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# WHY INDIA NEEDS A STEM EDUCATION SYSTEM?

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*Abstract— The rapid advancement of science and technology has significantly transformed the global economy and the nature of work, making it essential for education systems to equip learners with relevant knowledge and skills. In this context, STEM Education, combining four divergent disciplines, has emerged as an important approach for developing critical thinking, creativity, problem-solving abilities, and innovation among students. The present paper examines the prerequisites for a STEM education system in the Indian context and explores how it can contribute to preparing learners for the demands of the twenty-first century knowledge society. The study discusses the concept of STEM-based learning and highlights the importance of interdisciplinary learning and experiential approaches, such as design thinking and problem-solving processes, in enhancing students' scientific understanding and practical skills. The paper further reviews major government initiatives promoting STEM education in India, including the National Initiative for School Excellence (NISE) Programme, India's STEM (I-STEM) Mission, Tarunodaya, and Atal Tinkering Labs (ATL), which aim to foster innovation, research culture, and technological competence among students. In addition, the study explains the four pillars of STEM education and the process of building STEM readiness, emphasising the role of education in connecting scientific knowledge with societal needs. The relationship between STEM and society is also discussed, highlighting how STEM education can address contemporary challenges such as technological development, sustainability, and economic growth. Furthermore, the paper presents key arguments supporting the adoption of STEM education in India, including its potential to strengthen innovation, enhance employability, and prepare trained workers for emerging industries. The study identifies several challenges in implementing STEM education in India, such as inadequate infrastructure, a shortage of trained teachers, curriculum rigidity, and socio-economic disparities. The paper concludes that strengthening STEM education through effective policies, teacher training, and improved resources is essential for fostering innovation and ensuring India's progress in a rapidly evolving technological world.*

***Keywords****— STEM Education, Interdisciplinary learning, Innovation, Design thinking, STEM readiness, India*

## I. INTRODUCTION

The Indian education system has evolved and continues to evolve. The teaching and learning processes have undergone a massive transformation due to the innovative NEP 2020 education policy and the complexity of the post-pandemic new normal. There is more to the modern educational system than just classrooms, homework, and tests. The world has progressed from chalk-and-talk methods to online education and digital resources that break the regular classroom mould. Stakeholders and educators who can transcend traditional classroom routines are needed in India who could keep up with cutting-edge developments like online education, and our scholars have recognised the urgent need for STEM education.

Following the trend in the world's top educational systems, policymakers have incorporated STEM as a teaching-learning (T-L) strategy. Additionally, to succeed in the workforce and in their careers, our students must develop STEM readiness. With unparalleled talent and culture, India is the world's most populous nation. For India to take advantage of STEM education opportunities and advantages, the government and educational institutions must work together. The Indian government is now concentrating on initiatives like the **Make in India** Innovation Mission, which emphasises the development of manufacturing and innovation in schools. Even though it's still in its infancy, India needs a lot of innovation in the field of STEM education.

Beyond smart classrooms, the education sector is focusing on hands-on learning and improving the information and communication technology used in smart class platforms. Virtual reality, augmented reality, mixed reality, and extended reality are examples of emerging technologies that many STEM companies are collaborating with educational institutions to help set up Smart Labs. By combining science, technology, engineering, and mathematics into a single learning framework, STEM education marks a substantial shift in today's educational systems. STEM encourages an interdisciplinary and multidisciplinary approach that highlights the interconnectedness of scientific knowledge and its practical applications rather than treating these disciplines as separate subjects. This T-L approach encourages students to comprehend the connections between science, technology, engineering, and mathematics within a cogent

conceptual framework, going beyond the conventional philosophy of "science for science," which frequently presents scientific facts in fragmented forms.

