Global Journal of Educational Thoughts
GJET vol.3, no.2, December 2026

Submitted: 7 July 2026
Reviewed: 24 July 2026
Revised: 12 August 2026
Accepted: 13 August 2026

INTEGRATION OF STEM EDUCATION WITH 21ST CENTURY SKILLS IN PRIMARY CLASSROOMS

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ABSTRACT

The present study examined the effectiveness of a four-week STEM-based classroom intervention in developing critical thinking, creativity, collaboration, and problem-solving skills among primary school students in Pune, Maharashtra. A quantitative quasi-experimental design was adopted with 120 students from Classes III to V, comprising 60 students in a STEM intervention group and 60 in a conventional instruction group. The intervention integrated science, technology, engineering, and mathematics through inquiry-based activities, simple engineering-design challenges, collaborative projects, experimentation, problem-solving tasks, and technology-supported learning. Students were assessed using a Twenty-First Century Skills Assessment Scale, supported by classroom observations and teacher responses. Data were analysed using descriptive statistics, independent-samples *t*-tests, and Pearson's product-moment correlation. The findings indicated that students participating in STEM-based learning demonstrated significantly stronger critical thinking, creativity, collaboration, and problem-solving than students receiving conventional instruction. STEM activity participation was also positively associated with overall twenty-first-century skill development. The findings have practical implications for primary schools, particularly regarding curriculum planning, teacher professional development, interdisciplinary lesson design, and provision of accessible STEM resources. The study suggests that carefully structured STEM experiences can provide an effective pathway for competency-based and experiential learning in primary classrooms.

Keywords: *STEM education, primary education, critical thinking, creativity, collaboration, problem solving, experiential learning, inquiry learning.*

INTRODUCTION

Contemporary education is increasingly concerned with preparing learners not only to acquire disciplinary knowledge but also to apply knowledge flexibly in unfamiliar situations. Rapid technological development, globalization, changing employment patterns, and the increasing availability of information have strengthened the need for learners who can reason critically, generate original ideas, collaborate with others, communicate effectively, and solve complex problems (Partnership for 21st Century Learning, 2015; Bell, 2010). These competencies are commonly associated with twenty-first-century learning and have become important

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considerations in curriculum design and classroom pedagogy. The primary stage is particularly important because it establishes foundational habits of inquiry, reasoning, communication, cooperation, and independent learning. At this level, children learn effectively when abstract ideas are connected with observation, experimentation, manipulation of materials, discussion, and real-life situations (National Council of Educational Research and Training, 2020). Consequently, instructional approaches that provide opportunities for learners to explore, construct, test, revise, and communicate ideas have considerable educational value (Bell, 2010).

STEM education offers one such approach. STEM refers to the integration of science, technology, engineering, and mathematics through interdisciplinary learning experiences (Sanders, 2009; English, 2016). Rather than treating these disciplines as completely separate areas of knowledge, integrated STEM encourages learners to apply concepts from multiple domains while investigating authentic problems (Honey et al., 2014; Thibaut et al., 2018). Engineering-design activities, inquiry-based tasks, project work, experimentation, computational activities, and collaborative problem solving can create learning environments in which students are required to reason, test alternatives, communicate decisions, and revise solutions (Bell, 2010; English, 2016). Recent international research reinforces the relevance of such approaches in primary education. Systematic research on technology-oriented STEM education has highlighted the growing use of digital tools and technologies across primary and secondary STEM classrooms and has identified diverse instructional purposes and learning outcomes (Suna et al., 2023). A recent systematic review and meta-analysis of educational robotics in primary education further examined its contribution to STEM competence, demonstrating the increasing empirical attention given to technology-supported STEM experiences at the primary level (Sapounidis et al., 2023; Trapero-González et al., 2024). Similarly, recent work on STEM instructional design indicates that STEM teaching is increasingly organized around interdisciplinary knowledge, real-world problem solving, inquiry, and engineering-oriented learning rather than isolated subject instruction (Halawa et al., 2024).

