctions are summarized in **Table 1**.

Table 1 indicates that the principal distinction among STEM, STEAM, and STREAM lies not in the number of disciplinary initials represented but in the educational work performed by the additional disciplines. In integrated STEM, the central change concerns the coordination of scientific, technological, engineering, and mathematical knowledge around authentic problems and design activity. STEAM becomes distinguishable when artistic and design practices alter problem representation, interpretation, creation, critique, or communication rather than being appended to an

Table 2. Critical appraisal of the evidence base

Appraisal criterion	STEM	STEAM	STREAM
Evidential maturity	Comparatively established but operationally heterogeneous (Li et al., 2020; Thibaut et al., 2018).	Substantial and growing, but definitions and outcome measures remain heterogeneous (Aguilera & Ortiz-Revilla, 2021; Perignat & Katz-Buonincontro, 2019).	Emerging and comparatively thin; evidence for disciplinary literacy is stronger than evidence for STREAM as a distinct model (Sun & Zhong, 2024).
Central critical question	Are multiple STEM disciplines genuinely integrated or merely co-present?	Do artistic practices change inquiry and meaning-making, or function mainly as decoration or engagement devices?	Does explicit literacy integration change reasoning and knowledge construction, or mainly rename practices already intrinsic to disciplinary learning?
Primary evidential limitation	Wide variation in definitions and degree of integration.	Inconsistent definitions of the arts and variable measures of creativity, engagement, and transfer.	Terminological instability and limited direct empirical comparison with STEM or STEAM.

otherwise unchanged STEM task. In the literacy-explicit interpretation of STREAM adopted here, reading and writing become consequential when they contribute directly to problem definition, evidence gathering, reasoning, argumentation, documentation, and reflection. The comparison therefore shows that substantive acronym expansion should be visible across the organization of learning, particularly in learner activity, teacher orchestration, and assessment, rather than inferred from the label alone.

The evidence supporting these distinctions is uneven across the three labels; **Table 2** therefore compares their evidential maturity, central critical questions, and principal limitations.

Table 2 reveals an important asymmetry in the evidential status of the three approaches. Integrated STEM has the comparatively most established research base, although variation in definitions and levels of disciplinary integration continues to limit direct comparison across studies. STEAM has developed a substantial and growing literature, but its evidential interpretation is complicated by inconsistent definitions of the arts and by considerable variation in how creativity, engagement, and transfer are operationalized. STREAM occupies a more provisional position. Research strongly supports the educational importance of disciplinary reading, writing, evidence use, and argumentation, but this should not be interpreted as equivalent evidence that STREAM itself has been established as a distinct educational model. Thus, increasing acronym breadth does not correspond to increasing evidential maturity; instead, the evidence becomes progressively more dependent on demonstrating what the added disciplinary practices actually contribute to learning.

Pedagogical Foundations of the Three Models

STEM, STEAM, and literacy-rich interdisciplinary designs draw on overlapping traditions of inquiry, design, project-based learning, collaboration, experience, and knowledge construction (Hmelo-Silver, 2004; Kolb, 1984; Prince, 2004). Reviews of pedagogical theory in STEM education likewise place constructivist, experiential, inquiry-based, and collaborative approaches within the same broader instructional landscape (Gavrilas & Kotsis, 2025b). These shared foundations matter because active or project-based pedagogy does not by itself distinguish one acronym from another. What differentiates the models is the extent to which particular disciplinary practices change what learners investigate, create, communicate, and are assessed for.

Educational Robotics: Applying the Framework to Published Cases

Educational robotics provides a useful setting for examining the framework because published implementations vary in whether robotics functions mainly as a technical STEM medium, a platform for arts integration, or a setting in which literacy becomes part of the design process. Teacher-perception research also shows that educators may recognize robotics as relevant to STEM while still needing support to integrate it as a coherent learning environment rather than as an isolated technological activity (Gavrilas & Kotsis, 2024). The educational label therefore depends on the disciplinary practices enacted around the technology, not on the presence of the robot itself.

Sullivan and Bers (2018) provide a concrete STEAM example in a seven-week KIBO robotics curriculum implemented with 98 preschool children across five early childhood centres in Singapore. The “dances from around the world” curriculum combined programming and engineering with music and dance. Mapped against the six dimensions, the arts were not merely added to a completed robot: they contributed to the problem frame and learner role because children programmed robotic performances and worked within a creative, collaborative context. At the same time, the reported assessment concentrated primarily on programming concepts. The case therefore supports substantive STEAM integration at the level of disciplinary base, pedagogy, and learner activity, while also illustrating an evidential limitation: the arts component was more visible in the learning design than in the measured outcomes.

