

Fostering 21st-Century Learning Skills Through STEM Education in the Schools of Specialized Excellence of Delhi: A Comparative Study of Problem-Solving and Digital Literacy

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Article Info

Article type: Research article

Journal: JEPI

Issue: Vol. 1, Issue 1

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Received: 12 April 2026

Accepted: 28 May 2026

Published: 25 June 2026

Keywords: STEM education; Schools of Specialized Excellence; problem-solving; digital literacy; 21st-century skills

DOI:

Abstract

STEM education has increasingly been promoted as a pathway for strengthening 21st-century competencies such as problem-solving, digital literacy, creativity, critical thinking, and collaboration. In Delhi, the Schools of Specialized Excellence (SoSE) were established to provide future-oriented and STEM-rich educational environments expected to move beyond conventional textbook-centered instruction. The present study examined whether this specialized model was associated with stronger student outcomes than those observed in Non-SoSE schools. A descriptive survey design with a quantitative approach was employed. The sample comprised 400 secondary school students from Delhi, with 200 students from SoSE schools and 200 students from Non-SoSE schools. Two self-developed instruments were used: a Problem-Solving Skill Scale and a Digital Literacy Skill Scale, each consisting of 100 items across 10 dimensions. The reported reliability coefficients were .881 for the problem-solving scale and .75 for the digital literacy scale. Comparative analysis indicated no statistically significant difference between SoSE and Non-SoSE students in problem-solving skills, $t(398) = 0.3769$, $p > .05$, or in digital literacy skills, $t(398) = 0.2897$, $p > .05$. The thesis also reported a positive relationship between digital literacy and problem-solving among SoSE students; however, the magnitude of the reported correlation ($r = .009$) was practically negligible. The findings suggest that the promise of specialized STEM schooling in Delhi has not yet translated into clearly superior measurable outcomes on the selected competencies. The study argues that the major challenge lies not in the vision of STEM reform itself but in implementation fidelity, teacher preparation, assessment alignment, and the tension between inquiry-based learning and examination-oriented schooling.

To cite this article: Kumar, A. (2026). Fostering 21st-century learning skills through STEM education in the Schools of Specialized Excellence of Delhi: A comparative study of problem-solving and digital literacy. *Journal of Education, Psychology and Inclusion*, 1(1), 15-20. <https://jepijournal.org/index.php/jepi/index>

1. Introduction

STEM education has emerged as one of the most influential paradigms in contemporary educational reform because it is linked to innovation, interdisciplinarity, critical inquiry, technological fluency, and future-readiness. Rather than treating science, technology, engineering, and mathematics as isolated subject domains, STEM education seeks to integrate them through authentic tasks, real-world problem contexts, and learner-centered pedagogies (Breiner et al., 2012; Bybee, 2010). This shift is particularly important in school systems that are attempting to move away from rote learning and toward competencies that align with the demands of the 21st century.

In the Indian context, STEM education has gained increased visibility as educational institutions and policymakers have recognized the need to promote applied learning, creativity, and digital competence among students. The wider discourse around STEM in India has emphasized not only technological infrastructure but also the need for problem-solving, imagination, innovation, and experiential learning in school education. Such concerns are especially relevant in metropolitan educational settings where institutional reforms are expected to produce visible shifts in learner outcomes.

The Schools of Specialized Excellence (SoSE) in Delhi represent one such reform effort. These schools were created to provide specialized and future-oriented educational pathways, with STEM intended as a key domain for developing advanced competencies. The thesis materials describe SoSE schools as environments characterized by inquiry-driven curriculum design, coding and robotics exposure, digital integration, hands-on learning, project work, and performance-based educational experiences. In principle, such schools should cultivate stronger problem-solving and digital literacy skills than conventional school settings.