The relationship between STEM and higher-order competencies is also supported by recent research focusing specifically on primary learners. Yesnazar et al. (2024) proposed a methodological system in which interdisciplinary tasks and integrated projects are used to foster research, communication, analytical, creative, and problem-solving abilities among primary school students. Research on technology-enhanced collaborative inquiry similarly emphasizes the role of collaborative inquiry environments in promoting critical thinking and exploratory learning in K–12 contexts (Chen & Chen, 2024). Recent systematic work on computational thinking and STEM has additionally examined how computational approaches may transfer across STEM learning contexts, indicating the expanding conceptual scope of integrated STEM education (Li & Oon, 2024).

In the Indian context, the National Education Policy 2020 has strengthened the policy emphasis on experiential, competency-based, multidisciplinary, inquiry-oriented, and technology-supported learning (Ministry of Education, Government of India, 2020). These principles are particularly compatible with integrated STEM pedagogy because both emphasize application of knowledge, active participation, creativity, problem solving, and connections between classroom learning and real-world situations (National Council of Educational Research and Training, 2020; English, 2016). Despite increasing attention to STEM education,

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evidence concerning its effects on multiple twenty-first-century competencies among Indian primary-school learners remains comparatively limited. Existing literature frequently examines individual outcomes, particular STEM technologies, or older learners. There is therefore a need for empirical research that simultaneously considers critical thinking, creativity, collaboration, and problem solving within an integrated primary-school STEM intervention.

The present study addresses this need by examining a structured four-week STEM intervention among primary school students in Pune. Its significance lies not merely in determining whether STEM activities are associated with improved skill outcomes, but in providing practical evidence regarding how interdisciplinary, inquiry-oriented classroom experiences can contribute to competency development at the primary level. The findings are intended to inform teachers, school leaders, curriculum planners, and teacher educators about feasible strategies for integrating STEM with twenty-first-century learning in regular primary classrooms.

Objectives of the Study

1. To examine the implementation of STEM-based instructional practices in selected primary schools of Pune.

2. To assess the effect of STEM-based classroom instruction on students' critical thinking, creativity, collaboration, and problem-solving skills.

3. To compare the overall twenty-first-century skills of students exposed to STEM-based instruction with those receiving conventional classroom instruction.

4. To determine the relationship between students' participation in STEM classroom activities and their overall twenty-first-century skill development.

5. To identify the major classroom and institutional factors that facilitate or constrain STEM implementation in primary schools.

6. To suggest practical strategies for strengthening STEM integration in primary education.

Research Hypotheses

H_{01}: There is no significant difference in critical thinking skills between students receiving STEM-based instruction and those receiving conventional instruction.

H_{02}: There is no significant difference in creativity between students receiving STEM-based instruction and those receiving conventional instruction.

H_{03}: There is no significant difference in collaborative learning skills between students receiving STEM-based instruction and those receiving conventional instruction.

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H_{04}: There is no significant difference in problem-solving abilities between students receiving STEM-based instruction and those receiving conventional instruction.

H_{05}: There is no significant relationship between participation in STEM classroom activities and students' overall twenty-first-century skill development.

REVIEW OF RELATED LITERATURE

Integrated STEM and Primary Learning

Earlier conceptual literature established STEM education as an interdisciplinary approach in which knowledge from science, technology, engineering, and mathematics is connected through meaningful problems and applications. Sanders (2009) emphasized integration across disciplinary boundaries, while Bybee (2013) highlighted the role of STEM in scientific literacy, innovation, and analytical reasoning. Honey et al. (2014) further emphasized the importance of interdisciplinary learning experiences in which learners apply knowledge rather than merely receive information. More recent research has strengthened this perspective by examining STEM through systematic and evidence-based approaches. Halawa et al. (2024) found that STEM instructional designs vary considerably but commonly emphasize interdisciplinary integration, real-world problems, inquiry, and application of knowledge. Thus, the literature increasingly conceptualizes STEM not as an additional subject but as a way of organizing meaningful learning across disciplines.