Lim and Lee (2026) offer a more direct published example of the reading/writing interpretation of STREAM. Their qualitative case integrated Sphero BOLT robotics with visual art, storytelling, and reading/writing in interdisciplinary lessons that included pre-service art teachers. Here literacy was not confined to a final report; storytelling and written meaning-making were incorporated into artistic and technological activity. Within the present framework, this is stronger evidence of STREAM because literacy changes the learner role and communicative process. However, the case-study design and the small, emerging evidence base also illustrate why STREAM should not yet be treated as evidentially equivalent to STEM or STEAM.

Read side by side, the two robotics cases show that the technology itself does not determine whether an activity is best understood as STEM, STEAM, or STREAM. The distinction

lies in the work assigned to arts and literacy within the task and in whether those practices influence problem framing, learner activity, teacher orchestration, and assessment. They also expose a recurring measurement problem: an interdisciplinary program can be rich in design while its evaluation captures only a subset of the outcomes implied by its label.

Climate-Change Education: Applying the Framework to an Empirical Case

Climate-change education provides a second context in which the six dimensions can be examined. Choi et al. (2021) evaluated an SSI-STEAM climate-change program with 31 eighth-grade students in Seoul using pre- and post-program climate-literacy measures, interviews, and student-produced artefacts. The program was organized around a socioscientific problem and treated climate literacy as an explicit outcome, allowing the relationship among problem framing, interdisciplinary activity, and assessment to be examined in an enacted classroom setting.

Mapped against the framework, the case extends beyond a narrow technical problem frame because climate change is approached as a socioscientific issue involving scientific understanding, interpretation, responsibility, communication, and action. Students' artefacts and interview responses provide evidence of active participation and meaning-making, while the program's explicit climate-literacy assessment connects pedagogical claims to measured outcomes. Choi et al. (2021) reported improvement particularly in the perception and action domains and identified changes including more concrete ideas, wider scope of thinking, positive responsibility, and recognition of relevance. The case therefore illustrates substantive change in problem framing, learner role, and assessment rather than acronym expansion alone.

The climate-change case also marks a limit to acronym-based interpretation. The presence of arts within an SSI-STEAM program does not establish which outcomes are attributable specifically to arts integration, and the study did not compare otherwise equivalent STEM and STEAM conditions. The evidence is therefore strongest for the program as an integrated climate-literacy design rather than for a causal claim that the arts produced the observed gains. Published cases can establish that disciplinary integration occurred without showing that every added component independently caused the reported outcomes.

At the teacher level, the climate-change case highlights the orchestration demands of interdisciplinary learning: selecting and sequencing evidence, connecting scientific and societal dimensions, supporting discussion and communication, and aligning activities with assessment. These demands reinforce the framework's emphasis on teacher role but also caution against treating complex implementation requirements as proof of effectiveness.

Assessment and Evidence of Learning

Assessment is a critical test of whether an expanded acronym corresponds to an expanded learning design. If a program claims outcomes such as conceptual understanding, creativity, communication, argumentation, or reflection, the

evidence collected should make those outcomes visible. Traditional tests may capture conceptual knowledge but are often insufficient for design processes, interdisciplinary reasoning, creative work, and disciplinary discourse.

Accordingly, assessment should be aligned with the specific disciplinary practices that are central to the task rather than with a generic checklist attached to the acronym. Design performance and modeling may be appropriate in STEM; representation and critique may become relevant in STEAM; and evidence use, written explanation, documentation, or argumentation may become relevant when literacy is deliberately foregrounded. Rubrics, portfolios, design journals, annotated prototypes, oral presentations, and written arguments can make these processes visible, but the choice of evidence should follow the intended learning outcomes.

Creativity assessment is particularly challenging. Creativity is often discussed in STEAM research, but it must be defined in relation to originality, usefulness, elaboration, risk-taking, flexibility, or disciplinary appropriateness. General claims that students became more creative are not sufficient unless the study or classroom assessment explains how creativity was observed or measured (Brookhart, 2013). Similarly, claims about collaboration require evidence of interaction quality, shared responsibility, negotiation, and collective problem-solving rather than simply placing students in groups.