## II. STEM BASED LEARNING

Immersing students in real-world issues and useful applications, STEM education aims to develop students' critical thinking, problem-solving, creative, and analytical skills. It emphasises how useful science and technology are to people's lives and to the advancement of society, transforming learners from passive information consumers into active researchers and innovators through STEM-based learning, which encourages them to explore, investigate, and design solutions to problems that arise in everyday life (Kumar & Ozma, 2024). The STEM approach emphasises experiential and embodied learning in the classroom while drawing on knowledge from a variety of scientific disciplines, including physics, chemistry, biology, and environmental science. To help students comprehend difficult scientific ideas and phenomena, effective STEM education uses a variety of teaching techniques, such as models, experiments, simulations, and scientific analogies. These techniques improve students' capacity to apply theoretical knowledge in real-world situations while also making it more understandable. Additionally, STEM education facilitates differentiated instruction, which enables educators to meet students' varied skills, interests, and learning requirements. STEM promotes equity and inclusiveness in education and helps develop higher-order thinking abilities based on significant scientific knowledge by accommodating both advanced students and those with learning disabilities.

In light of this, determining whether India requires a STEM education system is essential to equipping students to handle the demands of the quickly changing technological and knowledge-driven world. To support holistic learning and development, the STEM approach is a teaching-learning framework that incorporates the four diverse fields, making connections between academic ideas and practical applications by emphasising inquiry, hands-on, problem-solving, collaborative and experiential learning. Students are inspired to investigate, try new things, and come up with creative answers to challenging issues through STEM education. Students actively participate in tasks like problem identification, data analysis, hypothesis generation, testing potential solutions, and outcome evaluation in STEM-based learning environments.

STEM curriculum is developed around these disciplines and has become very popular across the world for its applicability to current and future challenges. In contrast to traditional methods, where subject is taught in compartments, the approach of STEM is not dividing knowledge but blending the knowledge, making synergy between the different subjects. The introduction of technology and engineering from the fundamental years makes the context and concepts clear to the students (Mishra & Srivastava, 2025). STEM learning has been found to be aligned with the new educational frameworks, such as the Next Generation Science Standards (NGSS), which promote inquiry, innovation, and critical thinking. Tinkering, experimenting, and using STEM applications drive curiosity, innovation, and exploration. Teaching methods of modern STEM also use educational technologies, including digital tools and Web 2.0 technologies. These technologies provide new chances for self-directed, collaborative, and meaningful learning. By using these new methods, STEM education is facilitated so that students are given the knowledge and skills to succeed in an increasingly technology-dependent and knowledge-based world (Ahmed, 2025).

## III. GOVERNMENT INITIATIVES

The Indian government seeks to institute the STEM education system in the school curriculum so that students can take an interest in it from an early age, and it can help them with technology for a better understanding of STEM education. The government has also taken great steps to support STEM education. The government has launched programs that aim to improve STEM education in schools. There are several ways to promote STEM education in India, one way is to increase the number of STEM schools, bridge the gender gap, and provide more scholarships and financial assistance for STEM students. The government also started India’s largest Robotics Competition, collaborating with the National Council of Science Museums and the Ministry of Culture. India is now joining the league of the most STEM graduates all over the world.

India’s efforts toward strengthening STEM education involve both governmental and non-governmental initiatives. While programs such as Atal Innovation Mission (AIM) and Rashtriya Avishkar Abhiyan are key government-led interventions, organisations like the All-India Council for Robotics and Automation (AICRA) are also contributing significantly through independent STEM promotion initiatives. AICRA’s STEM framework is structured around three core pillars:

- STEM Learning, which emphasises laboratory development and hands-on modules;
- STEM Recognition, which focuses on encouraging students through competitions and awards; and
- STEM Payback, which aims to foster a scientific temper and prepare youth for future careers and entrepreneurship. It is important to note that AICRA’s initiatives are independent and should not be conflated with official government STEM missions.