STEM, Critical Thinking and Problem Solving

A major theme in the literature concerns the relationship between STEM experiences and higher-order thinking. STEM activities frequently require learners to identify problems, collect information, propose explanations, test possible solutions, interpret evidence, and revise their ideas. Such processes naturally create opportunities for analytical and critical thinking. Recent research involving primary students has particularly emphasized integrated projects and interdisciplinary tasks as mechanisms for developing analytical and research-related skills. Yesnazar et al. (2024) argued that STEM environments can encourage primary learners to analyse information, conduct investigations, evaluate evidence, and solve real-life problems. Similarly, systematic research into collaborative inquiry in K–12 settings indicates that technology-supported inquiry can facilitate exploratory learning and critical thinking when students work collectively to investigate problems.

STEM, Creativity and Collaboration

Creativity within STEM is closely connected with open-ended problem solving and engineering design (Honey et al., 2014; English, 2016). Learners may be required to generate multiple solutions, construct prototypes, test designs, identify weaknesses, and improve their products. Such activities create opportunities for originality, flexibility, experimentation, and creative decision-making (Bell, 2010). Collaboration is similarly embedded in many STEM learning environments. Group projects require learners to share responsibilities, communicate

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ideas, negotiate decisions, listen to alternative viewpoints, and jointly evaluate solutions (Bell, 2010; Thibaut et al., 2018). Thus, creativity and collaboration are not necessarily separate outcomes of STEM; they can emerge simultaneously through appropriately designed interdisciplinary activities. Recent scholarship on STEM and STEAM has further emphasized the potential of interdisciplinary learning to support creativity, critical thinking, and problem solving, particularly when learners are provided with opportunities to connect technical knowledge with design and creative expression (Zhang & Jia, 2024).

Technology and Contemporary STEM Learning

Technology has become an increasingly important component of STEM pedagogy. Systematic evidence covering STEM education in primary and secondary schools has identified a wide range of technologies and instructional applications, suggesting that technology can support simulation, investigation, creation, communication, representation, and problem solving (Suna et al., 2023). Educational robotics is another expanding area, with recent systematic review and meta-analytic research specifically examining its contribution to STEM competence in primary education (Sapounidis et al., 2023; Trapero-González et al., 2024). However, the literature also suggests that technology alone does not produce meaningful learning. Its educational value depends on how it is integrated with pedagogical purposes, collaborative activity, inquiry, reflection, and disciplinary understanding (Suna et al., 2023; Halawa et al., 2024). Therefore, effective STEM integration requires alignment between technology, curriculum objectives, teacher guidance, and learner activity.

Teacher Preparation and STEM Implementation

The quality of STEM implementation is strongly influenced by teachers' pedagogical knowledge, confidence, interdisciplinary understanding, and access to appropriate resources (Wu et al., 2024). Recent research has increasingly examined teachers' capacity to integrate multiple disciplines rather than focusing exclusively on student outcomes. A recent meta-analysis of interdisciplinary teaching abilities among STEM teachers highlights the importance of teachers' capacity to work across disciplinary boundaries in implementing integrated STEM education (Wu et al., 2024). This suggests that STEM implementation should not be understood simply as introducing robotics, coding, laboratory equipment, or digital devices. Effective implementation requires teachers who can design interdisciplinary tasks, facilitate inquiry, manage collaborative work, guide engineering-design processes, and assess competencies (English, 2016; Wu et al., 2024).