Assessment should also consider transfer. The goal of interdisciplinary education is not only to complete a project but to develop capacities that students can use in new contexts. Transfer is difficult to achieve and difficult to measure, but it is central to the argument for integrated learning (Perkins & Salomon, 1992). If STEM, STEAM, and STREAM are intended to prepare learners for complex real-world problems, researchers and teachers need to examine whether students can apply concepts, strategies, and communication practices beyond the original activity.

Curriculum Design Implications

Curriculum designers should begin with learning purposes rather than acronyms. The appropriate label should follow from what learners are expected to understand, investigate, create, communicate, and reflect on, not from the desire to maximize the number of represented disciplines. Coherence requires each included discipline to make an identifiable contribution to the central problem or learning process.

For STEM, this means that multiple STEM disciplines should interact rather than merely appear beside one another. For STEAM, artistic practices should influence inquiry, representation, design, interpretation, critique, or communication. For a reading/writing interpretation of STREAM, literacy should function as a tool for entering the problem, developing or evaluating evidence, documenting reasoning, and communicating conclusions. In each case, the design question is whether the added component changes the intellectual work of the task.

Curriculum designers should also avoid overload. Interdisciplinary projects can become too broad if they attempt to assess every possible outcome at once. A well-

designed unit should identify a manageable number of core outcomes and align activities, scaffolds, and assessments with those outcomes. Coherence is more important than the number of disciplines named in the acronym.

Teacher Education and Professional Development

Teacher education is central because interdisciplinary design requires more than enthusiasm for innovation. Teachers may need disciplinary and pedagogical knowledge, technological competence, assessment literacy, and confidence in managing open-ended work, while also negotiating subject boundaries and collaborating with colleagues whose expertise differs from their own (Darling-Hammond et al., 2017; Margot & Kettler, 2019). A broader conception of effective teaching similarly emphasizes the interaction of professional knowledge, adaptive practice, collaboration, and reflective judgment rather than any single competence in isolation (Gavrilas & Kotsis, 2026).

Professional development should help teachers design integrated units, scaffold inquiry and design, support student collaboration, assess complex outcomes, and reflect on implementation. It should also address the practical realities of schooling, including limited time, subject boundaries, resource constraints, standardized assessment pressures, and uneven access to technology or arts support.

Professional learning should therefore include opportunities to co-design and critique interdisciplinary units, examine how different disciplines contribute to a shared problem, and align assessment with those contributions. Arts and language educators should be treated as co-designers when their disciplinary practices are central to the intended STEAM or STREAM design, rather than as providers of decorative or end-stage support.

Equity Considerations

STEM, STEAM, and STREAM are often promoted as inclusive approaches because they provide multiple forms of participation. Students can contribute through designing, building, measuring, drawing, coding, explaining, writing, presenting, questioning, or critiquing. However, inclusion is not automatic. Interdisciplinary learning can reproduce inequality if access to resources, teacher expertise, digital tools, arts opportunities, and literacy support is uneven.

Technology-rich STEM activities may privilege students who already have experience with digital tools or robotics, while STEAM activities may privilege learners with prior access to arts education. A reading/writing interpretation of STREAM introduces a further tension: making literacy expectations explicit can enable teachers to scaffold them but increasing textual and academic-language demands can also disadvantage students who need additional linguistic or literacy support. Equity therefore depends on the design of access, scaffolding, representation, participation, and assessment rather than on the inclusiveness implied by an acronym.

Universal Design for Learning offers one useful framework because it emphasizes multiple means of engagement, representation, and expression (CAST, 2024). This aligns with STEAM and STREAM because students can access ideas through visual, textual, oral, spatial, digital, and embodied

modes. Culturally responsive pedagogy is also relevant because interdisciplinary problems should connect with learners' communities, identities, and lived experiences (Gay, 2018). Without attention to culture and access, STEM, STEAM, and STREAM may remain attractive labels that benefit some learners more than others.

Equity also requires institutional support. Schools need time for teacher collaboration, access to materials, flexible scheduling, inclusive assessment practices, and leadership that values interdisciplinary work. If these conditions are absent, innovative approaches may depend on individual teachers' extra labor rather than sustainable educational change.

DISCUSSION

The literature does not support treating STEM, STEAM, and STREAM as three equivalent stages of a single educational progression. Integrated STEM has the most established conceptual and empirical literature, although its operationalization remains heterogeneous. STEAM has a substantial but contested literature in which the meaning of arts integration and the evidence for outcomes such as creativity vary considerably. STREAM is less consolidated, and much of its conceptual justification rests on established research on disciplinary literacy rather than on evidence that STREAM functions as a distinct educational model.