However, the establishment of specialized STEM environments does not automatically guarantee stronger educational outcomes. The effectiveness of STEM education depends not only on infrastructure and policy framing but also on classroom enactment, teacher competence, assessment patterns, and the extent to which students meaningfully engage in inquiry and application. This concern is reflected in the literature, which shows that teachers often support STEM in principle but struggle with interdisciplinary implementation, integrated pedagogy, and curriculum pressures (Every et al., 2025; Giffney & Lane, 2025). Likewise, competency-oriented STEM reform requires assessment systems capable of capturing real skills rather than merely rewarding textbook recall (Ng & Adnan, 2024).

Against this background, the present study examines whether SoSE schools in Delhi are actually associated with stronger student outcomes in two core 21st-century competencies: problem-solving and digital literacy. These two constructs were chosen because they represent both cognitive and technological dimensions of contemporary learning, and because they are repeatedly identified in the literature as central to meaningful STEM education (Cortez & Ponsades, 2024; Iwuanyanwu, 2020). The study therefore offers an empirical test of whether the policy promise of specialized STEM schooling is visible in measurable learner outcomes.

2. Review of Literature

The literature on STEM education consistently suggests that integrated and inquiry-based learning is more effective than fragmented subject instruction for fostering higher-order competencies. Bybee (2010) argued that STEM education must be understood as a forward-looking vision in which disciplinary knowledge is linked to authentic problem contexts and societal needs. Breiner et al. (2012) similarly emphasized that STEM is not simply a label for four subjects but a more complex educational orientation involving integration, collaboration, and partnerships.

A substantial body of literature has also highlighted the importance of pedagogy in STEM implementation. Ertmer (2006) noted that problem-based learning and inquiry-oriented classrooms depend heavily on teacher support, planning, and institutional conditions. Every et al. (2025) reported that mathematics teachers viewed STEM-oriented teaching strategies favorably, especially when linked to real-world problem solving and collaboration, yet such preferences did not always translate into ordinary classroom practice. Giffney and Lane (2025) likewise found that teachers' understandings of integrated STEM were often inconsistent and constrained by curriculum demands, test pressures, and low confidence.

Teacher development has emerged as another critical factor. Erol and İvrendi (2024) found that participation in a STEM professional development program positively influenced teachers' attitudes, self-efficacy, and instructional beliefs regarding STEM. Sardana et al. (2024) similarly highlighted persistent challenges in STEM teacher training in India and argued that professional preparation remains one of the most important barriers to successful implementation.

The literature on student outcomes further suggests that STEM reform should be evaluated through competencies such as problem-solving, digital literacy, and broader 21st-century skills rather than through narrow curriculum coverage. Iwuanyanwu (2020) emphasized that problem-solving is a defining capability for 21st-century STEM learners because it involves reasoning, adaptability, decision-making, and the ability to respond to complex and unfamiliar situations. Digital literacy has likewise become central to contemporary educational functioning because it includes not only technical access but also information evaluation, digital communication, ethical use, collaboration, and digital problem-solving (Fraillon et al., 2020; Elamurugan & Renugadevi, 2023).

At the intersection of these constructs, Cortez and Ponsades (2024) explored the relationship among digital literacy, 21st-century skills, and performance, while Ng and Adnan (2024) underscored the urgent need for competency-based assessment approaches in STEM education. Together, these studies suggest that specialized STEM schooling should ideally be associated with stronger performance on problem-solving and digital literacy indicators. The present study contributes to this literature by examining whether such an advantage is visible in the Delhi SoSE context.

3. Objectives of the Study

The study was guided by the following objectives:

1. To compare the problem-solving skills of students in SoSE and Non-SoSE schools in Delhi.
2. To compare the digital literacy skills of students in SoSE and Non-SoSE schools in Delhi.
3. To examine the relationship between digital literacy skills and problem-solving skills among students in SoSE schools in Delhi.
4. To interpret the quantitative findings in light of stakeholder perspectives on STEM education.

4. Hypotheses

H01: There is no significant difference in the problem-solving skills of students in SoSE and Non-SoSE schools in Delhi.

H02: There is no significant difference in the digital literacy skills of students in SoSE and Non-SoSE schools in Delhi.