Synthesis and Research Gap

The reviewed literature collectively suggests that STEM education can create conditions favourable to critical thinking, creativity, collaboration, problem solving, inquiry, and interdisciplinary learning (English, 2016; Honey et al., 2014; Bell, 2010). Recent systematic reviews have strengthened the evidence base concerning technology use, instructional design, robotics, computational thinking, and interdisciplinary STEM teaching (Suna et al., 2023; Halawa et al., 2024; Trapero-González et al., 2024; Li & Oon, 2024; Wu et al., 2024). Nevertheless, three gaps remain particularly relevant. First, much of the international evidence

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emerges from educational systems with different curricular structures, teacher preparation systems, and technological resources. Second, Indian research focusing specifically on primary learners and multiple twenty-first-century competencies remains comparatively limited. Third, fewer studies have examined critical thinking, creativity, collaboration, and problem solving together within a single classroom intervention. The present study therefore contributes by examining these four competency dimensions simultaneously within a four-week STEM intervention involving primary school students in Pune.

RESEARCH METHODOLOGY

Research Approach and Design

The study adopted a quantitative research approach using a quasi-experimental, comparative pre-existing-group design, supplemented by structured classroom observation and teacher responses. The quasi-experimental design was selected because intact classrooms were used and random assignment of individual students to experimental conditions was not feasible within normal school arrangements. The independent variable was STEM-based classroom instruction, while the principal dependent variables were critical thinking, creativity, collaboration, and problem-solving skills. The intervention lasted four weeks and consisted of structured STEM learning experiences incorporating inquiry, experimentation, collaborative projects, simple engineering-design challenges, practical problem solving, and age-appropriate technology use.

Study Area and School Selection

The study was conducted in selected government and private primary schools in Pune, Maharashtra. Schools were considered eligible when they offered Classes III to V, had regular classroom schedules permitting a four-week intervention, possessed basic facilities required for classroom STEM activities, and provided administrative permission for participation. Schools were excluded when they were unable to accommodate the intervention schedule, had insufficient attendance during the study period, or were simultaneously implementing another intensive STEM programme that could confound the intervention. The selected schools represented both government and private institutional settings to provide variation in school context. Within eligible schools, participating students were drawn from Classes III to V. The final sample consisted of 120 students.

Sample and Classroom Allocation

The study included 120 primary school students. Sixty students constituted the STEM intervention group and sixty constituted the conventional instruction group. Students were selected from eligible classrooms using stratified procedures to ensure representation across school type and grade level. Because intact classrooms were retained, students were not individually randomized into the intervention and comparison groups. Instead, comparable classrooms were designated as either the STEM intervention or conventional instruction condition in consultation with school authorities and teachers. This classroom allocation

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represents a quasi-experimental arrangement and is acknowledged as a limitation of the study. To reduce possible confounding, efforts were made to maintain comparability in grade level, approximate age, instructional duration, school type, classroom conditions, and regular curriculum exposure.

STEM Intervention

The STEM intervention was implemented over four consecutive weeks. It was designed around the principle that primary students should learn disciplinary concepts through connected, practical, and age-appropriate problems. The intervention included:

- inquiry-based science investigations;
- practical mathematics activities;
- simple engineering-design challenges;
- construction and model-making tasks;
- measurement and estimation activities;
- technology-supported exploration;
- collaborative problem-solving tasks;
- group discussion and explanation;
- testing, evaluation, and modification of solutions; and
- short project presentations.

The intervention emphasized the process of identifying a problem, discussing possible explanations, planning an approach, creating or testing a solution, evaluating outcomes, and communicating findings, consistent with inquiry-oriented and integrated STEM practices described in the literature (English, 2016; Honey et al., 2014; Halawa et al., 2024). Teachers acted primarily as facilitators rather than relying exclusively on direct instruction, reflecting the emphasis on active learner participation and guided inquiry in experiential learning (National Council of Educational Research and Training, 2020). The comparison group continued with the regular classroom instructional practices followed by the participating schools during the same period.

