

REIMAGINING QUALITY SCHOOL EDUCATION THROUGH STEAM: CONCEPTUAL CHALLENGES AND STRATEGIC SOLUTIONS

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Abstract

In an era defined by rapid technological advancement and complex global challenges, traditional models of schooling are increasingly insufficient in preparing students for the demands of the 21st century. The STEAM (Science, Technology, Engineering, Arts, and Mathematics) framework offers a transformative vision for quality education by promoting interdisciplinary learning, creativity, innovation, and critical thinking. Despite its growing global relevance, the implementation of STEAM in school settings is fraught with conceptual and practical challenges. These include limited teacher preparedness, fragmented curricula, a lack of integration between disciplines, and the undervaluation of the Arts. The paper critically analyses these barriers and situates them within broader educational paradigms, such as constructivism and experiential learning, to highlight the systemic shifts required for meaningful change. It discusses practical implementation strategies for schools, including the establishment of STEAM laboratories, the adoption of toy-based pedagogy to stimulate early curiosity, the embedding of transdisciplinary examples into subject teaching, continuous professional development (CPD) programmes for educators, and expanding teaching-learning opportunities beyond the classroom through field projects, community engagement, and virtual collaborations. Aligned with India's National Education Policy (NEP) 2020, which emphasizes holistic, multidisciplinary, and experiential learning, the paper highlights the relevance of STEAM in fostering critical thinking and creativity from an early age.

Keywords: STEAM education, Quality school education, Interdisciplinary learning, Educational innovation, NEP 2020

Introduction

STEAM education is a holistic, interdisciplinary approach to learning that integrates Science, Technology, Engineering, Arts, and Mathematics. It emphasises a hands-on, interdisciplinary, and creative approach to problem-solving, encouraging students to explore connections between different fields of study. It fosters critical thinking, innovation, and collaboration, preparing students for a rapidly changing world. It is gaining impetus by emphasising the integration of Science, Technology, Engineering, Arts, and Mathematics to foster creativity, critical thinking, and problem-solving skills in students. The approach is aligned with NEP 2020, which promotes experiential and interdisciplinary learning. STEAM education in India aims to prepare students for the demands of the 21st-century workforce by developing skills relevant to various industries, including engineering, design, and data science. It is an approach to teaching and learning STEM subjects that incorporates artistic skills like creative thinking and designing to prepare students for an evolving workforce that is creative and prepared to respond innovatively to real-world problems (Dell'Erba, 2019). Key aspects of STEAM education in India include an interdisciplinary approach, focus on skills, real-world applications, benefits for future careers, and a focus on innovation and entrepreneurship.

Present Scenario: Issues and Challenges

A recent study (IERJ, July 2025) finds that while 70% of stakeholders value STEAM, gaps in teacher training and infrastructure, especially in rural areas, pose major hurdles. (Bhatia & Kumari, 2025). Herro et. Al. (2018) in his qualitative longitudinal study found that pacing/time constraints, student understanding of content and process, planning complexities, constraints of school district policies, technology integration and assessment issues are the challenges of STEAM education. Raj (2025) in his study provided valuable insights into the promise and challenges of implementing Atal Tinkering Labs in remote schools of the Kathua district of J & K, highlighting their role in fostering STEM interest while exposing gaps in teacher training, resources, and infrastructure. It offers practical recommendations for sustaining ATLs in rural contexts through improved capacity building and community involvement.

