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Promoting International Science, Technology, Engineering and Mathematics (STEM) Education by Creativity

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Abstract

The rising intricacy of international challenges has amplified the necessity for STEM education which goes yonder rote-leaning science and technology procedures. Creativity offers a vital pathway for aiding learners apply knowledge, reconnoitre possibilities, and advance innovative solutions to real-world issues. In this paper, the role of creativity in strengthening Science, Technology, Engineering and Mathematics (STEM) education globally was examined with focus on developing contexts like Nigeria. Drawing on relevant literature and theoretical perspectives, including Torrance's Creativity Theory with the 4Cs of 21st century skills, the paper establishes the close link among creative thinking, problem-solving, inquiry, design, collaboration, and innovation in STEM learning. It recognises curriculum inflexibility, examination-oriented assessment, and inadequate teacher preparation as major barricades to creative STEM education. To address these issues, the paper proposes the CREATIVE-STEM Framework, containing: Curiosity-Driven Inquiry, Real-World Problem Solving, Engaging Design Thinking, Artistic and Technological Integration, Teacher Facilitation, Innovation Hubs and Laboratories, Value of Failure and Iteration, and Equity and Inclusivity. The paper concludes that implanting creativity within STEM education can fortify learners' capacity to create, evaluate, and improve ideas while preparing them to address local and global challenges responsibly.

Keywords: STEM Education, Creativity, Creative Thinking, Design Thinking, STEM Pedagogy, CREATIVE-STEM Framework.

Introduction

Science, Technology, Engineering, and Mathematics (STEM) education is known as a key driver of innovation, economic growth, and maintainable development. This is because it arms learners with the knowledge and skills required to solve real-world problems. STEM education is beyond mere knowledge acquisition in science and technology to include creativity, critical thinking, collaboration, and problem-solving skills. To Bybee (2023) and Ayua et al. (2023b), STEM education can prepare learners to think/act innovatively in retort to modern societal and technological challenges, while Henriksen (2024) contends that creativity is a fundamental component of STEM learning because innovative solutions often emerge when scholars are stimulated to integrate thoughts with scientific perception. Nurturing creativity in STEM classrooms allow learners to transform theoretical knowledge into practical solutions, making them better ready to

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contribute meaningfully to scientific and technological development. Over time, conventional STEM education has focused on the acquisition of disciplinary knowledge and technical competence. This is still a fundamental problem to educational success, possessing knowledge alone is insufficient for fostering innovation. A student for instance, may understand the principles of electricity yet be unable to develop an affordable electrical solution to address a community problem. A learner may master mathematical formulas but struggle to apply mathematical reasoning to unfamiliar technological, environmental, or societal issues. Modern STEM education stresses the integration of disciplinary knowledge with essential 21st-century skills such as creativity, critical thinking, communication, and collaboration (Organization for Economic Co-operation and Development [OECD], 2024). STEM education can better prepare students to become innovators, responsible citizens, and problem solvers capable of contributing to sustainable societal development. In developing countries like Nigeria, the creativity in STEM education is important. The Federal Ministry of Education recognizes Technology and Science Education as a strategic area of educational development. Through its Technology and Science Education (TSE) Department, the Ministry is responsible for policy formulation and implementation, curriculum development and monitoring, standard setting, capacity building, and the supervision of science and technical education programmes below the tertiary level. Federal Ministry of Education (2019). Nevertheless, transformation in STEM education entails more than policy outlines and institutional oversight. Real STEM education hinges on classroom practices that encourage learners to question, investigate problems, explore alternative solutions, engage in experimentation, design and innovate, learn from errors, reflect on results, and refine their ideas by unceasing review.

Statement of the Problem

In spite of the mounting relevance of creativity in STEM education, some teachers still remain on one-size-fit-all teaching approaches and examination-driven learning that emphasize memorizing instead of creativity and problem-solving. Although, knowledge acquisition is indispensable, STEM education becomes more meaningful when learners are heartened to apply scientific ideas in real-world situations rather than merely reproducing them in examinations. To Beghetto and Kaufman (2024), creativity flourishes best in classrooms that combine intrinsic motivation, choice, and openness to unusual ideas with strong content learning, instead of treating the two separately. Practically, chances for creative STEM learning continue unevenly distributed, with well-resourced schools presenting laboratories, robotics, and maker spaces which poor schools lack, while many teachers, censored exam-driven schooling, receive little training in design thinking or project-based teaching (OECD, 2023). Inadequate resources, teacher preparation, creative teaching approaches, and assessment systems which prioritize stereotype answers continue to restrict opportunities for creative STEM learning. There is a wide gap between policy and practice in STEM classrooms limiting creativity and innovative skills required for present-day world. Addressing this gap is central for developing learners who can not only understand science but also create solutions to real-world problems (Anwar et al., 2023; Ayua et al., 2023b).

