Empowering 21st Century Teaching: Tpack Analysis of CBSE Elementary Teachers for Capacity Development and Quality Education

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Abstract:

This study examines the Technological Pedagogical Content Knowledge (TPACK) of elementary school teachers through detailed analysis of lesson plans and classroom demonstrations. Prior to data collection, the researcher conducted a targeted TPACK training program, during which participating teachers designed TPACK-based lesson plans and presented them online for collaborative discussion and feedback. These plans were later refined and implemented in classrooms for evaluation. Data were gathered from a total of 30 in-service Central Board of Secondary Education (CBSE) teachers across core subjects—English, Mathematics, Science, and Social Science—using a qualitative approach. Findings reveal that (i) some lesson plans frequently lacked full integration of technology with pedagogy even after initial training, and (ii) essential 21st-century competencies remained underrepresented. These results highlight the need for sustained professional development aligned with Sustainable Development Goal 4 (Quality Education). The conference's broader agenda of capacity development, networking, expos, school visits, and recognition through awards underscores the global significance of integrating TPACK into teacher education to raise the quality of learning worldwide.

Keywords: *TPACK Framework, Lesson Planning, Elementary School Teachers, 21st-Century Teaching Skills, SDG 4, Quality Education 2025.*

1. Introduction:

The rapid advancement of technology, globalization, and shifting job markets have compelled education systems to evolve—preparing learners not only with content knowledge but also with essential 21st-century skills such as critical thinking, creativity, collaboration, digital literacy, and lifelong learning. In India, the pursuit of Quality Education under Sustainable Development Goal 4 (SDG 4) underscores the need to empower teachers to integrate technology meaningfully with pedagogy and content (United Nations, 2015). Globally, education systems are transitioning towards a knowledge-based economy where creativity,

critical thinking, collaboration, and digital literacy are as vital as subject mastery. India's commitment to SDG 4 calls upon teachers to act as catalysts in fostering these competencies. The Central Board of Secondary Education (CBSE), one of India's largest school systems, reinforces this vision through the National Education Policy (NEP) 2020, which advocates for the adoption of technology-enhanced pedagogies (Government of India, 2020).

At the heart of this integration lies the Technological Pedagogical Content Knowledge (TPACK) framework, which posits that teachers require not only content knowledge (CK) and pedagogical knowledge (PK), but also technological knowledge (TK)—along with the crucial intersections of these domains: pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), and the unified TPACK (Mishra & Koehler, 2006). The TPACK framework provides a powerful foundation for achieving such integration. Extending Shulman's (1986) concept of Pedagogical Content Knowledge, TPACK incorporates technological knowledge and highlights the interplay among TK, PK, and CK. Teachers who effectively master these intersections—particularly the integrated TPACK "sweet spot"—are better equipped to design learning experiences that leverage technology to deepen understanding rather than simply digitize traditional methods.

Despite supportive policy frameworks, empirical research indicates persistent challenges in Indian classrooms. Teachers often demonstrate strong content knowledge but limited ability to integrate technology effectively into their teaching (Byker, 2014; Srivastava & Sharma, 2023). This study examines the impact of a structured TPACK-based training programme in enhancing CBSE elementary teachers' ability to integrate technology with pedagogy and content. Specifically, it investigates the extent to which these teachers demonstrate TPACK in their lesson planning and classroom practices after training, and how effectively 21st-century skills are reflected in their instructional approaches. The findings aim to inform future teacher capacity-building initiatives aligned with the goals of quality and technology-integrated education.

2. Literature Review:

2.1 TPACK Framework:

Mishra and Koehler (2006) argue that effective technology integration requires understanding not only the discrete domains of content (CK), pedagogy (PK), and technology (TK), but also their intersections: PCK, TCK, TPK, and TPACK. Research consistently shows that professional development (PD) aligned to TPACK enhances teachers' confidence and competence (Deshmukh &Shrouty, 2022).

2.2 Professional Development and Indian Context:

In India, online and blended PD models have improved teacher readiness for technology integration. Charania et al. (2024) report that teacher characteristics—such as prior digital experience and school support—strongly influence outcomes in Assam's statewide TPACK PD. Yet large-scale programmes face scaling challenges, including follow-up and contextualisation (Scardamalia et al., 2022).

2.3 21st-Century Skills and SDG 4:

Twenty-first-century skills encompass communication, critical thinking, collaboration, creativity, and digital citizenship (P21, 2019). Indian surveys show that fewer than half of young people are even familiar with the term (GRAAM, 2022), while teachers themselves often equate "digital skills" with basic operations rather than higher-order competencies (ASER/SAIS, 2021). Aligning classroom practice to SDG 4 therefore requires targeted teacher capacity building.