National Level Initiatives

The National Education Policy (NEP) 2020 of India places a significant emphasis on promoting STEM and STEAM (Science, Technology, Engineering, Arts, and Mathematics) education. While the term “STEAM” is not explicitly and frequently used in the official NEP 2020 document, its principles and spirit are well-aligned with STEAM education, which integrates arts and creativity into traditional STEM learning. The policy supports STEAM Education by promoting Holistic and Multidisciplinary education with critical and creative thinking. Its STEAM alignment is reflected by its recommendations of blending science and technology with arts and humanities. It advocates for art-integrated education as a part of the school curriculum to foster creativity and innovation and supports the 'A' (Arts) in STEAM, thereby helping students to approach STEM subjects in a more innovative and engaging way. The policy proposes that coding and computational thinking will be introduced from Grade 6 onwards. Coding forms a core component of STEM/STEAM education and promotes problem-solving and logical reasoning. The policy allows students to choose combinations of subjects across streams (science, commerce, arts), breaking traditional barriers. This flexibility fosters interdisciplinary learning—key to STEAM education. The policy emphasises hands-on learning, vocational exposure, and internships from an early age. It encourages real-world application of skills—blending theory (STEM) with practice and creativity (Arts). It promotes the continuous professional development of teachers to adopt innovative teaching methods and encourages the use of technology, storytelling, games, and projects in the learning process. Here, teachers are trained to foster curiosity, inquiry, and cross-disciplinary projects—central to STEAM. Therefore, though the policy may not have used the term "STEAM" directly, its vision clearly lays the groundwork for STEAM-based education in India by encouraging an education system that is flexible, creative, interdisciplinary, and rooted in real-world skills.

Among various key national educational institutions, at NCERT, NISHTHA (National Initiatives for School Heads' and Teachers' Holistic Advancement) is a teacher training program which aims to boost teaching competencies and foster critical thinking. It is available online via DIKSHA and includes courses like “Art Integrated Learning,” which directly supports STEAM objectives by integrating arts into pedagogy. CIET (Central Institute of Educational Technology) develops learning content via mass media tools such as television, radio, digital and drives innovation in how STEM (and by extension, STEAM) is taught across schools and teacher education programs. Kala Utsav is an annual celebration (since 2015) of school-level arts talent, promoting creativity across India, a crucial aspect of the “A” in STEAM. e-Jaadui Pitara is an interactive learning app for children aged 3–8, blending play, storytelling, and learning—a highly creative introduction to early STEAM exploration. Various research projects in NCERT resonate strongly with STEAM (Science, Technology, Engineering, Arts, and Math) objectives, such as the Development of Curriculum-Based AR/VR and Virtual Labs directly support STEAM by integrating immersive tech-enhanced experience in learning. (NCERT, 2025)

CBSE has also announced STEM education as its annual training theme for the year 2025, where it will conduct specialised Capacity Building Programmes (CBPs) to help educators integrate STEM-focussed

teaching strategies into classrooms. To further promote STEM education, CBSE has introduced the 3030 Eklavya STEM education online series in collaboration with IIT Gandhinagar. It allows subject teachers to earn up to 30 hours of Continuous Professional Development (CPD) training upon completing all 10 sessions. The 3030 Eklavya STEM education programme includes hands-on STEM activities, engaging questions and assignments designed to enhance conceptual understanding, critical thinking and creative problem solving (<https://eklavya.iitgandhinagar.ac.in/home/course/eklavya/1>, 2025).

Implementation Strategies in Schools

Aligning with the NEP 2020 goals, schools can make the following efforts to successfully implement the STEAM education-

(a) Establishing STEAM labs in schools- STEAM labs transform learning from rote memorisation to an experiential, inquiry-driven process. They provide hands-on, inquiry-based learning experiences and help to foster problem-solving and design thinking skills, integrating arts and creativity into science and technology learning. A teacher can develop collaborative and communication skills through group projects. By providing a dedicated space for creativity, critical thinking, and collaboration, they help build a future-ready generation equipped with both technical expertise and humanistic values. In India, initiatives like Atal Tinkering Labs (ATL) under the Atal Innovation Mission (NITI Aayog) and NCERT's push for a culture of innovation and scientific temperament among students align with the STEAM lab philosophy. These labs, implemented in thousands of schools, provide students from middle to secondary levels with tools, training, and mentorship to create working prototypes and innovative solutions for local problems. The schools should equip labs with low-cost, scalable materials such as robotics kits, 3D printers, art supplies, science apparatus, and digital tools. They can also equip the labs with locally available materials in their surroundings.

