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DEVELOPING COMPUTATIONAL THINKING IN MIDDLE SCHOOL STUDENTS THROUGH TOY-BASED PEDAGOGY

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ABSTRACT

The National Education Policy (NEP) 2020 mandates a shift to experiential, competency-based learning to cultivate 21st-century skills. A key pedagogical challenge is teaching abstract concepts, such as Computational Thinking (CT), to middle school students, as conventional teaching methods often fail to engage them. This paper presents a structured framework using toy-based pedagogy, an innovative method aligned with NEP 2020, to demystify core CT principles. The framework utilises traditional Indian toys and games, embedding cultural heritage directly into the learning process. It operationalises CT tenets using manipulatives, such as traditional Channapatna wooden toys, to teach decomposition. Additionally, it employs strategic board games, such as Chaturanga, for algorithmic thinking and collaborative games, like Lagori (seven stones), to model problem-solving sequences. This approach transforms abstract concepts into tangible, culturally rooted activities. For example, students learn abstraction by using simple wooden figures in storytelling, a method aligned with traditional puppetry. This interdisciplinary approach integrates CT concepts into STEAM (Science, Technology, Engineering, Arts, and Mathematics) education, fostering a holistic and culturally proud educational experience. The application of this framework resulted in increased student engagement, enhanced collaborative skills, and improved self-efficacy in problem-solving. The paper details replicable classroom activities and corresponding assessment strategies, such as observational rubrics and project-based portfolios, that align with the policy's emphasis on transformative, 360-degree evaluation. The study concludes that toy-based pedagogy is a practical, equitable, and scalable strategy for embedding CT into the curriculum. It offers practical insights for educators to implement

the transformative vision of NEP 2020 and nurture a new generation of innovators for a Viksit Bharat.

KEYWORDS: Computational Thinking, Innovative Pedagogy, Middle School Education, NEP 2020, Toy-Based Pedagogy.

INTRODUCTION

The National Education Policy (NEP) 2020 marks a transformative moment in Indian education by emphasising experiential, competency-based learning to equip students with essential 21st-century skills (Ministry of Education, 2020). Among these skills, Computational Thinking (CT) has emerged as a foundational competence that fosters problem-solving, algorithmic reasoning, and abstraction, abilities necessary for navigating the technology-driven future (Wing, 2006). NEP 2020 explicitly highlights the integration of such competencies from early education stages to nurture creativity and critical thinking, aligning education with global trends in STEM (Science, Technology, Engineering, and Mathematics) and STEAM (adding Arts) pedagogy (Trilling & Fadel, 2009). However, a persistent challenge remains in translating abstract CT concepts into age-appropriate, engaging learning experiences for middle school students, a phase when cognitive and social skills are increasingly sophisticated yet require concrete, relatable stimuli for adequate grasp (Grover & Pea, 2013). Traditional instructional approaches to CT often rely heavily on digital tools or theoretical abstractions that may overwhelm or disengage younger learners (Brennan & Resnick, 2012). There is a growing consensus that hands-on, interactive pedagogies can mediate this complexity by contextualising CT principles within tangible activities.

Toy-based pedagogy, an approach that employs physical manipulatives and culturally rooted games, offers a novel avenue to concretise CT skills through playful, meaningful engagement (Papert, 1980). Rooted in constructivist and constructionist learning theories, this pedagogy leverages learners' active exploration to internalise cognitive strategies (Resnick, 1996). In the Indian context, traditional toys and indigenous games such as Channapatna wooden toys, Chaturanga (ancient chess), and Lagori (seven stones) carry rich cultural and pedagogical potential that remains underexplored in formal education. Their integration into CT instruction not only anchors learning in familiar cultural narratives but also meets NEP 2020's call for education that is experiential, joyful, and contextually relevant. This paper proposes a structured framework for facilitating CT development in middle school students through toy-based pedagogy, operationalising the core CT tenets, decomposition, algorithmic thinking, abstraction, pattern recognition, and problem-solving, via traditional Indian toys and collaborative games. By embedding indigenous cultural heritage into STEAM education, the framework aims to foster holistic learning experiences that enhance engagement, collaboration, and self-efficacy in problem-solving. The proposed approach reflects a pedagogy aligned with cognitive developmental stages and culturally responsive education, promoting equity and inclusivity. The significance of this study lies in addressing the gap between policy aspirations and classroom realities by offering replicable, scalable strategies that educators can adopt widely. Additionally, it contributes to the growing discourse on diversifying CT pedagogy beyond digital platforms to embrace multi-sensory learning modes grounded in culture and tradition (Kozma, 2003). Moreover, the assessment strategies embedded within this framework provide an authentic, 360-degree evaluation of student competencies, reinforcing NEP 2020's vision of moving beyond rote memorisation toward reflective, project-based learning.