Twenty-First Century Skills Assessment Scale

The Twenty-First Century Skills Assessment Scale served as the principal instrument for assessing the outcomes of the intervention. The scale was designed to capture four dimensions directly relevant to the objectives of the study: critical thinking, creativity, collaboration, and problem solving. The critical-thinking dimension assessed students' ability to examine information, identify relationships, provide reasons, compare alternatives, and make logical judgments. The creativity dimension focused on originality, flexibility, generation of alternatives, experimentation, and willingness to develop new approaches. The collaboration dimension assessed cooperation, communication with peers, sharing of responsibilities, listening to others, and joint decision making. The problem-solving dimension examined students' ability to identify problems, plan solutions, apply relevant knowledge, evaluate alternatives, and modify approaches when necessary.

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The scale used age-appropriate statements and a structured response format. Higher scores indicated stronger expression of the relevant competency. Before the main study, the instrument was pilot tested with 20 students who were not included in the final sample. Items were reviewed for clarity, appropriateness, and comprehension. The internal consistency of the scale was assessed using Cronbach's alpha and produced a coefficient of .89, indicating high internal consistency. Content validity was established through expert review involving teacher educators, STEM education specialists, and an educational psychologist. Because the principal instrument relied partly on students' self-reported responses, classroom observations and teacher responses were also used as supplementary sources of evidence.

Data Collection Procedure

Permission was obtained from the participating schools before data collection. Parents or guardians provided informed consent, and students participated voluntarily. The assessment was administered under the supervision of the researcher and participating teachers. During the four-week intervention, classroom observations were conducted to document student engagement, collaboration, inquiry, use of STEM practices, and participation in problem-solving activities. Teachers also provided responses concerning the feasibility of STEM activities, student participation, and implementation challenges. The same general assessment conditions were maintained across the intervention and comparison groups. Data were coded without personally identifying information and were used exclusively for academic research.

Data Analysis

The collected data were analysed using descriptive and inferential statistical procedures. Frequencies, percentages, means, and standard deviations were used to summarize the sample and examine the distribution of responses. Independent-samples *t*-tests were employed to examine differences between students participating in STEM-based instruction and those receiving conventional instruction. Pearson's product-moment correlation was used to examine the relationship between STEM classroom activity participation and overall, twenty-first-century skills. Statistical significance was evaluated at the .05 level**.** Effect-size interpretation was considered alongside statistical significance to avoid relying exclusively on *p*-values. The analysis was conducted in accordance with the study objectives and hypotheses.

RESULTS AND INTERPRETATION

The sample comprised students from Classes III to V, with broadly balanced representation of boys and girls and equal representation from government and private schools. This distribution provided reasonable coverage of the intended primary-school population within the selected study setting. The comparison between the STEM and conventional instruction groups showed statistically significant differences in all four assessed competency areas. Critical thinking was significantly higher among students participating in STEM-based learning, $t(118) = 8.47$, $p < .001$. Creativity also differed significantly between the groups, $t(118) = 7.91$, $p < .001$. A significant difference was similarly observed for collaboration, $t(118) = 8.15$, $p < .001$, while problem solving showed a significant difference of $t(118) = 8.36$, $p < .001$. The overall twenty-

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first-century skills score also differed significantly, $t(118) = 8.72$, $p < .001$. The results therefore provide evidence against the null hypotheses concerning critical thinking, creativity, collaboration, and problem solving.

The findings indicate that students who participated in the STEM intervention demonstrated stronger development of the assessed competencies than students who continued with conventional classroom instruction.

Correlation analysis provided additional evidence concerning the association between STEM participation and competency development. STEM classroom activities were positively associated with critical thinking ($r = .71$, $p < .001$), creativity ($r = .68$, $p < .001$), collaboration ($r = .74$, $p < .001$), and problem solving ($r = .76$, $p < .001$). The association with overall twenty-first-century skills was also strong ($r = .79$, $p < .001$). Thus, the null hypothesis proposing no significant relationship between STEM activity participation and overall competency development was rejected.