2.4 Persistent Gaps:

Studies across Indian states highlight similar patterns: strong CK and PK but weaker TK and limited integration (Byker, 2014; Srivastava & Sharma, 2023). Even after training, teachers may revert to traditional methods due to assessment pressures, time constraints, or inadequate infrastructure (India Today, 2024). Validated measurement tools such as the AI-TPACK scale (QT Analytics, 2024) now enable more nuanced analysis of these gaps.

3. Research Questions:

This study is guided by the following questions:

1. To what extent do CBSE elementary teachers demonstrate TPACK in their lesson plans and classroom demonstrations after participation in a targeted TPACK training programme?

2. Which components of TPACK are well-represented, and which remain underdeveloped (particularly in integrating technology with pedagogy and content)?

3. How are 21st-century skills reflected in the lesson plans and demonstrations?

4. What are the challenges teachers perceive in integrating TPACK-based practices, and what supports do they need for capacity development?

4. Methodology:

4.1 Research Design:

A qualitative approach was adopted, combining document analysis (lesson plans), classroom observations (or demonstrations), and focus group discussions with teacher participants. This design enables in-depth understanding of how teachers function in real classroom contexts, and how their TPACK manifests.

4.2 Participants:

A total of 30 in-service CBSE elementary school teachers from a private/affiliated CBSE school in Ulwe, Navi Mumbai. The sample included teachers of English, Mathematics, Science, and Social Science, varying in years of experience (e.g., 2-15 years), gender, and prior exposure to ICT.

4.3 Intervention:

A training programme on TPACK was conducted over several sessions. Teachers were introduced to the TPACK framework, engaged in lesson plan design tasks focusing on integrating technology, pedagogy, and content. They submitted initial lesson plans, participated in online collaborative discussions for feedback, refined the plans, and then

implemented them in their classrooms. Demonstrations (actual classes or mock classes) were observed (or video recorded), and data collected.

4.3.1   TPACK Training Module:

As part of the TPACK-based teacher training program, a structured training session titled *"Introduction to the TPACK Module and Lesson Plan Presentation"* was conducted by the researcher and an expert to help teachers effectively integrate technology into their classroom practices. A total of 30 teachers participated in this phase. The first session provided an orientation to the TPACK framework, followed by a hands-on training session focused on lesson plan development using the TPACK approach. During the training, teachers gained practical insights into designing lesson plans that integrate technological, pedagogical, and content knowledge. Subsequently, teachers prepared their own lesson plans, drawing on the sample lesson plan demonstrated during the program. Ample time was allotted for this task, allowing teachers to effectively apply and blend the TPACK components in their lesson planning.

A training programme based on the Technological Pedagogical Content Knowledge (TPACK) framework for teachers was conducted. This programme was designed using the IDDIRR model (Introduce, Demonstrate, Develop, Implement, Reflect, and Revise) developed by Chia-Jung Lee and Chan Min Kim.

The lesson plan framework was based on the TPACK lesson planning models proposed by Mishra and Koehler, and further elaborated by Angeli and Valanides, as well as Mark Hofer and Judi Harris. The researcher combined, modified, and adapted these models to suit the teacher education context in the Indian scenario.