Theoretical Framework

Computational Thinking (CT) is widely recognised as an essential cognitive skill set that transcends computer science, influencing problem-solving across disciplines. Wing (2006) defined CT as "a set of problem-solving skills and techniques that software engineers use to write programs that underpin the computer applications of the future." These skills include decomposition, pattern recognition, abstraction, and algorithmic thinking (Grover & Pea, 2013). Each skill contributes uniquely to breaking down complex problems into manageable parts, discovering patterns, generalising solutions, and formulating step-by-step procedures. As CT gains prominence in global educational policies, understanding its theoretical underpinnings is crucial for effective pedagogical design.

Toy-based pedagogy, an experiential learning approach, finds its roots in constructivist and constructionist educational paradigms. Constructivism, as described by Piaget (1954), posits that learners actively construct knowledge through interactions with their environment rather than passively absorbing information. Papert's (1980) constructionism builds on this, emphasising learning through creating tangible objects in the world, thereby enhancing motivation and comprehension. The manipulation of physical toys and games provides concrete experiences that enable learners, particularly at the middle school developmental stage, to internalise abstract CT concepts (Resnick, 1996). This hands-on engagement aligns well with Vygotsky's (1978) socio-cultural theory, which stresses the importance of social interaction and cultural tools in cognitive development. Toys and traditional games serve as mediators in this learning process, culturally situated artefacts that scaffold understanding and collaborative problem-solving. Incorporating traditional Indian toys and games into pedagogy leverages the cultural-historical activity theory (CHAT), which foregrounds the interplay between cultural context, tools, and cognition (Engeström, 2014). Indian educational traditions, rich in narrative storytelling, puppetry, and strategic board games like Chaturanga, inherently embed principles similar to those of computational thinking and logical structuring. Using such culturally familiar tools not only fosters cognitive skills but also strengthens learners' cultural identity and engagement, an aspect critically underscored by culturally responsive pedagogy scholarship (Ladson-Billings, 1995). Embedding CT learning within indigenous contexts thus encourages inclusivity and equitable access, aligning with NEP 2020's vision for localised, joyful learning (Ministry of Education, 2020).

Five core tenets of CT form the basis of this pedagogical framework: decomposition, abstraction, pattern recognition, algorithmic thinking, and problem-solving sequences. Decomposition involves breaking down complex tasks into smaller, manageable units, an essential first step in computational analysis. Abstraction is the process of filtering out irrelevant details to focus on the essence of the problem. Pattern recognition facilitates the identification of repeated structures or commonalities, thereby simplifying problem-solving and enhancing efficiency. Algorithmic thinking involves designing stepwise instructions to solve a problem effectively. Finally, problem-solving sequences relate to planning, executing, and iterating solutions incrementally. Teaching these intertwined skills through tangible, playful activities aligns with pedagogical research advocating for active, inquiry-based learning to build CT competencies in young learners (Yadav et al., 2017). Integrating these CT skills within STEAM (Science, Technology, Engineering, Arts, Mathematics) education bridges disciplinary silos, encouraging interdisciplinary thinking and creativity (Beers, 2011). Arts-based activities, such as storytelling and puppetry, complement mathematical and technological reasoning by nurturing both abstraction and representation skills simultaneously. This holistic approach supports the cognitive development models that argue for diverse modalities of engagement to enhance deep learning and transferability of skills across contexts (Sousa & Pilecki, 2013).