Purpose of the Study

This paper examines how creativity can reinforce international STEM education and recommends the CREATIVE-STEM model for embedding creativity in STEM teaching and learning.

Significance of the Study

This paper provides policy makers, educators and the global STEM community with a real-world model for designing learning experiences which promote curiosity, experimentation, and critical thinking, while guiding curriculum designers on integrating creativity across STEM subjects.

Scope and Structure of the Paper

This paper centres on school-level STEM education, although its inferences cover higher and lifelong education. It involves international STEM education broadly, while focusing on challenges facing developing nations like Nigeria. Besides introduction, the paper clarifies STEM education concepts, and creativity; exploring how the two relate. The literature review then examines global STEM trends, the role of creativity, barriers to its growth, and germane theoretical standpoints, before presenting the CREATIVE-STEM Framework. Succeeding sections address the implications for policy, practice and teacher education alongside the challenges and strategies for implementation.

Conceptual Clarifications

Here, STEM education, creativity, and the link between creativity and STEM learning outcomes are discussed.

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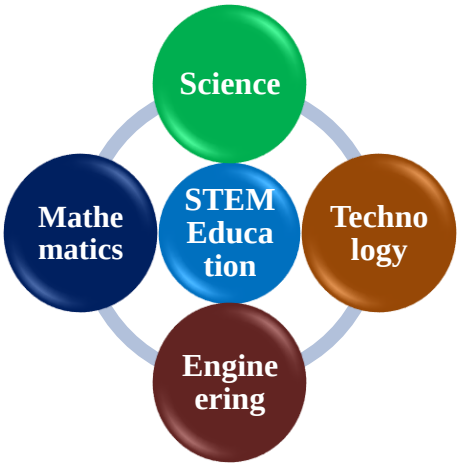
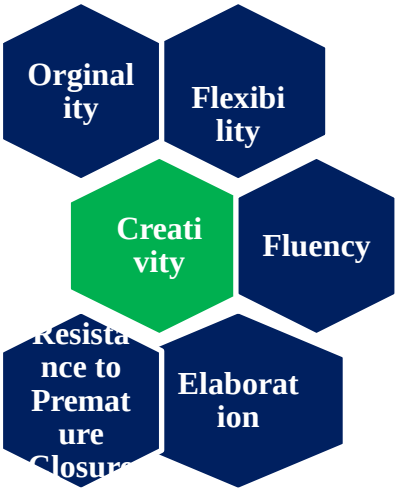


Figure 1: Diagrammatic Representation of STEM Education

Figure 1 represent an interdisciplinary educational approach involving Science, Technology, Engineering and Mathematics (STEM). Although the four disciplines possess distinct bodies of knowledge, contemporary STEM education emphasizes their connections. Real-world problems rarely appear in separated disciplinary categories. Climate change, for example, involves scientific understanding, technological systems, mathematical modelling, engineering design, economics and social decision-making. STEM education promotes the integration of science, technology, engineering, and mathematics to help learners apply knowledge in solving real-world problems rather than memorizing concepts. The engineering design process, which involves designing, testing, and refining solutions, provides valuable opportunities for creativity, critical thinking, and innovation (Diep et al., 2023). STEM education prepares learners for a rapidly changing workforce by developing adaptable competencies such as problem-solving, collaboration, and lifelong learning, which are essential in contemporary societies (UNESCO, 2024). The principal goals of STEM education could be seen as cultivating scientific literacy, technological aptitude, problem-solving ability, innovation, employability, responsible citizenship, and a vow to workable advancement. Reaching these goals require a cautious balance between laying foundational knowledge and building the higher-order capabilities which allow that knowledge meaningful use.

Creativity:

Is the ability to generate new, original, and useful ideas. Its key mechanisms include: imagination, originality, flexibility, fluency, and problem-solving.