The TPACK Instructional Module was grounded in the *learning-by-design* approach for the development of TPACK among teachers. It synthesized guiding prompts to activate relevant knowledge and resources to support teachers in framing their designs and facilitating informed design decisions (Angeli &Valanides, 2009; Koh et al., 2015; Kramarski& Michalsky, 2010; Mishra & Koehler, 2006).
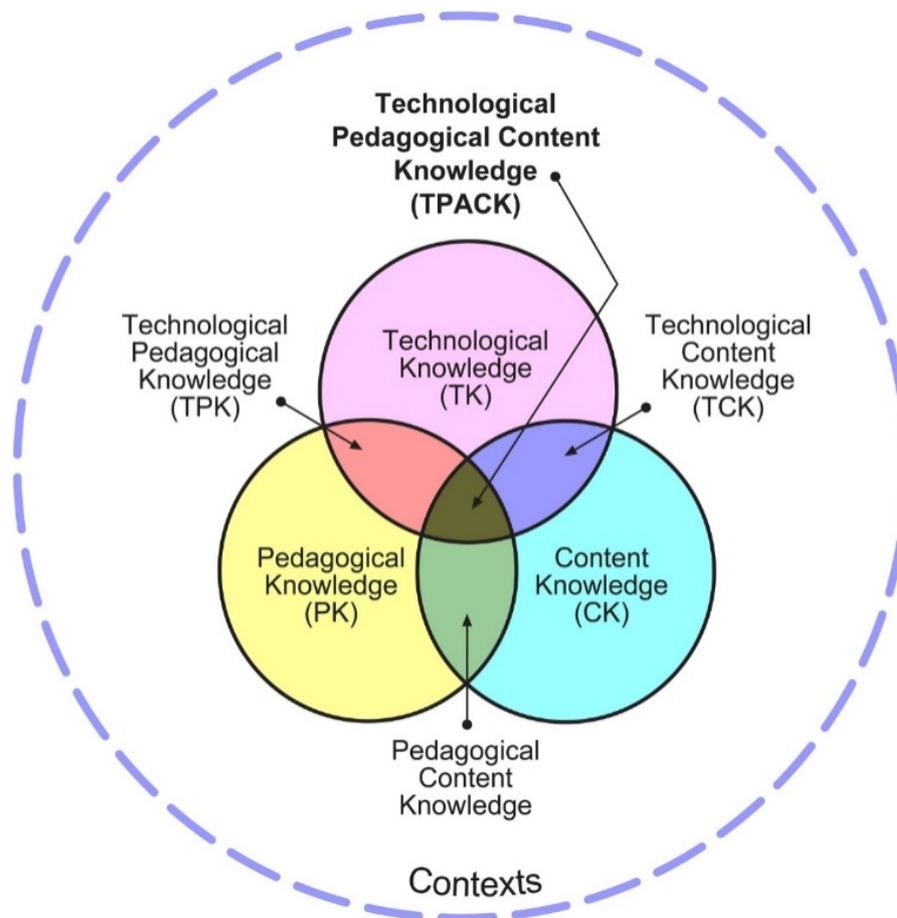

Fig 1 : The TPACK Framework

The TPACK module was designed and implemented in three phases:

a. **Exploratory Phase:** In this phase, the researchers explored the current status of TPACK among school-level teachers.

b. **Intervention Phase:** This phase involved the design and implementation of the TPACK-based training programme. The training was developed as a professional development module for teachers of all subjects from pre-primary to secondary levels following the CBSE syllabus. The module, grounded in the *learning-by-design* approach, aimed to enhance teachers' integration of technology, pedagogy, and content knowledge in their instructional practices. The IDDIRR model served as the guiding framework, providing a practical structure and sequential procedures for effective teacher training.

c. **Evaluation Phase:** This phase focused on reflecting upon and revising the training outcomes based on feedback and teacher performance.