(b) Toy-based pedagogy- Teachers must use educational toys, puzzles, and construction sets to introduce complex concepts in primary classes. A longitudinal study on 119 Taiwanese preschoolers over eight months focused on exploring the effects of STEAM building blocks games within a STEAM teaching framework in developing children's creativity, imagination and performance. The findings of the study indicated that the potential of integrating STEAM teaching strategies into early childhood education nurtures children's creativity and imaginative abilities (Lin & Williams, 2025). In a study conducted by Verma, Satsangi and Joshi (2023) with 120 learners in a blended learning environment, it was observed that the integration of arts and creativity with core STEM disciplines significantly improved engagement, critical thinking, and interdisciplinary connections. Such an inclusive and learner-centred approach promoted active participation, collaboration, and self-expression while deepening subject knowledge. Teachers reported that fun activities, toys and games based on STEAM activities opened new pedagogical possibilities, enabling them to link abstract concepts with practical applications. By incorporating local culture, storytelling, and design-thinking processes, the study also encouraged the preservation of indigenous knowledge alongside modern scientific learning. Overall, the findings suggested that STEAM-based pedagogy not only strengthens conceptual clarity but also nurtures creativity, social skills, and problem-solving abilities essential for holistic education.

(c) Discussing transdisciplinary examples and projects in subject teaching- Transdisciplinary teaching goes beyond an interdisciplinary approach. It merges concepts, skills, and perspectives from multiple subjects to address real-world issues in a meaningful way. It enables learners to view knowledge as interconnected. Illustration of human anatomy with digital 3D human body models, making natural dyes from plants, designing a school rainwater harvesting system, can be transdisciplinary projects in science subjects, which encourage critical-thinking skills, creativity and hands-on skills in students. Chowdhury et. Al. (2025) suggested the following steps to conduct transdisciplinary teaching with students.

- 1) Identifying the issues/ problems prevailing within the society, students and teachers should spot and define real-life complex problems that exist around them. *Example:* Water scarcity in a region.
- 2) Identifying the combination of epistemic perspectives to include in the science teaching-learning in seeking to address each issue/ problem. Next, decide which kinds of knowledge and viewpoints should be used to understand the problem. For example:
 - Scientific facts
 - Social science insights
 - Ethical viewpoints
 - Economic understanding
- 3) Putting forward resolutions drawing from the chosen combination of epistemic perspectives, in addressing the specified issue/ problem. Finally, propose solutions that come from mixing these perspectives together — rather than relying only on one subject’s knowledge.

Teaching- learning beyond the classroom

In the context of STEAM (Science, Technology, Engineering, Arts, and Mathematics) education, teaching and learning extend far beyond the confines of a traditional classroom. The interdisciplinary nature of STEAM inherently encourages experiential, hands-on, and inquiry-based learning that thrives in real-world settings. Outdoor environments, community spaces, museums, maker labs, and even digital platforms become vibrant extensions of the classroom where learners can explore, experiment, and innovate. Field trips to science centers, environmental reserves, or art installations, for example, enable students to contextualize theoretical knowledge, encouraging curiosity and critical thinking. Likewise, community projects such as designing eco-friendly solutions for local issues merge technical skills with social awareness, fostering empathy and collaboration.

Digital technologies also play a vital role in extending STEAM learning. Virtual labs, simulation software, coding platforms, and global collaboration tools allow students to engage with complex concepts interactively, at their own pace. Participation in national or global STEAM challenges, hackathons, and innovation fairs cultivate creativity, problem-solving, and resilience. By embracing learning beyond the classroom, educators not only break the monotony of textbook instruction but also prepare students for the fluid, collaborative, and innovation-driven demands of the 21st-century world. Ultimately, such an approach nurtures learners who are not only knowledgeable but also adaptable, reflective, and socially conscious.

Continuous Professional Development (CPD) in STEAM

Continuous Professional Development (CPD) is pivotal in equipping educators with the necessary skills and knowledge to effectively teach Science, Technology, Engineering, Arts, and Mathematics (STEAM). Research indicates that traditional, isolated professional development sessions often fail to produce lasting changes in teaching practices. Therefore, CPD initiatives must be sustained, contextually relevant, and collaborative to foster meaningful integration of STEAM disciplines. A study by Conradt and Bogner (2020) emphasizes the importance of long-term, integrated CPD programs that focus on creativity and social skills, rather than solely on cognitive learning. Their research found that such programs not only enhance teachers' abilities to teach STEAM subjects but also positively influence students' motivation and creativity. (Conradt & Bogner, 2020). “Additionally, incorporating inquiry-based and project-based learning methodologies into CPD programs has shown promise in enhancing teachers' pedagogical content knowledge (PCK). A study by Herro and Quigley (2017) demonstrated that teachers who participated in such professional development programs developed a deeper understanding of STEAM concepts and improved their instructional practices, leading to more engaging and effective learning experiences for students.” (Herro & Quigley, 2017) CPD activities for teachers in STEAM focus on helping educators

improve their skills, knowledge, and teaching methods in Science, Technology, Engineering, Arts, and Mathematics. Various CPD activities for teachers in STEAM may include