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Figure 2: Schematic Representation of Creativity

As shown in Figure 2, the components help individuals to think variously, develop innovative possibilities, and find real solutions to challenges. Ayua, et al. (2023a) and Ayua et al (2026a) make a related point in the Nigerian context, that fostering learners' creative minds and hands in science, technology and engineering is central to producing graduates capable of sustainable innovation in the aftermath of disruptions such as the COVID-19 pandemic. This classroom-level of everyday creativity aligns with the OECD's current definition, which emphasizes the generation of diverse and original ideas alongside the capacity to evaluate and refine them (OECD, 2019). Additionally, Ayua (2019) and Ayua, et al. (2023) reported that creative teaching strategies significantly improve students' creative-thinking originality, suggesting that creativity is an essential educational outcome that supports innovation, problem-solving, and lifelong learning.

Creativity and STEM learning outcomes:

Creativity is fundamentally connected to the nature of STEM disciplines. Scientific investigation entails scholars to frame hypotheses and consider alternate clarifications. Engineering demands designers to produce and test likely solutions. Mathematics involves finding diverse strategies to solving complex problems. Technology deals with creating and improving tools and systems. Thus, creativity is an important element in STEM education because scientific and technological advancement depends on learners' ability to create ideas, explore substitutes and develop solutions to unfamiliar problems. So, STEM learning entails more than factual knowledge acquisition. It requires learners to question, investigate, design, test and improve ideas. Ayua et al. (2023) emphasized that developing creative minds and practical skills in science, technology and engineering is essential for addressing contemporary challenges (Ayua & Terhemba, 2025) and promoting sustainable development. Creativity is associated with learners' engagement with STEM. Pont-Niclòs et al. (2024) reported that meaningful relationships between scientific creativity, learners' engagement and their intentions to pursue STEM-oriented fields, highlighting the importance of creativity-tailored learning experiences in maintaining interest in STEM. Intercontinental evidence further strengthens this relationship. The OECD's PISA (2022) assessment found positive associations between creative thinking and performance in Mathematics, reading and science. This suggests that creativity and academic learning complements rather than compete each other. Creativity supports numerous key STEM results. It betters engagement, active participation, problem-solving ability, consideration of multiple possibilities, and creativity, and knowledge transfer to unfamiliar contexts.

Literature Review and Theoretical Framework

This are review covered global trends in STEM education, the role of creativity in STEM, barriers to creativity in STEM classrooms, and theoretical underpinnings.

Global trends in STEM education:

The features of universal STEM education include: interdisciplinary learning, digital technologies, problem-based learning, inquiry, engineering design, and real-world applications. Since artificial intelligence emergence, these transitions have accelerated. Learners need not only know how to use technologies but also how technologies are designed, evaluated and applied responsibly. This method encourages learners to examine problems, collaborate, advance solutions and think creatively across subject boundaries (Couch et al., 2024). As AI and digital technologies are rapidly reshaping STEM education, teachers and learners are expected not only to use them but also understand their applications, limitations and ethical implications. UNESCO (2024) stresses human-centred thinking, AI ethics, technological application and AI system design as important capabilities for modern learners. Tus, teachers are anticipated to facilitate inquiry, support collaboration, fit in digital tools, and create learning settings that encourage higher-order thinking. UNESCO (2024) highpoints teachers' AI-related didactic competence and responsible use of technology. Creativity is an important outcome of STEM learning. The OECD's inclusion of creative thinking in PISA 2022 tells the growing intercontinental recognition that learners can create, evaluate, and improve ideas rather than merely reproducing existing knowledge in examinations (OECD, 2024). Thus, present-day STEM education emphasizes knowledge application, creativity, innovation, problem-solving and responsible use of technologies.

The Role of Creativity in Science, Technology, Engineering and Mathematics:

The role of creativity in STEM education is discussed as follows.