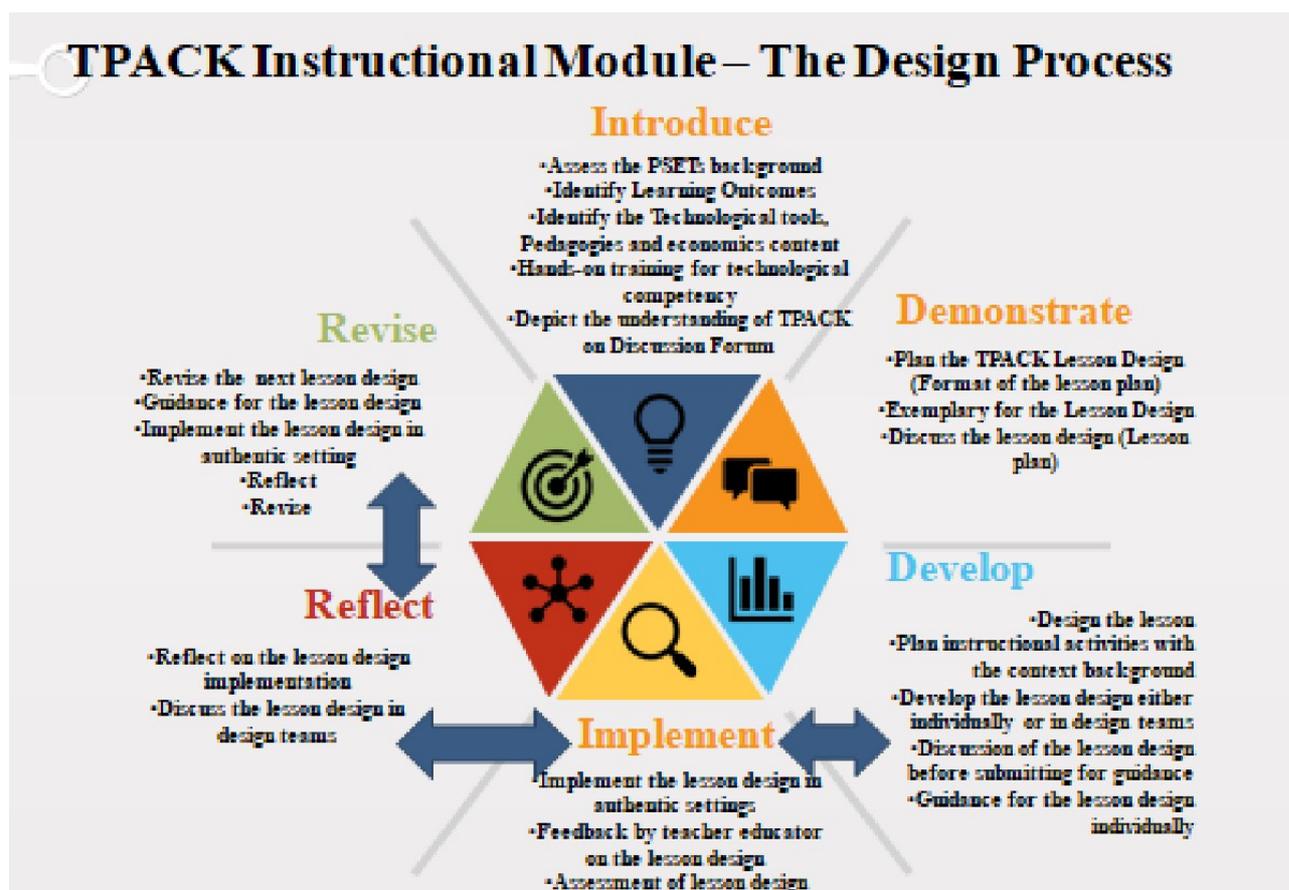The following figure illustrates the TPACK instructional model.

Fig 2 :TPACK Instructional Module- The Design Process

The lesson plan was developed with Reference to Mishra and Koehler's TPACK-based lesson planning model, along with the suggestions provided by Angeli and Valanides, and Mark Hofer and Judi Harris. The researcher combined, modified, and adapted these frameworks to suit the teacher education context within the Indian scenario. The integrated framework guided teachers through the following steps:

- Planning specific lessons for school students using learning activity types appropriate for knowledge building;

- Choosing clear and measurable learning goals;

- Making pedagogical decisions about the nature of learning experiences based on the selected activity types;

- Selecting and sequencing suitable activity types to promote knowledge construction, particularly in Science and Mathematics for elementary students; and

- Identifying summative assessment strategies that effectively reveal what and how well students have learned.

Teachers initially prepared draft lesson plans, participated in online collaborative discussions to receive feedback, refined their plans accordingly, and subsequently implemented them in their classrooms.

Demonstrations—either through actual or mock teaching sessions—were observed or video recorded, and relevant data were collected for analysis.

4.3.2 Lesson Plan Presentation and Feedback Session:

Implementation Process:

a. Presentation of Lesson Plans:

Teachers presented their TPACK-based lesson plans through both offline and online modes. Each presentation highlighted key components such as lesson objectives, learning outcomes, integration of technology, pedagogical strategies, content delivery methods, and assessment techniques.

b. Feedback and Suggestions:

Constructive feedback was provided by the researcher and peers using structured criteria that assessed clarity, innovation, appropriateness of technological tools, and engagement strategies. Teachers were encouraged to reflect on the feedback, make necessary revisions, and enhance the overall quality of their lesson plans.

c. Revision and Resubmission:

Based on the feedback received, teachers revised and resubmitted their lesson plans for final review. This iterative process significantly improved the quality, coherence, and practicality of the plans. The second drafts demonstrated a stronger and more balanced integration of TPACK components compared to the initial versions.

d. Classroom Implementation:

The revised lesson plans were implemented in actual classroom settings. The researcher planned and conducted classroom observations, recording the sessions to evaluate how effectively teachers applied TPACK principles during instruction.

Outcomes:

- Increased teacher confidence in integrating technology into daily lessons.

- Improved alignment between pedagogy and digital tools.

- Enhanced collaboration and reflective teaching practices among teachers.

- Valuable qualitative data collected for research analysis through classroom observations.