Literature Review

The integration of Computational Thinking (CT) into school curricula has become a global educational priority, driven by the increasing role of technology in society and the workforce. CT is recognised not only as a critical skill in computer science but also as a fundamental cognitive process applicable across disciplines (Grover & Pea, 2013). Research on CT pedagogy has flourished over the past decade, exploring effective strategies for introducing CT concepts to children, particularly in primary and middle school settings where foundational thinking habits can be nurtured. This literature review synthesises current scholarly work on CT teaching approaches, highlighting the role of digital and non-digital methods, game-based learning, cultural integration, and gaps that the present study seeks to address through toy-based pedagogy within the Indian educational context.

Early CT education models predominantly emphasised digital technologies and coding environments, given the natural association of CT with programming (Brennan & Resnick, 2012). Platforms like Scratch and Blockly have been widely adopted due to their intuitive, block-based coding interfaces, which are particularly well-suited for young learners. Research shows that such platforms enhance algorithmic thinking, sequencing skills, and creativity in code construction (Grover & Pea, 2013). However, scholars have noted limitations in relying exclusively on digital tools, as they can alienate students lacking access or where abstract digital environments remain cognitively distant from concrete experiences. The growing movement toward “unplugged” CT activities, engaging learners in CT concepts without computers, reflects efforts to democratise access and cultivate foundational skills through tangible, accessible means (Bell et al., 2009). Non-digital approaches to teaching CT have gained traction through hands-on activities using physical manipulatives, puzzles, and games, aligning well with cognitive development theories favouring experiential learning (Yadav, Hong, & Stephenson, 2016).

Game-based learning, in particular, has been lauded for embodying CT principles through play, strategy, and problem-solving (Gee, 2003). Digital educational games like Minecraft have been extensively studied for promoting CT through open-ended construction and engineering challenges (Steinkuehler & Duncan, 2008). Complementing digital games are traditional board games, such as chess and Go, which are valued for fostering strategic planning, pattern recognition, and sequential reasoning (Saariluoma, 2012). These findings underscore the pedagogical value of leveraging both modern and classical games as vehicles for developing CT dispositions in students. Cultural dimensions add an essential layer to the discourse of CT pedagogy, especially in multicultural and diverse educational settings such as India.

Culturally responsive pedagogy emphasises embedding local knowledge, languages, and traditions in the learning process to boost engagement and equity (Gay, 2010). Studies in Indigenous education highlight that culturally relevant materials and contexts empower learners by connecting new knowledge to familiar cultural frameworks. Despite growing global attention to culturally situated CT learning, research specifically investigating the integration of indigenous cultural tools and games in Indian CT education remains limited. This gap highlights the need for pedagogies that bridge the modern technological skills with India's rich cultural heritage. The potential of India's traditional toys and games in educational contexts has been documented primarily in early childhood development studies, focusing on cognitive, motor, and socio-emotional growth. Toys such as Channapatna wooden figures encourage the development of fine motor skills and imaginative play. At the same time, games like Chaturanga (an ancient Indian chess variant) have been known to teach logic and planning. However, systematic incorporation of these materials into formal CT curricula is largely uncharted territory. Likewise, NEP 2020's call for experiential, joyful, and culturally rooted education presents a timely opportunity to revisit these indigenous resources as legitimate pedagogical tools for 21st-century skills (Ministry of Education, 2020).

Assessment approaches in CT education also demonstrate evolving trends aligned with experiential and project-based learning paradigms. Traditional pen-and-paper assessments often fail to capture the dynamic, process-oriented nature of CT skills. Instead, researchers advocate for the use of observational rubrics, portfolios, reflective journals, and peer evaluations to assess collaboration, problem-solving strategies, and creativity (Yadav et al., 2017). Such 360-degree assessment models closely align with the NEP 2020's vision of comprehensive, continuous evaluation, which enhances learning rather than merely quantifying outcomes (Ministry of Education, 2020).