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1. **Creativity in science:** Creativity plays an important role in science because scientific inquiry requires learners to ask questions, develop hypotheses, plan investigations, interpret evidence and reconsider explanations when findings do not match expectations. The National Research Council identifies asking questions, planning and carrying out investigations, analysing and interpreting data, constructing explanations, and engaging in argument from evidence as central scientific practices (National Research Council, 2022). Creativity in science is not about producing unusual ideas; it involves generating questions and explanations that can be investigated and revised in response to evidence. Scientific inquiry therefore provides opportunities for students to look at familiar phenomena from different perspectives and develop new interpretations of observations.
2. **Creativity in technology:** In technology, creativity is closely associated with designing, adapting and evaluating tools or technological solutions to address human needs. Modern technology education requires learners to consider not only whether a technological product works, but also whether it is appropriate, accessible, safe and responsible. For example, UNESCO's (2023) guidance on digital learning technologies stresses that technology could respond to identified learner needs and can be evaluated in relation to equity, sustainability, safety and evidence of effectiveness. AI competency framework places creativity and design alongside human-centred thinking and ethics, highlighting the importance of developing technologies that are both innovative and responsible (Miao, et al, 2024).
3. **Creativity in engineering:** Creativity is fundamental to engineering because engineering problems commonly permit several possible solutions rather than a single predetermined answer. The engineering design process involves identifying a problem, establishing criteria and constraints, generating alternative solutions, developing prototypes, testing them and refining the design (National Research Council, 2020). Engineers can balance finding an alternative method for solving a familiar problem or recognising a novel relationship within a pattern. Such activities encourage learners to justify their reasoning and transfer mathematical knowledge to unfamiliar situations rather than relying exclusively on memorised procedures. Rather than treating science, technology, engineering and mathematics as completely separate areas, integrated STEM approaches connect disciplinary knowledge within meaningful problems and design challenges. The National Academies competing considerations such as safety, cost, efficiency, available materials and other constraints when selecting among possible solutions. The National Academies further explains that engineering accommodates multiple solutions provided that they satisfy the requirements and constraints of the design problem, with iterative testing and improvement used to reach an effective solution (National Academies of Sciences, Engineering, and Medicine, 2020).
4. **Creativity in mathematics:** Creativity in mathematics involves more than applying established procedures. It can be expressed through generating multiple solution strategies, identifying patterns, posing problems, using different representations and making connections between mathematical ideas. Research in mathematics education indicates that multiple-solution and problem-posing activities provide opportunities for students to develop fluency, flexibility and originality in mathematical thinking (Albert & Kim, 2023). For example, mathematical creativity may involve finding an alternative method for solving a familiar problem or recognizing a novel relationship within a pattern. Such events inspire learners to justify their reasoning, and transfer mathematical knowledge to unusual situations rather than depending completely on memorized procedures.

Creativity in Interdisciplinary STEM

Interdisciplinary STEM provides chances for creativity by demanding learners to combine knowledge and practices across fields in solving complex, real-world problems. Rather than treating science, technology, engineering and mathematics as separate areas, integrated STEM approaches connect disciplinary knowledge within meaningful problems and design challenges. The National Academies describes integrated STEM education as an approach that can bring together concepts and practices from multiple STEM disciplines, while engineering design itself draws on mathematics, science and technological tools. National enabling learners to adapt the design to local conditions, generate alternative solutions and respond to constraints. Such interdisciplinary learning reflects the broader goal of STEM education: using disciplinary Academies of Sciences, Engineering, and Medicine (National Research Council, 2020). For example, designing a solar-powered water system could require students to apply physics to understand energy conversion, mathematics to calculate energy requirements, engineering to develop and test the system, and technology to monitor its operation. Creativity

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connects these disciplinary contributions by enabling learners to adapt the design to local conditions, generate alternative solutions and respond to constraints. To UNESCO (2026), intersubject learning reflects the broader goal of STEM education. Thus, linking subject content knowledge with creativity, problem-solving, and critical thinking to solve complex issues.

Barriers to Creativity in STEM Classrooms

These hinderances to creativity in STEM classrooms are hereby stated.