**National Education Policy (NEP) 2020** is the foundation of STEM reforms in India. It emphasizes:

- Experiential and inquiry-based learning
- Integration of science, mathematics, and technology
- Coding and computational thinking from early grades
- Multidisciplinary and flexible education
- promotes hands-on learning, critical thinking, and innovation.

**INSPIRE Programme (DST)**

The **Innovation in Science Pursuit for Inspired Research (INSPIRE)** scheme by the Department of Science and Technology aims to: Attract students to basic sciences, provide scholarships and mentorship, and support innovation and scientific research. It includes programs like INSPIRE-MANAK, INSPIRE Scholarship for Higher Education, and Vigyan Jyoti (encouraging girls in STEM). The NISE program aims to progress STEM education in schools across India. The program provides funding to schools to implement STEM-focused curriculum and activities, and it also provides training for the teachers.

**Tarunodaya**

The All-India Robotics Council for robotics and automation (AICRA), under its India STEM mission, envisions introducing the concept of Robotics to 10 million students through this program. The mission will lead students' interest in robots and robotics by providing free robotic training sessions by industry experts, inspiring and motivating minds to choose their career paths in the technology of tomorrow. Also, it is a nation-building exercise to create a diverse community of skilled individuals and entrepreneurs. It has relevance in the modern world as follows:

- **Technological advancements:** STEM fields drive technological innovations that shape our daily lives and industries.
- **Interconnected world:** In an interconnected world, understanding STEM Concepts is essential for informed decision-making.
- **Digital age:** STEM skills are fundamental for utilising and creating technology. Job market stem related careers are among the fastest-growing and highest-paying in the job market.

**Atal Innovation Mission (AIM) & Atal Tinkering Labs (ATL)**

Launched by NITI Aayog, this initiative promotes innovation among school students:

- Establishment of Atal Tinkering Labs in schools
- Provides tools like robotics kits, 3D printers, and DIY models
- Encourages problem-solving, design thinking, and creativity

The government plans to expand ATL infrastructure significantly across schools to strengthen STEM exposure. Envisioning to "*Cultivate One million children in India as modern innovators*", Atal Innovation Mission and ATAL Tinkering laboratories will establish schools across the country. With a punchline "where imagination meets creativity," this scheme aims at nurturing inquisitiveness, inventiveness and imagination in young students and imparting skills such as design thinking, adaptive learning, and computing, etc. 'ATL is a laboratory where young minds can shape up their ideas via hands-on 'Do-it-yourself Mode and Learn innovation skills. Young students get a chance to work with equipment and tools to grasp concepts of STEM. The STEM tinkering experience centre at IISER Pune has recently been inaugurated, which is part of the STEM-ready project that seeks to popularise STEM education in schools (Shastry, 2025).

**PM SHRI Schools Scheme**

The **Pradhan Mantri Schools for Rising India (PM SHRI)** initiative schools, acting as centres of excellence in STEM education aims to:

- Develop model schools aligned with NEP 2020
- Integrate smart classrooms, digital labs, and innovation-based learning
- Promote scientific temper and 21st-century skills

**I-STEM**

I-STEM, themed as "*Linking Researchers and Resources*", is an active, multidimensional and interactive national web portal that covers a range of scientific activities and programmes. The primary aim is to support the researchers in creating an ecosystem to support R&D, support "Digital India", reinforce the concept of "Optimal Usage of R&D Resources", "Equal Opportunities to All", reduce the downtime of the scarce tools /equipment, the idea of "Local to Vocal", and start-ups. The portal inculcates in every researcher the concept of Aatma Nirbhar Bharat or self-dependence so that the researchers can be independent and self-reliant to make the best usage of resources that have been set up across the country. It was also in line with SWAYAM initiatives in constructing skills development modules.