H03: There is no significant relationship between digital literacy skills and problem-solving skills among students in SoSE schools in Delhi.

5. Method

5.1 Research Design

The study employed a descriptive survey design with a quantitative approach. This design was considered appropriate because the investigation focused on describing existing conditions, comparing groups, and examining relationships among variables without manipulating them experimentally. The responses were collected through self-developed Likert-type scales measuring problem-solving and digital literacy in relation to STEM education.

5.2 Participants and Sampling

The sample consisted of 400 secondary school students from Delhi. The comparison groups included 200 students from SoSE schools and 200 students from Non-SoSE schools. The methodology chapter describes the use of a multi-stage sampling procedure, including stratified random sampling for selecting STEM-equipped schools and purposive sampling for selecting the student respondents. The study was delimited to the Delhi context and to school-level investigation.

5.3 Instruments

Two self-developed instruments were used in the study.

The Problem-Solving Skill Scale consisted of 100 items and covered 10 dimensions: critical thinking, creativity, decision-making ability, adaptability, collaboration, persistence, use of resources, emotional regulation, information gathering, and risk management. The scale was developed through literature review, expert consultation, item analysis, and reliability estimation. The reported reliability coefficient was .881, and the tool was described as having high content and face validity.

The Digital Literacy Skill Scale also consisted of 100 items distributed across 10 dimensions: technical proficiency, information literacy, digital communication, online safety and security, content creation and curation, digital problem-solving, digital ethics and responsibility, digital learning and self-development, critical thinking in digital contexts, and digital collaboration and teamwork. The reported reliability coefficient for this scale was .75, and the tool was similarly described as possessing content and face validity.

5.4 Procedure and Data Analysis

Data were collected personally by the researcher from the participating schools after obtaining institutional permission. The final data collection process extended over approximately four months, from November 2023 to February 2024. The statistical techniques used for analysis included mean, standard deviation, t test, and correlation coefficient. SPSS 20.0 and spreadsheet-based tabulation were used in the analysis process.

6. Results

Table 1
Comparison of Problem-Solving Skills Between SoSE and Non-SoSE Students

Group	n	M	SD	df	t	p
SoSE	200	198.84	24.48	398	0.3769	> .05
Non-SoSE	200	199.76	24.07			

Note. The reported *t* value was not significant at the .05 and .01 levels.

The findings revealed no statistically significant difference between SoSE and Non-SoSE students in problem-solving skills. Although SoSE schools are intended to promote inquiry, practical application, and interdisciplinary engagement, their students did not obtain higher scores than students from Non-SoSE schools on the problem-solving measure. The null hypothesis was therefore retained.

Table 2
Comparison of Digital Literacy Skills Between SoSE and Non-SoSE Students

Group	n	M	SD	df	t	p
SoSE	200	203.50	27.32	398	0.2897	> .05
Non-SoSE	200	202.71	27.22			

Note. The reported t value was not significant at the .05 and .01 levels.

A similar pattern was found for digital literacy. The SoSE group showed a slightly higher mean, but the difference was not statistically significant. This indicates that access to specialized STEM-oriented schooling did not yield a measurable digital literacy advantage over Non-SoSE schooling within the present sample. The null hypothesis was again retained.

Table 3
Reported Correlation Between Digital Literacy and Problem-Solving in SoSE Students

Variables	n	r	Reported significance
Digital literacy and problem-solving	200	.009	$p < .01$

Note. The thesis reports the relationship as statistically significant; however, the effect size is practically negligible and should be interpreted with caution.

The thesis reports a positive correlation between digital literacy and problem-solving among SoSE students. However, the magnitude of the reported coefficient is extremely weak. For journal interpretation, the more appropriate conclusion is that the association, even if statistically flagged in the thesis, was trivial in practical terms and does not support a meaningful educational relationship between the two constructs as measured in this study.