1. **Curriculum Constraints:** One challenge to creativity in STEM education is the burden to complete a content-heavy curriculum within a inadequate period. When teachers are chiefly concerned with completing the syllabus before examinations, learners may have fewer chances to examine problems, experiment ideas, or create their solutions. Creativity does not typically emerge from merely receiving more information; it necessitates time to explore, question, test, revise, and reflect. Ayua et al. (2026b) emphasize learner-centred, activity-oriented, and exploratory approaches to science education. Thus, curriculum practice can afford enough time for creative and practical STEM activities rather than depending primarily on content transmission.
2. **Assessment Constraints:** Creativity can either encourage or discourage by assessment modes. Typical examinations habitually place more emphasis on obtaining the correct answer, remembering information, and completing tasks within a specified time. Such practices give learners little reason to propose unusual ideas or explore other solutions. Naramore (2025) notes that uncertainty on how creativity could be assessed remains one of the challenges to nurturing it. Ayua and Agbidye (2020) showed that Science-Technology-Society can provide prospects for developing entrepreneurial creativity among learners. STEM assessment should be yonder conventional tests to include projects, practical investigations, design tasks, portfolios, presentations, and other activities that allow learners display originality and problem-solving dexterity.
3. **Teacher Capacity:** The worth of STEM creativity mostly depends on what, why and how teachers are ready to teach. Teachers need more than knowledge of their subject; they need real-world skills in inquiry-based learning, project work, joint problem-solving, creative questioning, and formative evaluation. Shernoff et al. (2017) identified proficient development needs as key consideration in implementing integrated STEM education. In Nigeria, Nwachukwu and Njoku (2021) also identified capability gaps among Basic Science teachers as a factor inhibiting effective teaching. Ayua and Eriba (2014) found that teachers' creative behaviours are vital to learners' interest in science and technology learning. Non-stop professional upgrading makes better teachers than otherwise.

Theoretical Underpinning

The theories underpinning this paper are presented as follows:

Torrance's Creativity Theory

Torrance's (1974) Creativity Theory conceptualises creative thinking as a multidimensional process linking fluency, flexibility, originality, and elaboration. Fluency entails generating multiple ideas, flexibility mirrors the ability to consider various tactics, originality concerns creating fresh ideas, and elaboration requires advancing and refining those ideas. The theory is relevant to STEM education because operative STEM learning requires learners exploring alternatives, solving open-ended problems, designing solutions, and improving their ideas. consequently, the theory provides useful basis for understanding and assessing how STEM learning experiences could foster learners' creative thinking.

The 4Cs of the 21st-Century Skills

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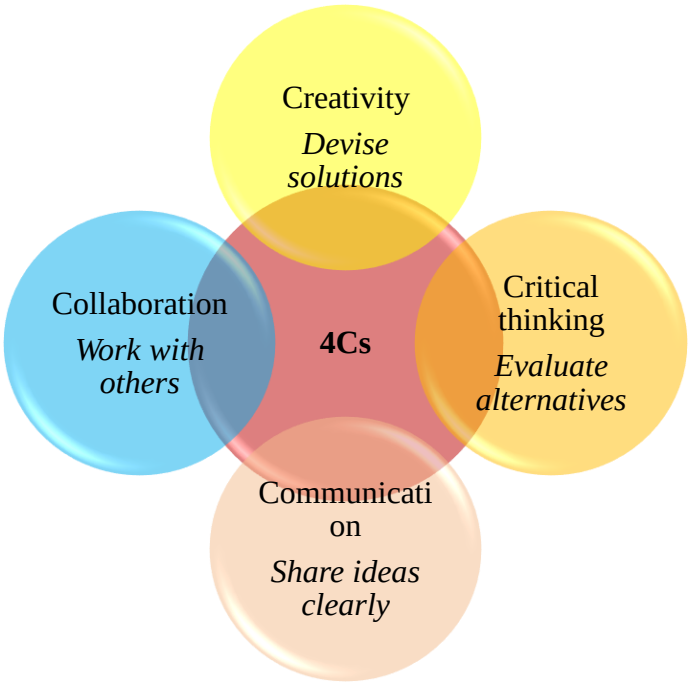


Figure 3: The 4Cs of the 21st-Century Skills

As contained in Figure 3, each of the Cs has a shared work of solving STEM problems, rather than separate, standalone skills. It shows that STEM problems are not only solved by committal to memory, but also via learners drawing on all the four competencies at once creating ideas, evaluating them critically, articulating them clearly, and building abilities with others.

The CREATIVE-STEM Framework

The CREATIVE-STEM model is presented in Figure 4.