4.3.3 Lesson Plan Observation, Presentation and Feedback Session:

Following the presentation and feedback phase of the TPACK-based teacher training program, teachers were asked to implement their revised lesson plans in their respective classrooms. The implementation phase was observed systematically to assess the extent to which teachers integrated Technological, Pedagogical, and Content Knowledge (TPACK) components in real classroom contexts.

Focus of Observations:

The rubric served as a structured tool for observation and data collection, ensuring consistency and objectivity in evaluating each teacher's performance. A detailed observation rubric was developed to guide the assessment of lesson implementation. The rubric focused on the following dimensions:

1. Integration of TPACK Components – Effective balance between technology, pedagogy, and content.

2. Appropriate Use of Technology – Relevance, accessibility, and meaningful application of digital tools.

3. Pedagogical Strategies – Appropriateness of instructional methods used to facilitate learning.

4. Student Engagement – Level of learner participation, collaboration, and involvement in activities.

5. Assessment Strategies – Use of formative and summative assessment aligned with lesson objectives.

6. Classroom Management – Teacher's ability to maintain flow, discipline, and student focus during technology use.

4.4 Data Collection Instruments:

● Lesson plan analysis rubric based on TPACK components (CK, PK, TK, PCK, TCK, TPK, TPACK) and presence of 21st century skills (communication, critical thinking etc.)

● Classroom observation/demonstration checklist

● Interview / focus group protocol to elicit teacher perceptions, challenges, and support.

Rubric as an Observation Tool:

The use of a rubric as an observation instrument proved to be effective in collecting structured and quantifiable data. It facilitated systematic analysis of teacher performance, allowing the researcher to identify individual strengths and areas for improvement. The rubric also served as a reflective guide for teachers, enabling them to self-assess and refine their instructional practices.

Following rubric was followed to access the TPACK lesson observations:

Table 1: TPACK Lesson Observation Rubrics (Maths/Science/Social/Languages/Music/P.E/P.A)

Category	Excellent (5)	Good (3)	Developing (2)	Needs Improvement (1)
Content Knowledge (CK)	Demonstrates strong subject knowledge; Explains concepts clearly with real life examples.	Covers content well but may lack real-life connections.	Some content inaccuracies ; limited explanation	Lacks understanding of the subject; multiple inaccuracies
Pedagogical Knowledge (PK)	Uses child friendly teaching strategies (stories, activities, discussions) with effective classroom management	Uses appropriate methods but may lack engagement strategies	Limited strategies with minimal student involvement	Ineffective teaching methods with disengaged students
Technological Knowledge (TK)	Uses age appropriate technology tools (videos, interactive games, simulations) to enhance learning	Uses technology effectively but not interactively	Technology is used but does not engage student actively	Technology is absent or used in a way that does not support learning

Technological pedagogical knowledge (TPK)	Technology is used to enhance student-centred learning (e.g Collaborative tasks, interactive quizzes)	Technology Supports pedagogy but could be more interactive	Technology is used passively or teacher-centred	No meaningful technology integration with pedagogy
Technological content knowledge (TCK)	Technology is used to clarify concepts(e.g math manipulatives, map timelines, animation)	Technology supports content but is not fully optimized	Technology is present but does not add much value to content	No meaningful connection between technology and content
Technological pedagogical content knowledge (TPACK)	Technology pedagogy and content are seamlessly integrated for engaging hands on lesson	Integration is effective but could be optimized further	Some elements are integrated, but the connection is weak.	No meaningful integration of technology, pedagogy and content Knowledge
Student engagement and integration	Students actively participate, collaborate and demonstrate curiosity using technology	Most of the students engage, but some remain passive	Limited engagement; students struggle to interact	Students are disengaged or confused by the lesson plan
Assessment and feedback	Uses quizzes, games, or other tools for assessment and gives constructive feedback	Some assessment methods are used but feedback is minimal	Basic assessments with little feedback	No assessment or feedback

Scoring Interpretation:

a.   32-40: Excellent TPACK integration

b.   28–32: Outstanding TPACK integration

c.   22–27: Good integration with minor gaps

d.   15–21: Developing; needs improvement in some areas

e.   Below 15: Weak TPACK integration; requires major revisions.

4.5 Data Analysis

The lesson plans were coded qualitatively per rubric. Observations were analysed for evidence of actual implementation. Interviews were transcribed and thematically analysed to identify emergent themes regarding challenges and needed support.