These findings should be interpreted as evidence of a strong association between participation in the intervention and skill development rather than as definitive proof of causation, because the study used a quasi-experimental rather than randomized design.

Discussion

The findings suggest that the educational value of STEM in primary classrooms is closely connected with the type of learning experiences it creates. STEM activities place students in situations where knowledge must be used rather than simply recalled (Honey et al., 2014; English, 2016). When learners investigate a problem, construct a model, test an idea, compare possible solutions, and explain their reasoning, they are required to engage in cognitive processes that are central to inquiry-oriented and project-based learning (Bell, 2010; Halawa et al., 2024). The improvement in critical thinking can therefore be understood in relation to the inquiry-oriented structure of the intervention. Students were encouraged to ask questions, examine evidence, consider alternatives, and justify their decisions. Such experiences provide natural opportunities for analytical reasoning and may help children gradually move from accepting information to evaluating it (Yesnazar et al., 2024; Chen & Chen, 2024).

The development of creativity can similarly be interpreted through the open-ended nature of STEM tasks. Engineering-design activities often allow more than one acceptable solution. Students can experiment with materials, modify their designs, and learn from unsuccessful attempts, processes that are consistent with integrated STEM and design-oriented learning (English, 2016; Honey et al., 2014). This creates a classroom culture in which revision becomes part of learning rather than an indication of failure. Such an environment may encourage flexibility, originality, and confidence in generating ideas (Zhang & Jia, 2024). Collaboration was supported because many STEM activities required students to work in small groups. Group-based design and investigation tasks require learners to divide responsibilities, exchange explanations, listen to peers, and reach collective decisions (Bell, 2010; Thibaut et al., 2018). Consequently, collaboration becomes embedded within the learning process rather than being treated as an independent social activity.

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Problem solving was particularly compatible with the intervention because STEM learning frequently begins with a practical challenge. Students must understand the problem, identify available resources, select an approach, test the solution, and reconsider it when necessary (Sanders, 2009; English, 2016). This cycle provides repeated opportunities to practise structured problem solving and to develop persistence when an initial solution does not work (Bell, 2010; Yesnazar et al., 2024).

The findings are broadly consistent with recent international literature. Systematic reviews have highlighted interdisciplinary STEM design, technology-supported learning, robotics, collaborative inquiry, and computational approaches as important areas in contemporary STEM education. The present findings also correspond with recent primary-school research emphasizing interdisciplinary projects and meta-subject learning as mechanisms for developing analytical, research, communication, and problem-solving competencies. However, the findings should not be interpreted as suggesting that STEM automatically produces higher levels of competency. The quality of implementation is likely to depend on teacher preparation, availability of materials, classroom management, time allocation, curricular flexibility, and the extent to which activities are genuinely interdisciplinary. Recent research on STEM teachers' interdisciplinary teaching abilities reinforces the importance of teacher capacity in successful STEM implementation.

The findings therefore have a broader pedagogical implication: effective STEM integration requires a shift in classroom culture from passive reception toward inquiry, application, collaboration, experimentation, and reflection. The intervention provides evidence that even relatively short, structured STEM experiences can be associated with meaningful differences in students' reported competencies, but sustained implementation would require institutional support and appropriately prepared teachers.

Major Findings

1. STEM-based classroom practices provided students with opportunities for inquiry, experimentation, interdisciplinary learning, and practical problem solving.

2. Students exposed to STEM instruction demonstrated stronger critical-thinking skills than students receiving conventional instruction.

3. STEM learning was associated with enhanced creativity through open-ended tasks, experimentation, design challenges, and opportunities to generate alternative solutions.

4. Collaborative STEM activities encouraged communication, shared responsibility, peer interaction, and cooperative decision making.

5. STEM-based experiences were associated with stronger problem-solving abilities, particularly through practical and real-life classroom challenges.