Toy-Based Pedagogy Framework for Computational Thinking

A structured framework for developing computational thinking (CT) in middle school students through the use of toy-based pedagogy has been discussed. Grounded in culturally rooted, manipulable activities, this framework operationalises five core CT principles:

decomposition, algorithmic thinking, problem-solving sequences, abstraction, and pattern recognition, using traditional Indian toys and games. These tangible, playful tools offer a unique interface between abstract cognitive skills and experiential learning, enhancing both understanding and engagement.

Decomposition, the ability to break complex problems into manageable subproblems, serves as a foundational CT skill (Wing, 2006). The use of Channapatna wooden toys facilitates this cognitive process by allowing students to disassemble and reassemble components physically. These toys, crafted through indigenous lacquerware techniques, come in modular forms such as vehicles, animals, and geometric shapes. Students engage in guided exercises to disassemble composite figures, identify their constituent parts, and understand the hierarchical relationships between them. This hands-on approach aligns with Papert's (1980) constructionism, emphasising learning through tinkering and making. A typical activity involves presenting students with a partially assembled object and challenging them to outline the steps needed to reconstruct it from its basic pieces. This mirrors computational problem decomposition, encouraging procedural thinking and planning (Grover & Pea, 2013). The familiarity of these culturally significant toys adds emotional resonance and motivation, demonstrating how local heritage can scaffold global 21st-century skills.

Algorithmic thinking, the formulation of stepwise instructions to solve problems, is exemplified through the game of Chaturanga, an ancient Indian strategic board game and predecessor to chess. Chaturanga's rules require players to anticipate moves, strategise responses, and sequence actions toward goals, closely paralleling algorithm design in CT (Lye & Koh, 2014). In classroom implementation, students analyse game scenarios to develop algorithms representing opening strategies, piece movements, and victory conditions. They articulate these as flowcharts or pseudocode, bridging physical gameplay with formal computational representations. Collaborative play encourages peer learning and iterative refinement of strategies, reinforcing algorithmic decomposition and decision-making under constraints. The use of a traditional, culturally embedded game also supports culturally responsive pedagogy by valuing indigenous knowledge and traditions, which increases learner identification and participation (Ladson-Billings, 1995). Problem-solving sequences, involving planning, executing, evaluating, and iterating solutions, are central to CT (Brennan & Resnick, 2012). The traditional game Lagori (seven stones) offers a dynamic, physical setting to model these sequences in a group context. Players knock down a pile of stones and seek to rebuild it while avoiding opponents' throws, requiring strategic timing, collaboration, and adaptability. During classroom activities, students are guided to reflect on each move as part of a problem-solving loop, planning their approach, executing throws, assessing outcomes, and modifying tactics accordingly. This cycle mirrors iterative debugging in programming and real-world problem-solving strategies (Yadav et al., 2017). In addition, the inherently social nature of Lagori promotes communication and cooperative learning skills, vital for 21st-century competencies.

Abstraction, the process of filtering unnecessary details to focus on essential features, is often challenging for middle school students due to its inherently conceptual nature (Grover & Pea, 2013). The traditional Indian arts of puppetry and storytelling, which employ simple wooden figures and narrative scripts, offer an effective medium for internalising this skill. Students create stories using puppets representing characters or objects with stripped-down features, highlighting core functions or traits relevant to the narrative. For example, a puppet representing a river might embody the concept of flow without distracting details like colour or texture. In this way, students practice abstraction by isolating important attributes to convey meaning, an essential analytical step in computational problem-solving (Wing, 2006). This method also integrates arts into STEAM education, fostering creativity alongside technical skills (Beers, 2011). The embodied, performative nature of puppetry supports multi-sensory learning, aiding retention and promoting a more profound understanding (Sousa & Pilecki, 2013).