Design thinking is a problem-solving approach that helps people to understand and address problems to come up with innovative solutions. The design thinking in STEM encourages students to address challenges with a sense of empathy, viewing a problem through the eyes of someone actually confronting it. It is a mindset and a process that allows creativity, empathy, and experimentation. By using the design thinking process, children can learn to approach problems in a structured and creative way and develop critical thinking and problem-solving skills. The steps and

benefits of design thinking are user centred solutions, innovative ideas, supports collaboration among team members, early focus on understanding the end users, allow teams to agree on missions early, experimental approach of presenting the ideas as hypothesis, reduces the risk and cost of failure, allow for easier acceptance of failures, increased efficiency, continues improvement, and liveliness.

## IV. STEM AND SKILL DEVELOPMENT

Science and technology do not advance without each other. Science is a way of knowing that answers the questions "What/Why." Technology is a way of doing, which answers the emergent questions "How." Technological innovation is essential for human development, but whether it is good or bad depends on how it is being used. To design the experiential aspect of STEM learning, the teaching and learning strategies ought to be contextual and related to real-life experiences wherein each learner gets a chance to observe, to express, to question, to discuss, to critically think, to improvise, to analyse and to participate.

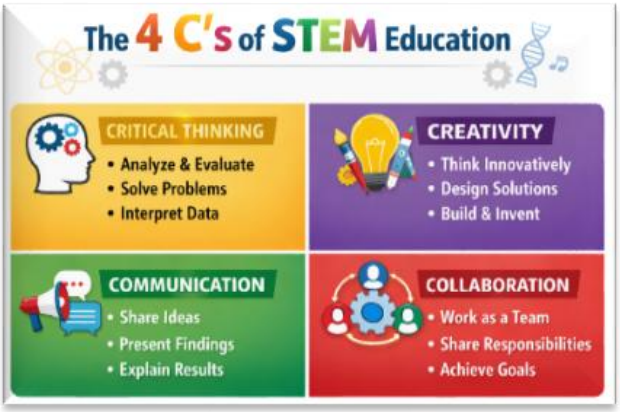
**Table 1: Integration of STEM with VR, AR, MR, XR**

| STEM Area | Technology Integration | Learning Outcome |
|---|---|---|
| **Science** | AR/VR simulations | Better conceptual understanding |
| **Technology** | XR tools | Digital skills and competencies |
| **Engineering** | MR prototyping | Design thinking skills |
| **Mathematics** | VR visualization | Abstract concept clarity |

India needs a strong STEM education system to prepare its vast youth population for a rapidly evolving, technology-driven world. With growing demands in sectors such as artificial intelligence, digital innovation, healthcare, and sustainable development, STEM equips learners with critical thinking, problem-solving, and analytical skills essential for both employability and nation-building. It helps bridge the gap between theoretical knowledge and real-world application, fostering innovation and entrepreneurship. Moreover, STEM education promotes inclusivity by encouraging participation from underrepresented groups, thereby strengthening the country's human resource potential.

In the context of global competition and initiatives like **Digital India** and **Atmanirbhar Bharat**, a robust STEM framework is crucial for driving economic growth, scientific advancement, and self-reliance. Similarly, Samagra Shiksha Abhiyan supports the holistic development of school education by promoting ICT-enabled learning, science labs, including NIPUN Bharat Mission and teacher training programs to enhance STEM teaching practices. Skill India Mission aim to equip youth with industry-relevant STEM skills, aligning education with employability and workforce demands. In addition, platforms like DIKSHA and SWAYAM provide free digital courses, e-content, and interactive STEM learning materials, making quality education accessible to a wider population.

STEM is a tool for students to develop key skills like *communication, collaboration, critical thinking, and creativity* by thinking and acting out of the box. They also gain the confidence needed to thrive in a competitive workplace. Students are consistently challenged to solve problems. This develops skills of reasoning, innovation, imagination, independent thinking, initiative, teamwork, persistence, resilience and understanding.