Table 2: Rubric score

Teacher	Subject with class and topic	CK	PK	TK	TPK	TCK	TPACK	Technology/ app/tools/ platform	Student engagement and integration	Assessment and feed back	Total Score
1	Sub: Physics Class 9 Topc: Work and Energy	5	5	5	5	5	3		3	5	33
2	Sub: Math Class 6 Topic: Perimeter	5	5	5	5	5	5	YouTube video, Toy theater	5	5	40
3	Sub: Math class : 4 Topic: Carts and Wheels	3	3	3	3	5	3	Smart board, Tata class edge,	3	3	26
4	Sub: Maths, Class 2 Topic : Rani 's Gift	5	5	5	5	5	5	Tata classed gee content, hands on activities	5	2	37
5	Sub: Hindi Class 5 Topic: Guru bhakt Kali bai	5	5	5	3	5	3	You tube video, work sheet	3	5	34
6	: 3	5	5	3	3	3	3	You tube video	3	3	28
7	sub: English Class 5 Topic: Active voice and Passive voice	2	2	2	2	2	3	online e PPT	2	5	18
8	Sub: SST Topic: Early Man class : 5	3	2	2	2	3	3	PPT, Video	2	3	20
9	Sub: Maths Topic: Rani 's Gift Class : 2	5	5	5	5	5	5	Tata Class edge	5	5	40
10	Sub: Maths Topic: Carts and wheels	5	3	3	3	5	3	Tata Class edge	3	3	28
11	Sub: SST Topic: Media Class 7	5	5	5	5	3	5	You tube, google chrome, recording	3	3	34
12	Sub: Maths Topic: Can you see the patterns Class :5	2	2	2	2	3	2	You tube video, work sheets	2	3	18

#	Description							Tools			Total
13	Sub: EVS Topic: Air around us Class : 2	5	3	5	3	3	3	You tube video, Hands on activities	5	5	32
14	Sub: Mara thi Topic: Vachan Class : 4	3	3	3	3	5	3	You tube, Online quiz	3	5	28
15	Sub: Hindi Topic: Safaiki Seek H Class : 3	5	5	5	5	5	3	Video, Quiz z	5	3	36
16	Sub: science Topic: Water Class : 3	2	3	5	3	2	3	You tube videos	3	3	24
17	Sub: Eng Topic: Verb Agreement Class 7	5	5	5	5	5	5	PPT, you tube, online game base d quiz	5	5	40
18	Sub: Hindi Topic: Su dhama Char it Class 8	5	3	2	2	3	3	You tube vide o	3	5	26
19	Sub: Mara thi Topic: Vach anache Ved Class : 8	5	5	5	5	5	3	game base d vide o	3	5	36
20	Mara thi Topic: Gurubhakt Kali bai Class :5	5	5	5	3	5	3	You tube vide o to show story, Quick assessment on the screen	3	5	34
21	Sub: English Topic: Action word Class: Sr.kg	3	5	5	3	5	3	videos on action word s	3	3	30
22	Sub: English Topic: 'M' Class : Nur	5	5	5	3	3	3	vide o, puppets	3	3	30
23	Sub: EVS Topic : Colours Class Jrkg	5	5	5	3	2	3	Interactive Pane	3	5	31
24	sub: Math s Topic: Or dinalnos Class: Sr.kg	3	3	2	3	2	2	videos	3	2	22
25	Sub: EVS Topic: wild animals Class: Sr.kg	5	5	3	3	3	3	videos	5	5	32
26	Sub: Computer Topi c: Inter net Class 7	5	5	5	5	5	3	Google, YouTube videos	5	3	36

27	Sub: PE Topi c: Ches s Class :6	3	3	3	3	3	3	yout ube video	3	3	24
28	Sub: ART and Craft Topi c: Mem ory draw ing Class : 3	5	5	5	5	3	3	You tube video	3	3	27
29	Sub: Eng Topi c: Adje ctive s Class : 3	3	5	3	3	5	5	yout ube vidos	3	3	30
30	Sub: Musi c Topi c: Basi c Sarg ams and Alan kars Class : 2		5	5	5	5	5	vide os, instruments	3	3	36

5. Findings:

The lesson plan observation phase provided valuable insights into teachers' evolving capacity to integrate technology meaningfully into their teaching. The rubric-based observation method, coupled with learner reflections, offered a comprehensive view of classroom dynamics under TPACK implementation. Overall, the findings suggest that teachers demonstrated growing proficiency in using technology to enhance pedagogy and content delivery, resulting in more interactive and learner-centered classrooms.