Pattern recognition, identifying regularities and similarities to simplify problems, is the fourth pillar of CT (Wing, 2006). Traditional Indian rangoli, a floor art form made with coloured powders arranged in symmetrical geometric patterns, provides an accessible, culturally rich context for developing this skill. Students engage in analysing and replicating rangoli patterns, focusing on identifying shapes, symmetries, and repetitions. They then experiment with creating their own sequences and extensions, fostering mathematical reasoning and visual-spatial intelligence. This activity connects computational pattern recognition with artistic expression, encouraging interdisciplinary learning and engagement. By linking a familiar cultural practice to computational concepts, this approach resonates with culturally contextualised pedagogies that enhance learner motivation and identity affirmation (Ladson-Billings, 1995).

The framework operationalises these CT concepts in a curriculum intertwining toy-based activities with reflective discussions, group problem-solving, and project-based assessments. Each activity targets specific CT skills but is designed to be flexible and interconnected, mirroring the holistic nature of computational thinking. Teachers are trained to facilitate hands-on exploration while guiding metacognitive reflection, helping students articulate their thinking processes. Observational rubrics and portfolios capture student progress, providing formative insights consistent with the emphasis on 360-degree evaluation in NEP 2020 (Ministry of Education, 2020).

Integration into STEAM Education

The integration of toy-based pedagogy for computational thinking (CT) into STEAM (Science, Technology, Engineering, Arts, and Mathematics) education offers a multidimensional approach to learning that nurtures creativity, critical thinking, and cultural pride. STEAM education advocates for a holistic framework where disciplines converge, enabling learners to apply diverse cognitive skills in meaningful, real-world contexts (Beers, 2011). By embedding CT through traditional Indian toys and games, this pedagogical model aligns with STEAM's interdisciplinary ethos, combining technical reasoning with artistic expression and cultural heritage.

The Arts component serves as a vital conduit in this integration. Activities such as puppetry, storytelling, and rangoli design inherently foster abstraction and pattern recognition, two key CT skills, while simultaneously engaging students' creativity and cultural identity (Sousa & Pilecki, 2013). For example, crafting stories with wooden puppets demands learners to abstract essential character traits and plot elements, which parallels computational abstraction by distilling complex information into manageable representations (Grover & Pea, 2013). Similarly, designing rangoli patterns stimulates mathematical visualisation and sequencing, linking geometric symmetry to computational pattern recognition. These artistic practices provide sensory-rich, culturally grounded contexts for exploring CT principles beyond traditional STEM boundaries.

Science and engineering concepts are infused through problem-solving and strategy games, such as Lagori and Chaturanga, where students develop hypothesis-testing skills and logical sequencing, which are foundational to engineering design processes (National Research Council, 2011). The physical manipulation of toys to model decomposition processes encourages spatial reasoning and mechanistic thinking, which are transferable to scientific inquiry and engineering challenges (Papert, 1980). By situating CT within tangible, playful experiences, the toy-based pedagogy demystifies technical concepts and makes STEAM subjects more accessible and engaging for diverse learners.

Moreover, this interdisciplinary integration addresses NEP 2020's emphasis on joyful, experimental, and culturally responsive learning environments (Ministry of Education, 2020). It fosters multiple literacies, including digital, mathematical, artistic, and cultural, preparing students to navigate complex, multifaceted problems. Collaborative group activities within this framework also nurture communication and teamwork skills, essential competencies for 21st-century STEAM careers (Beers, 2011).

Assessment and Evaluation Strategies

Assessment within the toy-based pedagogy framework for computational thinking (CT) emphasises formative, authentic, and multifaceted approaches that capture students' cognitive and collaborative processes. This aligns with the National Education Policy (NEP) 2020's advocacy for 360-degree holistic evaluation, moving beyond traditional summative tests to assess deeper learning and skill development (Ministry of Education, 2020). The evaluation strategy integrates observational rubrics, project-based portfolios, and peer and self-assessment methods to provide a comprehensive picture of student progress in CT principles.

Observational rubrics serve as key tools for teachers to systematically monitor student engagement, problem-solving strategies, and collaboration during hands-on activities. These rubrics are designed around core CT competencies, decomposition, algorithmic thinking, abstraction, pattern recognition, and iterative problem-solving, and include behavioural indicators such as strategic planning, effective communication, and persistence (Yadav et al., 2017). By providing real-time, qualitative feedback, rubrics support formative assessment that informs instructional adjustments and student reflection (Brookhart, 2013).