Balancing listening and contributing involves a great deal of concentration. Defending ideas and theories is a core skill and one that is required throughout life, which is grown through STEM. Feedback is a part of learning and part of life. Students work together, share responsibility, accountability, and cooperation with others to realise a shared goal. Students practice developing healthy work habits such as being on time, prepared, and respecting the contributions of others. Stem is an approach to teaching and learning that is higher than its integral parts. STEM removes the traditional divide between the four disciplines by integrating the four subjects into one cohesive curriculum, such as outdoor play, Minecraft, 3D printing, coding, and robotics.

### Building STEM Readiness

- STEM content should be integrated across all subjects.
- Learning should be more engaging, with reduced reliance on lectures.
- Greater emphasis should be placed on structured problem-solving.
- Instructional strategies should encourage students to actively seek STEM-based answers.
- Increased participation of underrepresented populations in STEM should be promoted.
- More opportunities for collaborative learning experiences should be provided.
- Learning should foster deep understanding and creative thinking.
- A supportive environment should be created that values and acknowledges new ideas.

- Students should be encouraged to think beyond conventional boundaries (out-of-the-box thinking).
- Learning experiences should be enjoyable, interactive, and engaging.

## V. STEM AND SOCIETY

STEM prepares students to face future challenges of real-life situations regardless of the professions they choose. It prepares the learners to succeed in life, and we will substantially fail if we do not teach children how to think critically and solve ill-structured problems. STEM programs must be conducted to create individuals capable of new solutions and better decisions. STEM is a paradigm shift from the factory model of education to the broadcast model of education. It believes that the increased science and math capability is not enough, but the experiences centred on design & innovation in engineering and technology increase creativity, inventiveness, ingenuity, and imagination capabilities. Such characteristics must be fostered in STEM-centred learning experiences.

- Stem gives values and methods to society for accessibility, equity, and sustenance.
- It encourages cohabitation of acceptance and respect.
- Stem gives new roles of a teacher like facilitator, innovator, coworker, mentor, modelling, leader, resource provider, catalyst for and of and for a change.
- It enhances skills like observing, classifying, inferring, predicting, measuring, communicating, experimenting, investigating, using space and time relations, formulating models, recognising variables, formulating hypotheses, and interpreting data.
- Stem gives new roles to learners like discoverer, retriever, interpreter, and manager.
- Stem allows the child to follow instructions and do tasks, read, and understand text, develop logical arguments, develop concepts, develop the use of language, develop inferential skills, articulate, and use experience, observe closely, record and organise data.
- Teaching Process through STEM is sensitised and receptive in nature, and the learner gets clear, accurate, brief, and specific knowledge of the concept.
- STEM encourages a learning cycle originated from knowing to being and being to doing.

## VI. STEM EDUCATION (KEY ARGUMENTS)

### 1. Preparing Students for the Future professionals

STEM education is essential for preparing students with the skills required in a rapidly evolving technological world. Industries such as artificial intelligence, robotics, biotechnology, and data science require strong foundations in science and mathematics. By promoting STEM education, India can equip its youth with the competencies necessary to participate effectively in the global knowledge economy and meet the increasing demand for technologically skilled professionals (Selvan & Kalaiyarasan, 2024).

### 2. Promoting Innovation and Technological Advancement

Innovation is a key driver of economic growth and national development. STEM education encourages creativity, experimentation, and problem-solving skills that enable students to develop new technologies and innovative solutions. Strengthening STEM education can help India transition from being primarily a consumer of technology to a producer and innovator, contributing to global technological progress.

### 3. Addressing Societal and Global Challenges

Many of the challenges faced by modern societies, such as climate change, healthcare issues, energy sustainability, and food security, require scientific and technological solutions. STEM education equips students with the knowledge and analytical skills needed to address these complex problems and contribute to sustainable development.

### 4. Enhancing Critical Thinking and Problem-Solving Skills

STEM learning focuses on inquiry-based and experiential learning, which promotes higher-order thinking skills. Through activities such as experimentation, data analysis, and engineering design, students learn to think critically, evaluate evidence, and develop innovative solutions to real-world problems. These skills are essential for both academic success and professional growth (Singh, 2024).