Classroom Observations:

Classroom observations revealed varied learner responses:

- In several classes, students were actively engaged, especially where teachers provided hands-on, interactive learning experiences using digital tools.

- In some instances, learners appeared passive, mainly when technology use was limited to teacher presentations rather than student participation.

- A few teachers were found to be struggling to integrate all three TPACK components cohesively, emphasizing the need for continued mentoring and practice.

The observations highlighted that effective integration occurred when teachers maintained a balance among technology, pedagogy, and content while ensuring active learner involvement.

Based on the rubric scores, it was observed that most teachers scored between 22 and 25, indicating a competent level of performance in technology integration. The data suggested that the majority of participants were able to apply TPACK principles effectively in their classroom instruction.

- Technology Use: Most teachers selected tools suitable to their content areas and used them to enhance conceptual clarity.

- Pedagogical Application: Teachers demonstrated understanding of learner-centered methods, although some required further refinement in integrating pedagogy with technology.

- Content Delivery: Content knowledge was generally strong, but in a few cases, overemphasis on technology diluted the pedagogical focus.

Teachers' Reflections and Responses:

Learner reflections gathered during and after the lessons indicated positive attitudes toward technology-supported learning. Students reported enjoying interactive and experiential activities, particularly those involving multimedia, simulations, and collaborative tools. Such responses demonstrated increased engagement and motivation, confirming that TPACK-based lesson implementation fosters active learning and enhances classroom participation.

Discussion on Scores:

The overall score distribution suggested a moderate to high level of competency among participating teachers. While most teachers performed within the 22–25 range, the variation in scores pointed to differences in comfort levels and prior experience with technology. This variation underscores the importance of ongoing professional development, mentoring, and reflective practice to ensure consistent and sustainable integration of TPACK principles across all classrooms.

5.1 Extent of TPACK after Training:

- Many teachers show strong content knowledge (CK) and pedagogical knowledge (PK). They plan lessons that are accurate in content and use appropriate pedagogical strategies (e.g., group work, questioning, differentiation).

- Technological knowledge (TK) is present but more superficial: use of PowerPoint, Google Slides, basic digital tools are common. More advanced or subject-specific technologies (e.g., simulations, interactive apps) less so.

- When integrating technology with pedagogy and content (the intersections TPK, TCK, PCK, and full TPACK), gaps are noticeable. Some lesson plans incorporate technology merely as a presentation tool (e.g., slideshow) rather than as an integrative tool to enable student inquiry, collaboration, or formative feedback.

5.2 Representation of 21st-Century Skills

- Some inclusion of communication and collaboration; peer work, digital sharing of work.

- Critical thinking, creativity less evident; few tasks require students to design, evaluate, produce original work or use technology for problem solving.

- Digital literacy is evident but often limited to basic operations.

- Global citizenship, ethics or citizenship education rarely appear.

5.3 Challenges Identified:

Teachers reported several obstacles:

- Limited access to reliable technology infrastructure (computers/tablets, internet connectivity) in classrooms and at home.

- Time constraints: preparing TPACK-based lessons takes extra time; workload is high.

- Lack of continuous support or follow-up after training; sometimes reverting to traditional methods.

- Some teachers feel low confidence with certain technologies or uncertain about pedagogical strategies to integrate them.

- Assessment mechanisms that reward rote learning discourage creative / technology-integrated pedagogies.

5.4 Supports Needed:

- Regular / sustained professional development (not one-off workshops) with mentoring, peer observation, feedback.

- Access to resources: hardware, software, connectivity.

- Institutional support: school leadership encouraging innovation, allowing flexibility in lesson plans, adjusting time schedules.

- Community / peer networks for exchange of best practices.

6. Discussion:

The findings align with the existing literature: while CBSE elementary teachers display strong CK and PK, their TK and especially integrative TPACK components are less consistently present. This is similar to findings in Tamil-medium schools (Jaffna) where technological integration lagged behind. (RSIS International) And in the Assam study, teacher characteristics (prior experience, comfort with technology) affected how well TPACK-based PD translated into classroom practice. (Science Direct)

The under-representation of 21st-century skills like critical thinking, creativity, global citizenship indicates that while policy aims (SDG4) emphasise these, on ground lesson designs and teacher practices still fall back on traditional content delivery.

This suggests that capacity development for teachers needs to go beyond technical training to include deeper pedagogical change: shifting teacher beliefs about learning, assessment, and the role of technology. It also means that school systems need to offer structural support: time, access, leadership support, and feedback cycles.