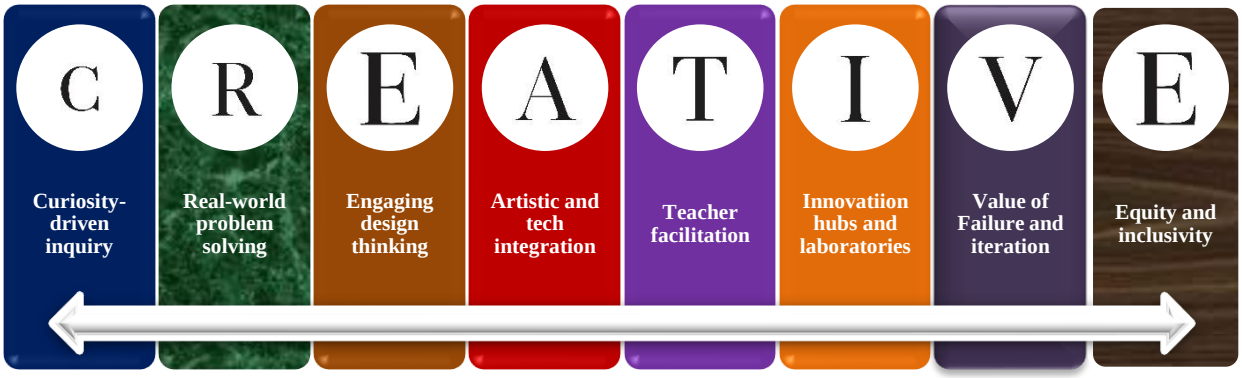


Figure 4: The CREATIVE-STEM Framework

Figure 4 treats Creativity as a pedagogical core, with each letter carrying a principle that is meant to be actionable rather than aspirational from starting lessons with a genuine "what if" question, through making sure innovation opportunities aren't quietly reserved for well-resourced schools.

Rationale for a Creativity-Driven Approach to International STEM

The focus of this paper is that STEM education can move from a predominantly knowledge-reproduction model towards a knowledge-creation and problem-solving model. This does not mean reducing attention to scientific facts, mathematical concepts or technical skills. Rather, it means creating opportunities for learners to use those foundations creatively.

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Components of the Creative-STEM Framework

These components are further presented in their themes.

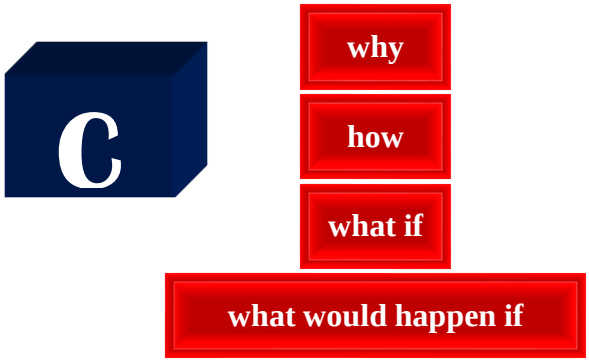


Figure 5: C – Curiosity-Driven Inquiry

Figure 5 point of creative STEM learning explains that teachers may encourage learners to ask "why," "how," "what if" and "what would happen if." questions. Inquiry activities can begin with familiar local phenomena such as water quality, waste management, energy use, agricultural production or transportation.

R – Real-World Problem Solving explicate that STEM learning may connect classroom concepts with authentic problems. Students could be challenged to identify problems within their communities and develop evidence-based solutions. This approach may help learners recognise the usefulness of STEM knowledge beyond examinations.

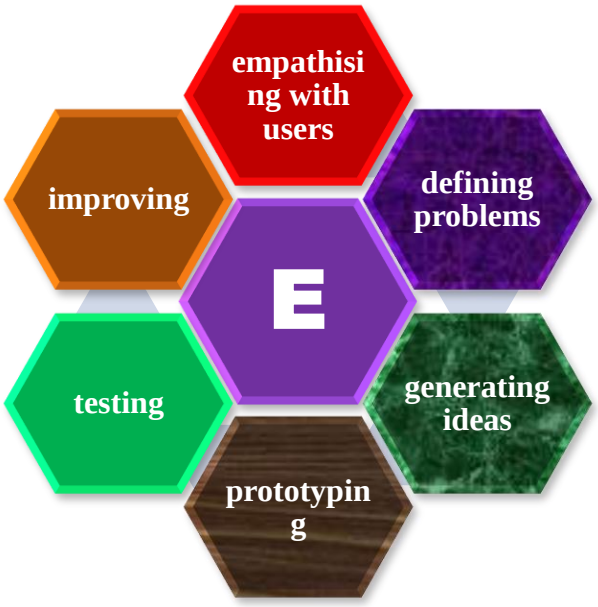


Figure 6: E – Engaging Design Thinking:

Figure 6 shows that in STEM education, students can use these processes to develop solutions while learning disciplinary concepts.