6. Overall, twenty-first-century skill development was stronger among students participating in STEM-based instruction.

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7. Participation in STEM activities showed a positive relationship with the development of overall twenty-first-century competencies.

8. Classroom observations indicated greater student engagement and active participation during STEM-based learning experiences.

9. Teachers identified limited infrastructure, availability of materials, time constraints, and insufficient professional preparation as important implementation challenges.

10. Teachers nevertheless demonstrated generally positive attitudes toward integrating STEM activities into primary classroom instruction.

11. STEM activities supported interdisciplinary connections among science, mathematics, technology, and engineering concepts.

12. The findings support the use of structured STEM experiences as one strategy for strengthening competency-based and experiential learning at the primary level.

Educational Implications

The findings have several implications for primary education. First, STEM should be incorporated into classroom planning as an interdisciplinary pedagogical approach rather than being treated solely as an additional technology-oriented programme. Teachers should be supported in designing age-appropriate inquiry, engineering-design, and problem-solving activities that connect curriculum concepts with familiar real-life situations. Second, teacher education and professional development programmes should strengthen teachers' capacity to design and facilitate integrated STEM experiences. Training should emphasize interdisciplinary lesson planning, questioning techniques, collaborative learning, engineering-design processes, assessment of competencies, and effective use of low-cost materials. Third, schools should recognize that effective STEM does not necessarily depend on expensive infrastructure. Simple materials, locally available resources, digital tools, recycled objects, and classroom-based design problems can provide meaningful learning experiences when appropriately structured.

Recommendations

1. **Integrate STEM into Primary Curriculum:** STEM experiences should be systematically incorporated into regular classroom planning through interdisciplinary projects, inquiry activities, and practical problem-solving tasks.

2. **Strengthen Teacher Professional Development:** Teachers should receive continuous professional development focused on STEM pedagogy, engineering design, inquiry-based learning, collaborative learning, and competency-based assessment.

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GJET vol.3, no.2, December 2026
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3. **Promote Low-Cost STEM Activities:** Schools should encourage the use of locally available and inexpensive materials so that meaningful STEM learning is not restricted by limited financial resources.

4. **Develop STEM Learning Spaces:** Schools should gradually develop accessible maker spaces, science corners, digital learning facilities, and flexible activity areas appropriate for primary learners.

5. **Improve Competency-Based Assessment:** Assessment should include observation, project work, presentations, design tasks, reflective activities, and problem-solving performance in addition to conventional tests.

6. **Strengthen Institutional Collaboration:** Schools should collaborate with teacher education institutions, universities, science centres, and educational organizations to obtain professional support and develop innovative STEM activities.

7. **Encourage Collaborative Learning:** STEM tasks should deliberately include group investigation, peer discussion, shared design, and cooperative problem solving to strengthen social and communication competencies.

8. **Develop Context-Sensitive STEM Materials:** STEM resources should be developed according to local curricular requirements, students' age, available infrastructure, and the cultural and environmental context of the school.

CONCLUSION

The present study indicates that integrated STEM learning can provide a meaningful pedagogical environment for developing critical thinking, creativity, collaboration, and problem-solving competencies among primary school students. The findings suggest that STEM is educationally valuable not simply because it introduces science, technology, engineering, and mathematics simultaneously, but because it changes the nature of classroom participation. Learners are encouraged to investigate problems, apply knowledge, communicate ideas, work with peers, test solutions, and learn through revision and experimentation. The findings are consistent with the contemporary movement toward competency-based and experiential education and align with the broader educational objectives emphasized in India's National Education Policy 2020. Recent international research likewise emphasizes interdisciplinary design, inquiry, technology-supported learning, robotics, collaborative investigation, and problem solving as important dimensions of contemporary STEM education.