This study was guided by the following questions:

RQ1: To what extent do CBSE elementary teachers demonstrate TPACK in their lesson plans and classroom demonstrations after participation in a targeted TPACK training programme?

Before the introduction of the TPACK module, teachers were largely unaware of its framework. Although they were using technology in their classrooms, it was not effectively integrated with content and pedagogy. After the training sessions, teachers began identifying appropriate ways and stages to integrate technology meaningfully into their lessons. However, some teachers still face challenges in implementing the TPACK model due to limited technological proficiency.

RQ2: Which components of TPACK are well-represented, and which remain underdeveloped (particularly in integrating technology with pedagogy and content)?

Most teachers demonstrated strong Content Knowledge (CK), Pedagogical Knowledge (PK), and Technological Knowledge (TK). However, the components involving integration — particularly Technological Pedagogical Knowledge (TPK), Technological Content Knowledge (TCK), and the overall Technological Pedagogical Content Knowledge (TPACK)

— remained underdeveloped. This indicates that while teachers possess individual strengths in each domain, they still need support in effectively blending technology with pedagogy and content to enhance teaching and learning outcomes.

RQ3: How are 21st-century skills reflected in the lesson plans and demonstrations?

Most of the teachers' lesson plans and demonstrations showed limited incorporation of the 3 Cs of 21st-century skills — Critical Thinking, Creativity, and Collaboration. While the use of technology was evident in many classrooms, it was often used as a tool for presentation rather than for enhancing interactive or higher-order learning. Additionally, some essential life skills such as decision-making, problem-solving, and adaptability were not adequately emphasized. This indicates a need for further capacity-building to help teachers design lessons that not only integrate technology effectively but also foster core 21st-century competencies and life skills among students.

RQ4: What are the challenges teachers perceive in integrating TPACK-based practices, and what supports do they need for capacity development?

Challenges and Support Needed for Integrating TPACK-Based Practices: Teachers identified several challenges in effectively integrating TPACK-based practices. Although they have developed basic technological, pedagogical, and content knowledge individually, many still struggle to combine these components seamlessly in classroom practice. Some teachers lack sufficient skills to operate and apply digital tools effectively, and many are unfamiliar with the range of educational technologies available for subject-specific use.

In addition, infrastructure limitations, such as inadequate digital resources and connectivity issues, hinder the smooth implementation of technology-enhanced lessons. Teachers also cited workload and time constraints as major barriers, leaving little opportunity to explore or practice new tools and strategies.

To strengthen TPACK implementation, teachers expressed the need for continuous hands-on training, peer learning opportunities, and institutional support in terms of resources, time, and encouragement to experiment with technology in their pedagogy. Regular follow-up workshops and mentoring could further build teacher confidence and sustain meaningful integration of technology with content and pedagogy.

7. Implications for Policy and Practice:

Policy Level: CBSE and State Boards should embed TPACK explicitly into teacher training norms. Accreditation, teacher education curricula should include TPACK components and 21st-century skill competencies.

- School Leadership: School principals must provide infrastructure (ICT labs, internet), allocate time for collaborative planning, peer observation, support experimentation without penalising failure.

- Teacher Education / PD Programs: Programs should be long-term, contextually relevant, subject-specific, and include design tasks, implementation, feedback, reflection. Use of role models, authentic

experiences, collaboration, lesson design cycles shown effective in other studies (e.g., primary school science teacher education models). (MDPI)

- Assessment Practices: Rethink assessment to value creativity, inquiry, collaboration, and use of technology, rather than only recall.

8. Limitations:

The study's sample size was limited to 30 teachers from a single school or region, which may restrict the generalizability of the findings. Additionally, the possibility of an observer effect during demonstrations or observations could have influenced teacher behavior. The reliance on self-reported data in interviews may also introduce bias. Furthermore, the rapid pace of technological advancement means that the tools and platforms used in the study may quickly become outdated, potentially affecting the long-term relevance of the findings.

9. Conclusion:

Empowering elementary school teachers in CBSE contexts to effectively integrate technology, pedagogy, and content (TPACK) is essential for achieving quality education in the 21st century, in line with SDG 4. While teacher training programmes can improve awareness and basic competence, meaningful integration – especially in promoting 21st-century skills like critical thinking, creativity, collaboration, and digital literacy – requires more than one-time interventions. Sustained support, adequate resources, institutional backing and reflective practice are key. For substantial improvement in quality of education, stakeholders must commit to long-term capacity development initiatives aligning policy, practice, and teacher growth.

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