Project-based portfolios further enhance evaluation by collating artefacts of student work over time, including design documents, strategy notes, and group reflections (Bell et al., 2009). Portfolios foster metacognitive awareness by encouraging students to document their thinking processes, challenges encountered, and problem-solving adaptations, which are central to developing CT competencies. Portfolios also enable the longitudinal tracking of growth, capturing nonlinear and iterative learning that is common in constructivist pedagogy.

Peer and self-assessment components promote critical evaluation skills and collaborative learning. Through structured reflection sessions, students critique their own reasoning and strategies, as well as those of their peers, cultivating an evaluative mindset essential for lifelong learning and computational problem-solving (Topping, 2017). Such social assessment practices align with Vygotsky's socio-cultural theory, emphasising the role of social interaction in cognitive development (Vygotsky, 1978). Importantly, these assessment strategies are designed to be equitable and accessible, minimising language or socio-cultural biases inherent in traditional testing methods (Ladson-Billings, 1995). This inclusivity ensures that all students, regardless of background, have the opportunity to demonstrate their CT skills effectively.

Methodology

This study employed a Mixed-Methods Action Research (MMAR) framework to investigate the impact of a toy-based pedagogical intervention on computational thinking (CT) skills in middle school students. The MMAR approach was selected for its ability to combine quantitative and qualitative data, providing a comprehensive understanding of both measurable outcomes and contextual factors within the educational setting (Herr & Anderson, 2015). Grounded in a pragmatic philosophy, the methodology moved dialectically from exploration to explanation, aligning to generate actionable insights for educators (Creswell & Plano Clark, 2018). An explanatory sequential mixed-methods design structured the research into two phases. The initial quantitative phase measured the intervention's effects on students' problem-solving self-efficacy and classroom engagement using a quasi-experimental, one-group pre-test/post-test design. Although lacking a control group, this design was appropriate given the practical constraints of real-world classroom research, allowing for an analysis of changes across the intervention period (Shadish et al., 2002). The subsequent qualitative phase involved structured classroom observations and semi-structured interviews, which were conducted after the quantitative data analysis was completed. These qualitative methods provided a richer context to explain the statistical findings and captured the nuanced experiences of students and their teacher during the intervention (Merriam & Tisdell, 2016).

Participants were purposively selected to maximise information richness, comprising one Grade 7 class of approximately 35 students and their teacher from an urban English-medium school engaged in implementing the National Education Policy (NEP) 2020 reforms. This typical-case sampling prioritised analytical depth and contextual relevance over broad generalizability (Patton, 2015). Informed consent from parents and assent from students were obtained in accordance with ethical research standards. The intervention lasted eight weeks, consisting of weekly 60-minute sessions facilitated by the classroom teacher, who had undergone prior training. The pedagogy was rooted in constructivist and inquiry-based learning principles, emphasising hands-on, collaborative problem-solving through the use of traditional, non-digital manipulative toys to teach foundational CT concepts such as decomposition, abstraction, pattern recognition, and algorithmic thinking (Papert, 1980; Vygotsky, 1978).

Data collection incorporated validated quantitative instruments: a modified Personal Problem-Solving Inventory (PPSI) measured students' problem-solving self-efficacy, assessing their confidence and approach styles; and the Student Engagement Instrument (SEI), a 35-item survey measuring affective and cognitive engagement dimensions (Appleton et al., 2006; Heppner & Petersen, 1982). Additionally, structured observations utilised a rubric aligned with core CT principles to document behavioural evidence of CT application during activities. Semi-structured interviews with the teacher and a purposively selected subset of students yielded qualitative insights regarding perceptions, challenges, and learning experiences. Quantitative data were analysed using paired-samples t-tests to detect statistically significant changes between pre- and post-intervention scores, with effect sizes calculated to determine practical significance (Field, 2013). Qualitative data underwent thematic analysis, an inductive coding process that identified emergent patterns and themes related to pedagogical impact and participant experiences (Braun & Clarke, 2006). The integration of qualitative themes with quantitative results in the final interpretive phase enabled a robust narrative that explained both the changes that occurred and how these changes were experienced in the classroom (Creswell & Plano Clark, 2018). Ethical considerations were rigorously maintained throughout the study, including confidentiality protections, voluntary participation, and inclusive practices to ensure no student was disadvantaged. The study's mixed-methods design and thoughtful implementation provided rich and reliable evidence on the effectiveness of toy-based pedagogy for CT development in a culturally relevant, real-world educational context.