A – Artistic and Technological Integration explains that an integration of arts with STEM creates opportunities for communication, visualisation, creativity and interdisciplinary thinking. This does not mean turning every STEM lesson into an art lesson. Rather, artistic representation, storytelling, visual design, music, cultural knowledge and creative expression can enhance technological and scientific learning.

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T – Teacher Facilitation of Creative Pedagogy: Means that teachers are central to the framework. Their role is to design environments in which students can explore ideas while maintaining academic rigour. Effective teachers ask productive questions, encourage evidence-based reasoning and provide feedback that helps learners improve their ideas.

I – Innovation Hubs and Laboratories: Highlight that schools may establish innovation spaces where learners can experiment, design, and team-work. These spaces do not certainly require costly equipment. A well-organised classroom corner with recycled materials, basic tools, computers or improvised resources can function as a small innovation laboratory.

V – Value of Failure and Iteration: Creative STEM necessitates a different understanding of failure. When experiments do not produce the probable result or prototypes fail, learners should be motivated to investigate why. Thus, failure becomes information which guides perfection. This principle is key in engineering, where solutions emerge by repeated testing and modification.

E – Equity and Inclusivity in Creative Access: Creativity can be accessible to all learners regardless of gender, socioeconomic background, location or disability. Global STEM education avoids creating learning situation where bias is practiced.

How the Framework Promotes International STEM Education

The CREATIVE-STEM model aids global STEM education by promoting mutual competencies like: creativity, problem solving, collaboration, inquiry and design; while permitting the capabilities to be applied to problems that are meaningful within different cultural and ecological contexts. This tactic is imperative because STEM education is not experienced homogeneously across nations. Its priorities and practices are designed by historical, cultural, socioeconomic and political circumstances (Mudaly & Chirikure, 2023). Thus, learners in Nigeria may design low-cost water purification systems, solar energy solutions or agricultural technologies. Learners elsewhere could explore coastal erosion, urban transport, renewable energy or digital inclusion. The basic creative procedure is transferable even when the problem differs. This context-sensitive style braces meaningful STEM learning while knowing cultural variances (Kier & Johnson, 2022). This may also aid world-wide team-work by digital platforms, where learners exchange ideas, compare data and jointly devise solutions to global problems.

Implications for Policy, Practice and Teacher Education

Implications on curriculum redesign, Teacher professional development, Institutional support, and Global Partnerships are discussed here.

Curriculum Redesign for Creativity: To better prepare students for real-world challenges, curriculum developers should create greater opportunities for inquiry, project-based and interdisciplinary learning alongside essential content knowledge. Curriculum goals should therefore emphasize creativity, critical thinking, collaboration, problem-solving and innovation. STEM learning can support these outcomes by engaging students in authentic tasks that require learners to apply knowledge, develop solutions and reflect on their work. Assessment should provide opportunities for students to show creative thinking through projects, design tasks, investigations, products and other forms of performance-based assessment alongside traditional examinations (OECD, 2024).

Teacher Professional Development in Creative STEM Pedagogy: Professional development should extend beyond one-off workshops that simply introduce new technologies. Effective STEM teacher development requires sustained, active opportunities for teachers to experience and practise innovative pedagogies, reflect on their classroom application, and collaborate with colleagues (Surahman & Wang, 2023). Training should therefore address inquiry-based, project-based and problem-based learning, design thinking, interdisciplinary STEM, creative assessment, low-cost experimentation, digital and AI-supported learning, and inclusive pedagogical practices. Effective STEM professional development commonly incorporates learning by doing, learning by design, reflection, collaboration and connections between professional learning and classroom practice (Huang et al., 2022).

Institutional Support through Laboratories, Funding and Assessment Reform: Creative pedagogy requires institutional support through adequate laboratories, digital resources, teaching materials and funding for innovation. However, such investment should reflect local realities. In resource-constrained settings, schools can encourage creativity through locally available and recycled materials, community partnerships and low-cost STEM activities, making learning

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more relevant to students' contexts (Holmes et al., 2021; Playful and frugal learning design, 2025). Assessment should similarly provide opportunities for students to demonstrate reasoning, originality, problem-solving and improvement through open-ended projects, investigations and design tasks. Evidence from recent meta-analyses indicates that project-based, problem-based and STEM learning approaches can positively support students' creativity and scientific problem-solving (Pinar et al., 2025).