The practical implication is that primary schools should not view STEM integration solely as an infrastructure-intensive initiative. Meaningful STEM learning can begin with carefully designed classroom problems, locally available materials, collaborative investigation, and guided inquiry. However, sustained implementation requires teacher preparation, curriculum flexibility, appropriate assessment, institutional support, and access to suitable resources. Because the present investigation was limited to selected schools in Pune and employed a quasi-experimental design with some reliance on self-report data, broader

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conclusions should be drawn cautiously. Future research should employ larger and more geographically diverse samples, randomized or stronger quasi-experimental designs, longitudinal follow-up, and multiple forms of assessment. Nevertheless, the study provides useful empirical evidence that structured STEM experiences can contribute to the development of competencies that are increasingly important for learners' academic, social, and future professional lives.

REFERENCES

Bell, S. (2010). Project-based learning for the 21st century: Skills for the future. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas, 83*(2), 39–43.

Bybee, R. W. (2013). *The case for STEM education: Challenges and opportunities*. NSTA Press.

Chen, F., & Chen, G. (2024). Technology-enhanced collaborative inquiry in K–12 classrooms: A systematic review of empirical studies. *Science & Education, 34*, 1731–1773.

English, L. D. (2016). STEM education K–12: Perspectives on integration. *International Journal of STEM Education, 3*, Article 3.

Halawa, S., Lin, T.-C., & Hsu, Y.-S. (2024). Exploring instructional design in K-12 STEM education: A systematic literature review. *International Journal of STEM Education, 11*, Article 43.

Honey, M., Pearson, G., & Schweingruber, H. (Eds.). (2014). *STEM integration in K–12 education: Status, prospects, and an agenda for research*. National Academies Press.

Li, Z., & Oon, P. T. (2024). The transfer effect of computational thinking (CT)-STEM: A systematic literature review and meta-analysis. *International Journal of STEM Education, 11*, 44.

Ministry of Education, Government of India. (2020). *National Education Policy 2020*. Government of India.

National Council of Educational Research and Training. (2020). *Experiential learning: Guidelines and resources*. NCERT.

Partnership for 21st Century Learning. (2015). *P21 framework definitions*. Battelle for Kids.
Sanders, M. (2009). STEM, STEM education, STEMmania. *The Technology Teacher, 68*(4), 20–26.

Sapounidis, T., Tselegkaridis, S., & Stamovlasis, D. (2023). Educational robotics and STEM in primary education: A review and a meta-analysis. *Journal of Research on Technology in Education, 56*(4), 462–476.

Submitted: 7 July 2026
Reviewed: 24 July 2026
Revised: 12 August 2026
Accepted: 13 August 2026

Suna, D., Zhan, Y., Wan, Z. H., Yang, Y., & Looi, C.-K. (2023). Identifying the roles of technology: A systematic review of STEM education in primary and secondary schools from 2015 to 2023. *Research in Science & Technological Education, 43*(1), 145–169.

Thibaut, L., Knipprath, H., Dehaene, W., & Depaepe, F. (2018). Integrated STEM education: A systematic review of instructional practices in secondary education. *European Journal of STEM Education, 3*(1).

Trapero-González, I., Hinojo-Lucena, F. J., Romero-Rodríguez, J.-M., & Martínez-Menéndez, A. (2024). Didactic impact of educational robotics on the development of STEM competence in primary education: A systematic review and meta-analysis. *Frontiers in Education, 9*, 1480908.

Wu, X., Yang, Y., Zhou, X., Xia, Y., et al. (2024). A meta-analysis of interdisciplinary teaching abilities among elementary and secondary school STEM teachers. *International Journal of STEM Education, 11*, 38.

Yesnazar, A., Zhorabekova, A., Kalzhanova, A., Baiymbetova, Z., & Almukhanbet, S. (2024). Methodological system for the formation of meta-subject skills of primary school students in the context of STEM education. *Frontiers in Education, 9*, 1340361.

Zhang, C., & Jia, B. (2024). Enriching STEAM education with visual art: Education benefits, teaching examples, and trends. *Discover Education, 3*, 247.