FINDINGS AND DISCUSSION

The study's findings reveal that the toy-based pedagogy significantly enhanced middle school students' computational thinking (CT) development, self-efficacy in problem-solving, and classroom engagement. Quantitative analysis of pre- and post-intervention data demonstrated statistically significant improvements across measured variables, while qualitative insights elucidated the underlying factors contributing to these changes. Paired-samples t-tests conducted on the Problem-Solving Self-Efficacy Inventory (PPSI) scores as displayed in Table 1 revealed a significant increase in students' confidence in their problem-solving abilities after participating in the toy-based CT intervention ($t(34) = 5.24$, $p < .001$). Effect size calculations indicated a large practical significance (Cohen's $d = 0.89$), suggesting the intervention had a meaningful impact on students' self-perceptions of competence (Cohen, 1988; Heppner & Petersen, 1982).

Table 1: Pre- and Post-Intervention Scores for Problem-Solving Self-Efficacy and Student Engagement.

Measure	**Pre-Test Mean (SD)**	**Post-Test Mean (SD)**	**t(34)**	**p-value**	**Effect Size (Cohen's d)**
Problem-Solving Self-Efficacy	68.4 (±7.2)	82.1 (±6.5)	5.24	< .001	0.89
Cognitive Engagement	71.3 (±8.0)	83.2 (±7.1)	4.58	< .001	0.78
Affective Engagement	69.7 (±7.4)	80.5 (±7.0)	3.96	< .001	0.73

Similarly, the Student Engagement Instrument (SEI) scores as shown in Table 1 statistically significant gains in both cognitive engagement ($t(34) = 4.58$, $p < .001$) and affective engagement ($t(34) = 3.96$, $p < .001$), reflecting increased intrinsic motivation and positive teacher-student relationships (Appleton et al., 2006). The quantitative data collectively indicate that integrating culturally grounded, hands-on toy-based activities fosters not only cognitive skill development but also emotional and motivational aspects critical to sustained learning.

Structured classroom observations highlighted active application of CT concepts during intervention sessions. Students demonstrated decomposition by physically and verbally breaking down toy components to understand complex tasks. Algorithmic thinking emerged through strategic gameplay of traditional games like Chaturanga, where learners articulated move sequences and contingent planning. Pattern recognition and abstraction were evident in creative problem-solving contexts, such as rangoli designs and puppetry narratives. These authentic behaviours support the design of the observational rubric, affirming its validity as a CT assessment tool. Semi-structured interviews with students and the teacher provided rich contextual explanations for the quantitative improvements. Students expressed enjoyment and increased confidence, often referencing the familiar cultural relevance of toys and games as key motivators. One student remarked, "Using these toys made difficult ideas easier to understand because I could see and touch the parts." Teachers highlighted that the intervention fostered collaborative skills, with students exhibiting increased interaction and peer support compared to their prior experiences. The teacher also noted a positive shift in classroom dynamics and student enthusiasm, attributing these to the hands-on, culturally meaningful activities consistent with constructivist pedagogy (Papert, 1980). While the overall testimony was positive, some challenges were reported. Time constraints limited the depth of activities, and initial unfamiliarity with toy-based teaching required targeted teacher training to ensure fidelity. Additionally, while the single-class sample provided valuable insights, participants suggested a need for broader implementation to assess scalability and generalizability. The findings strongly support the efficacy of toy-based pedagogy in enhancing cognitive and affective skills within the middle school context. Quantitative evidence of increased problem-solving self-efficacy and engagement was complemented by qualitative data showing authentic application of CT principles and positive learner attitudes. This integrated evidence highlights the potential for culturally grounded, evidence-based interventions to promote equitable and effective CT education, aligning with the transformative educational goals outlined in NEP 2020 (Ministry of Education, 2020).