### 5. Strengthening Economic Growth and Employment Opportunities

STEM-related sectors generate a large number of high-skill jobs and contribute significantly to economic development. As industries increasingly rely on technological innovation, countries with strong STEM education systems are better positioned to compete in the global economy. Developing STEM skills among youth can help reduce unemployment and create a more productive workforce (Patel et al., 2024).

## VII. CHALLENGES OF IMPLEMENTING STEM EDUCATION IN INDIA

### 1. Lack of Infrastructure and Resources

Many schools in India, particularly in rural areas, lack adequate laboratory facilities, technological tools, and internet connectivity. Without proper infrastructure, it becomes difficult to implement hands-on learning and experimentation, which are essential components of STEM education.

**2. Shortage of Trained STEM Teachers**

Effective STEM education requires teachers who are trained in interdisciplinary teaching methods and modern educational technologies. However, India faces a shortage of qualified STEM educators, and many teachers have limited exposure to innovative pedagogical approaches.

**3. Traditional Rote-Learning Education System**

The ancient education system has historically emphasised memorisation and examination-oriented learning, which often discourages creativity, experimentation, and critical thinking. This traditional approach limits the adoption of inquiry-based and problem-solving methodologies required for STEM education.

**4. Urban–Rural Educational Divide**

There is a significant disparity between urban and rural schools regarding access to quality education, technology, and learning resources. Students in rural areas often have limited opportunities to participate in STEM activities compared to those in urban institutions.

**5. Gender and Socio-Economic Inequality**

Social and cultural barriers sometimes discourage girls and students from disadvantaged communities from pursuing STEM fields. Addressing gender stereotypes and access to STEM opportunities is essential for inclusive education (Singh & Singh, 2025).

**6. Rigid Curriculum and Limited Interdisciplinary Learning**

Many school curricula still treat science, mathematics, and technology as separate subjects, limiting interdisciplinary learning. A lack of flexibility in the curriculum makes it difficult to integrate real-world problem solving and collaborative projects, which are central to the STEM approach (Yadav, 2025).

## VIII. CONCLUSION

The real problem with STEM is the shortage of skills in the technical and scientific fields due to the substantial difference between the academic curriculum and industry needs. The Indian education system needs to focus on structural changes and equal changes in the pedagogical practices and andragogical practices. STEM has the power to nurture our young generation to think deeply so that they become innovators, educators, researchers, and leaders to solve pressing challenges of the nation and world today and tomorrow. The real strength of the Indian youth lies in having a strong scientific temper, intellectual content, fascination, a sense of philosophy and being imaginative rather than looking at the problems or social issues.

In conclusion, strengthening STEM education in India is not merely an educational reform but a strategic necessity for national development. It empowers learners with essential 21st-century skills vital in addressing complex global and local challenges. By integrating STEM across all levels of education, India can nurture innovation, enhance employability, and reduce the gap between academic knowledge and industry demands. Furthermore, inclusive STEM practices can ensure broader participation, especially among underrepresented groups, thereby maximising the country's human capital. As India aspires to become a global leader in science and technology, a robust and equitable STEM education system will play a pivotal role in achieving sustainable growth and self-reliance.

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Dr Rakhi Sawlani has earned a prestigious degree of PhD from the Department of Education, Devi Ahilya University, Indore. She has more than ten years of working experience in Teaching, training, data analysis, and Research. She has attended several national and international conferences in India and abroad and presented papers in the fields of science, education, economics and psychology. She has actively participated in various minor and major government-funded projects and has developed learning material for undergraduate courses. She has many publications to her credit, including Scopus and UGC listed journals. She has peer-reviewed 20 manuscripts included in Web of Science. She has also contributed significantly to the domain of educational assessment by developing and standardising tools, published by the National Psychological Corporation.

 