This asymmetry suggests that acronym expansion is meaningful only when the added discipline introduces identifiable changes in educational practice. Arts integration becomes pedagogically consequential when artistic practices alter design, representation, interpretation, critique, or communication. Literacy integration becomes consequential when reading and writing shape problem definition, evidence use, explanation, argumentation, documentation, or reflection. The relevant unit of analysis is therefore the enacted disciplinary practice rather than the acronym itself.

Viewed together, the six dimensions provide a practical way to examine these differences without assuming that the acronym itself is evidence of integration. They direct attention to the six diagnostic dimensions identified in the framework: disciplinary base, problem framing, pedagogical process, learner role, teacher role, and assessment. A strong interdisciplinary design does not require all six dimensions to change equally; it does require the claimed contribution of an added discipline to be visible somewhere in the enacted learning process and in the evidence used to evaluate it.

STREAM illustrates the importance of this distinction most clearly. Reading, writing, and argumentation are already constitutive of scientific and other disciplinary practices. Their educational importance therefore provides the strongest justification for a separate acronym when these literacy practices are explicitly designed, scaffolded, and assessed. The strongest justification for STREAM arises when literacy practices that might otherwise remain implicit are deliberately designed, scaffolded, and assessed as mechanisms of interdisciplinary knowledge construction. Where that does not occur, STREAM may function primarily as a relabeling of

practices that strong STEM or STEAM education can already contain.

Future Research Directions

Future research should report interdisciplinary designs with greater operational precision. Studies should specify which disciplines are involved, how they interact, which practices are central to the task, and which outcomes are assessed. Using multidisciplinary, interdisciplinary, or transdisciplinary terminology where appropriate would make comparisons more meaningful and reduce reliance on acronym labels.

Research should also examine mechanisms rather than only outcomes. Where a STEAM intervention is associated with creativity, engagement, or conceptual learning, studies should identify which artistic practices plausibly contributed to those outcomes and how they were measured. Where literacy-rich or STREAM interventions are associated with learning gains, studies should examine whether reading, writing, vocabulary, argumentation, or metacognitive reflection mediates the effect. Directly comparing well-specified designs would be more informative than comparing labels alone.

Longitudinal and equity-focused research is also needed. Short interventions provide limited evidence about whether interdisciplinary competencies transfer or persist, and aggregate outcomes can obscure who benefits under which conditions. Future studies should therefore examine sustained learning, transfer, identity, and participation while attending to language background, socioeconomic conditions, disability, digital and arts access, and the scaffolds required for equitable participation.

Limitations

This review is critical and narrative rather than systematic. The search and selection procedure has been documented to increase transparency, but the review was designed for conceptual comparison rather than exhaustive retrieval, formal study-quality appraisal, or effect-size synthesis. Consequently, absence of a study from the review should not be interpreted as evidence that no such study exists.

The evidence base is also uneven across the three focal labels. STEM has a considerably larger and more mature research literature than STREAM, while STEAM occupies an intermediate but highly heterogeneous position. Direct comparison among the three therefore risks implying an equivalence in conceptual maturity and empirical support that does not exist. The framework is used specifically to make this asymmetry visible rather than to eliminate it.

CONCLUSION

The central problem examined in this review is not how many disciplines can be represented within an educational acronym, but whether their inclusion changes the design and evidence of learning. Across the literature, STEM, STEAM, and STREAM differ not only in disciplinary scope but also in conceptual maturity and empirical support. These differences

make a simple progressive sequence from STEM to STEAM to STREAM difficult to sustain.

The six-dimensional framework developed in this review treats disciplinary base, problem framing, pedagogical process, learner role, teacher role, and assessment as diagnostic sites of educational change. Arts integration is substantive when artistic practices reshape how problems are interpreted, represented, designed, or communicated. Literacy integration is substantive when reading and writing become mechanisms for evidence use, reasoning, argumentation, documentation, and reflection.

The broader implication is that acronym expansion should not be treated as evidence of educational innovation. What matters is whether disciplinary practices become consequential to what learners do and to what educators recognize as evidence of learning. In this sense, the strongest future for STEM-related interdisciplinary education may depend less on producing additional acronyms than on describing educational design with greater conceptual and evidential precision.

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