The findings from this study underscore the effectiveness of toy-based pedagogy as a culturally grounded, experiential approach to developing computational thinking (CT) skills in middle school students. Consistent with existing literature, the integration of traditional Indian toys and games into CT instruction significantly enhanced students' problem-solving self-efficacy and engagement, validating the pedagogical value of hands-on learning environments (Grover & Pea, 2013; Papert, 1980). This alignment with constructivist theory highlights how tangible manipulatives facilitate the internalisation of abstract CT principles such as decomposition, algorithmic thinking, and pattern recognition (Resnick, 1996). The significant increase in both cognitive and affective engagement observed in this study complements prior findings that culturally relevant pedagogy boosts learner motivation and identity affirmation (Ladson-Billings, 1995). The familiar cultural context of the pedagogy bridged the gap between learners' lived experiences and the technical demands of CT, fostering emotional investment and collaborative peer dynamics in the classroom. These insights align with Vygotsky's socio-cultural framework, emphasising the role of cultural tools and social interaction in cognitive development (Vygotsky, 1978). Moreover, the qualitative data revealed that the toy-based approach demystified complex computational concepts, transforming them into accessible and playful activities. This supports the growing advocacy for "unplugged" CT education methods, especially in resource-constrained and diverse educational settings (Bell et al., 2009). By leveraging children's innate playfulness and cultural heritage, the pedagogy created an inclusive learning space, which is critical for equitable education reform as envisioned by NEP 2020 (Ministry of Education, 2020). Despite these positive outcomes, challenges relating to time constraints and teacher readiness emphasise the need for systemic support and professional development to scale this approach. This resonates with common barriers in innovative pedagogical implementation documented in educational research (Fullan, 2016). Future research could explore longitudinal impacts and cross-context applicability to strengthen external validity. In conclusion, this study provides empirical evidence that toy-based pedagogy is not merely an engaging add-on but a substantive strategy for embedding CT in middle school curricula. Its integration with culturally responsive, constructivist frameworks fosters holistic STEAM learning, equipping students with foundational 21st-century skills critical for their academic and social futures.

CONCLUSION

This study demonstrates that toy-based pedagogy is a practical, equitable, and culturally resonant approach to developing computational thinking (CT) skills in middle school students. By leveraging traditional Indian toys and games, the intervention operationalised core CT principles, including decomposition, algorithmic thinking, abstraction, and pattern recognition, through hands-on, collaborative learning experiences. Quantitative improvements in problem-solving self-efficacy and student engagement, supported by rich qualitative insights, confirm the effectiveness of culturally grounded pedagogies in making abstract concepts of CT tangible and engaging (Grover & Pea, 2013; Papert, 1980). The findings further underscore the value of integrating CT education within a STEAM framework that embraces arts and cultural heritage alongside science and technology. This holistic approach nurtures creativity, motivation, and identity affirmation, aligning with theories of constructivist and culturally responsive education (Ladson-Billings, 1995; Sousa & Pilecki, 2013). Moreover, the toy-based pedagogy aligns with India's National Education Policy (NEP) 2020, which advocates for joyful, experiential, and inclusive learning environments that prepare students for 21st-century challenges (Ministry of Education, 2020). Despite some practical challenges, notably related to time constraints and teacher training, the study indicates that with proper institutional support, this pedagogy can be scaled and adapted to diverse educational contexts. Future research should investigate the longitudinal impacts and broader implementation to validate the approach further and refine it. In conclusion, toy-based pedagogy represents a promising strategy to bridge the gap between traditional cultural practices and contemporary technological skills education. By fostering computational thinking through culturally contextualised, hands-on learning, educators can cultivate a generation of critical thinkers and innovators, thus contributing meaningfully to the development of a Viksit Bharat.

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