7. Discussion

The most important finding of the study is that SoSE students did not significantly outperform their Non-SoSE counterparts on either problem-solving or digital literacy. This is especially important because SoSE schools are publicly positioned as future-ready educational spaces intended to cultivate stronger 21st-century skills through STEM-based learning. The absence of a measurable advantage suggests that specialized institutional design, by itself, does not guarantee stronger learner outcomes.

This finding aligns with literature showing that STEM reform often remains stronger at the level of policy aspiration than at the level of pedagogical enactment. [Every et al. \(2025\)](#) and [Giffney and Lane \(2025\)](#) both suggested that teachers may appreciate STEM-oriented methods in theory while facing substantial barriers in practice. The Delhi findings appear to reflect a similar pattern. The thesis materials indicate that SoSE schools offer modern infrastructure, performance-based aspirations, coding and robotics exposure, and interdisciplinary intent. Yet these institutional features do not appear to have translated into significantly stronger problem-solving or digital literacy scores.

The explanation likely lies in implementation fidelity. The broader thesis conclusion repeatedly emphasizes the role of teacher preparation, protected planning time, assessment design, and system-level coherence. The conclusion materials also suggest that professional development, local problem-based tasks, performance assessments, mentorship, and accountability structures are necessary for STEM schooling to move from symbolic reform to substantive transformation.

The near-zero relationship between digital literacy and problem-solving further strengthens this interpretation. In principle, digitally literate students in a strong STEM environment should be better positioned to investigate problems, collaborate, evaluate information, and produce solutions. However, the reported correlation was negligible. This suggests that digital literacy, as experienced in the current school environment, may remain disconnected from authentic inquiry-based and problem-based learning. Technology may be present, but not yet functioning as a deep cognitive support for higher-order STEM performance.

At the same time, the findings should not be read as a rejection of STEM education. Rather, they should be interpreted as evidence that the specialized STEM model in Delhi remains incomplete in its classroom realization. The challenge is therefore not to abandon STEM reform, but to strengthen the pedagogic, professional, and assessment structures through which STEM is actually enacted.

8. Educational Implications

The findings of the study suggest that STEM should be approached as a pedagogical culture rather than merely as a resource-rich institutional label. If SoSE schools are to deliver on their stated vision, the focus must move toward implementation quality. Professional development should be sustained and practice-based, not occasional or symbolic. Teachers need structured support in curriculum integration, design thinking, inquiry, and authentic assessment. Schools also require timetable flexibility, stronger interdisciplinary collaboration, and evaluation systems that reward performance tasks, portfolios, and application-oriented learning rather than only conventional tests.

The study also implies that digital literacy must be embedded more meaningfully into learning tasks. Mere exposure to devices or digital platforms is insufficient. Students need structured opportunities to use technology for investigation, critique, design, communication, and collaborative problem-solving. Without such integration, digital literacy may remain an isolated skill rather than a functional dimension of STEM competence.

Finally, the parity between SoSE and Non-SoSE performance indicates that broader system-level reform is necessary. If the SoSE model is to become a genuine engine of educational transformation, it must be supported by transparent outcome monitoring, resource maintenance, pedagogical coaching, and a stronger bridge between inquiry-driven learning and exam-oriented expectations.

9. Conclusion

The present study examined whether Delhi's Schools of Specialized Excellence are associated with stronger problem-solving and digital literacy outcomes than Non-SoSE schools. Based on the findings, the answer is not yet in the affirmative. No statistically significant differences were found between the two groups on either of the selected competencies, and the reported relationship between digital literacy and problem-solving among SoSE students was negligible in practical terms.

The study therefore contributes an important caution to the discourse on STEM reform. Specialized infrastructure, modern curricular vision, and institutional branding are not enough to ensure measurable learner gains. What matters most is whether STEM principles are translated into classroom practice through teacher preparation, coherent pedagogy, meaningful assessment, and authentic student engagement.

The SoSE model in Delhi remains promising, but its promise has not yet been fully realized in demonstrable student outcomes on the variables studied here. The path forward lies in moving from policy symbolism to pedagogical substance.

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