Global Partnerships and Cross-Border Collaboration: Universal partnerships can strengthen STEM creativity by connecting schools, industries and research organizations through joint projects, virtual laboratories, research team-work, and online STEM communities. These partnerships should stress shared learning, merging technical expertise with locally grounded knowledge and resource-efficient solutions to solve shared challenges (OECD, 2025; York et al., 2025).

Challenges and Strategies for Practice

In this section, challenges of culture, infrastructure, resource, and strategies for overcoming them are discussed.

Cultural, Infrastructural and Resource Challenges

Implementing creative STEM education faces several challenges. Cultural resistance may continue where teachers are traditionally viewed as the main source of knowledge and learners as passive recipients. Still Creative STEM entails more interactive, collaborative and learner-centred relationships. Examination burden limit creativity when teachers prioritize preparation for standardized examination over projects and open-ended activities. Scarce infrastructure, mostly restricted access to laboratories, digital technologies and learning resources, may additionally inhibits implementation in rural schools. Another issue is limited teacher preparation for interdisciplinary teaching, as science, Mathematics, technology and engineering are habitually taught separately. Cultural and contextual variances should be considered when accepting global STEM models. Rather than being copied directly, such frameworks can be modified to local needs, resources and cultural contexts (Holmes et al., 2021; Mudaly & Chirikure, 2023).

Strategies for Overcoming Barriers in Developing Contexts like Nigeria

In developing countries like Nigeria, creative STEM practice should prioritize hands-on, affordable, and context-sensitive methods. Schools can use improvised or recycled materials for activities such as water filtration, solar energy, irrigation, bridge construction and simple engineering designs. Teacher professional growth should emphasize creative teaching (Ayua, 2019; Ayua & Eriba, 2023, Ayua & Terhemba 2025), enabling teachers to engage learners in designing, testing and refining solutions even where laboratory resources are limited. Universities can support schools by mentorship, laboratory access and innovation programmes, while industry can provide equipment, internships and real-world problem-solving prospects. Policy could promote equitable STEM access, particularly for rural schools. Such context-based tactics can make STEM learning more relevant while firming teacher capacity, community involvement and learners' linking with real-world problems (Holmes et al., 2021).

Conclusion

Creativity is key to the future of STEM education. Outside acquiring established knowledge, STEM learners need to question, generate and assess ideas, project solutions and improve existing tactics. This shift is reflected in international education. The OECD's PISA 2022 framework identifies creative thinking as the ability to generate, evaluate and improve ideas, while UNESCO's AI Competency Framework highpoints human agency, critical judgement, responsible technology use and creative engagement with AI (OECD, 2024; Miao et al., 2024). Together, these growths strengthen the need for STEM education to prepare learners not only to understand knowledge, but also to use creativity to solve evolving real-world problems. The shift from rote learning to creative STEM cannot diminish the importance of foundational knowledge. Rather, knowledge can assist as a foundation for inquiry, problem-solving and innovation. STEM learners want to move beyond remembering concepts to applying them in unacquainted situations, assessing evidence, creating solutions and refining ideas. Therefore, functional STEM education requires not only what learners remember, but also how they can the acquired knowledge in solving real-world problems.

Call to Action for Educators, Policymakers and Global Stakeholders

Globally, all stakeholders in education may recognise creativity as a core element of STEM education rather than an optional augmentation. The future of STEM depends not only on mounting scientific and technical knowledge but also on producing learners who can apply that knowledge creatively, critically and correctly. The projected CREATIVE-STEM

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model provides a conceptual pathway towards this goal. Its effectiveness, however, will depend on contextual edition, effective practice and empirical authentication. Future research could examine its applicability across countries, educational systems, age groups and socioeconomic setting.

Recommendations

From the discourse, these recommendations are proposed:

1. STEM curricula should integrate creativity, inquiry, design thinking, problem solving and innovation alongside knowledge of subject content.
2. Teachers should ensure professional improvement in creative STEM teaching, including inquiry-based learning, project-based learning, design thinking, intersubject teaching and responsible use of emerging technologies.
3. Schools should find accessible innovation spaces, with both conventional laboratory equipment and improvised materials to ease creative STEM learning.
4. Assessment systems should be diversified to include projects, portfolios, open-ended problems, prototypes and other tasks which test creativity, reasoning, evaluation and development besides factual knowledge.
5. Governments, universities, industries and global organisations should fortify STEM collaborations to provide learners with equitable access to mentors, technologies, and innovation programmes.

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