1. **Workshops and Training Sessions**, including hands-on workshops on coding, robotics, or 3D printing, training in integrating arts into STEM (turning STEM into STEAM), using new tech tools (like VR/AR in the classroom).
2. **Online Courses and Webinars**, including MOOCs on platforms like Coursera, EdX, or FutureLearn, covering STEAM topics, webinars by STEAM experts on innovative teaching strategies and tutorials on project-based learning in STEAM.
3. **Collaborative Projects and Networking**, including joining STEAM teacher networks or communities to share ideas, collaborating on interdisciplinary projects with other teachers and participating in hackathons or design challenges.
4. **Curriculum Development and Lesson Planning, including** developing integrated STEAM lesson plans, learning how to assess STEAM projects effectively and adapting curriculum to include hands-on, creative activities.
5. **Research and Reflection**, including reading current research on STEAM education, reflecting on your own teaching practice and making adjustments and writing or presenting about your STEAM teaching experiences.
6. **Attending Conferences and Events**, including STEAM education conferences, maker fairs or innovation expos and science fairs and arts integration seminars.

Therefore, effective CPD for STEAM educators should be sustained, collaborative, and centred on innovative teaching methodologies. By fostering creativity, promoting interdisciplinary collaboration, and engaging teachers in reflective practices, CPD programs can significantly enhance the quality of STEAM education.

Overcoming challenges in STEAM education

Following ways can be used to overcome the challenges in STEAM education,

- Atal tinkering lab, Ratriya Avishkar Abhiyan, TATA, Infosys foundation, Pratham NGO are the funding and support sources from which the schools can approach or gain ideas for STEAM teaching from their efforts.
- Adopt project-based learning where one project links multiple subjects.
- Use real-world problems.
- Provide Continuous Professional Development in STEAM methods.
- Use low-cost or recycled materials for hands-on activities.
- Encourage students' engagement to design inclusive, interest-based projects
- Use portfolio-based assessment, rubrics and formative assessments
- Provide mentorship programs, UDL in STEAM spaces for inclusiveness.
- Administrative & Policy support is needed to align STEAM initiatives with NEP 2020.

Educational Implications & Conclusion

NEP 2020 replaces the rigid 10+2 structure with a 5+3+3+4 model, promoting activity- and experiential learning from early grades, and blending disciplines rather than compartmentalizing them. STEAM aligns seamlessly with this vision by integrating the arts into STEM, it fosters creativity, critical thinking, and real-world problem solving. Policy's emphasis on competency-based assessments, inquiry-driven, and discussion-based curricula matches STEAM's focus on practical application over memorization. This approach nurtures deeper conceptual understanding and fluency with ideas that is the key strengths of STEAM pedagogy. STEAM cultivates curiosity, collaboration, logical reasoning, social skills, and real-world relevance—helping prepare students for an increasingly interdisciplinary workforce. Its emphasis

on arts and design alongside STEM promotes creative innovation and empathy—beneficial qualities in any learner. NEP 2020 mandates coding from grade 6, and supports EdTech development through initiatives like the National Educational Technology Forum. STEAM brings this to life via robotics labs, AI modules, maker spaces, and hands-on digital tools. Under policy, STEAM isn't just an enriching add-on, it is foundational to the vision of holistic, flexible, and future-ready education in India. Therefore, for STEAM's potential to be fully realized,

- Teacher training must be strengthened, especially for rural and underserved areas.
- Infrastructure, like STEAM and digital labs, needs equitable distribution.
- Local adaptation is key—STEAM should reflect regional culture, language, and resources.
- Systemic reforms, from assessment methods to curriculum flexibility, must fully embrace STEAM principles.

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