# Toys as Learning Technologies: A Systematic Literature Review of Their Role in Elementary Engineering Education (Fundamental)

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# Toys as Learning Technologies: A Systematic Literature Review of Their Role in Elementary Engineering Education (Work-In-Progress)

## Abstract

This work-in-progress reports the initial stages of a systematic literature review examining the use of toys as learning technologies in elementary engineering education. As educators seek developmentally appropriate and engaging ways to introduce engineering concepts to young learners, toys such as construction kits, robotics platforms, and hands-on manipulatives have emerged as promising instructional tools. This review asks: what is known about how toy-based learning is used in elementary engineering education, and what evidence exists regarding its educational value? Guided by an adapted PRISMA framework for engineering education, a comprehensive search of major academic databases was conducted to identify peer-reviewed studies published between 2010 and 2025. The review examines the types of toys used, the engineering domains they target, the learning outcomes they aim to support, the research methods employed, and the educational results reported. Preliminary findings indicate growing interest in toy-based approaches to support early engineering learning, with studies highlighting their potential to enhance problem-solving, engagement, and engineering-related thinking. At the same time, the literature shows substantial variation in toy types, instructional goals, and methodological rigor. By mapping current research trends and identifying gaps in the evidence base, this review aims to inform the design of inclusive, hands-on, and meaningful pre-college engineering experiences and to guide future research in early engineering education.

## Introduction

The integration of engineering content and skills into the elementary curriculum (ages 5–11) is becoming increasingly important for the continued development of STEM literacy of the future innovators capable of solving the world's increasingly complex technological and social problems [1]. According to Baillargeon [2] and Piloto et al.[3] children in this age group possess intuitive and functional understandings of physical and mechanical phenomena. However, translating these intuitions into formal engineering knowledge requires carefully designed, developmentally appropriate instruction. Key obstacles include the need for educators to develop pedagogical and engineering-specific content knowledge [4][5], the use of concrete, experiential learning strategies to mediate abstract engineering concepts [6][7], and bridging the persistent gaps between higher-education engineering pedagogy and elementary classroom practices [8]. In that sense, designing educational technologies that effectively introduce engineering concepts to elementary students presents unique pedagogical challenges and opportunities.

In response to these challenges, toys have been recognized as valuable tools for supporting children's understanding of engineering concepts [9], extending their role beyond entertainment. Through play, children manipulate materials, test ideas, and observe cause–and–effect relationships, allowing them to explore physical and mechanical principles in concrete ways. Such interactions encourage exploration, experimentation, and iterative problem solving, processes that support the construction of new knowledge [10]. Research indicates that toy-based learning can support engineering instruction by strengthening problem-solving skills and increasing students' interest in STEM fields [11]. However, this body of literature shows substantial variation in toy types, targeted engineering domains, age groups, outcome measures, and methodological approaches [12].

This systematic review investigates the role and impact of toy-based learning in elementary engineering education over the past 15 years (1 January 2010 to 31 December 2025). Guided by a modified PRISMA framework for engineering education [13], the review addresses the following overarching question: How has toy-based learning been used and studied in elementary engineering education, and what evidence exists regarding its educational value? To answer this question, the review examines: (1) the types of toys employed and the engineering disciplines or domains they are intended to support; (2) the expected learning outcomes associated with their use, including students' knowledge, skills, engagement, and attitudes toward engineering; (3) the research methods and study designs used to investigate their implementation and impact; and (4) the results reported in terms of student learning, motivation, and development.

## Literature Review

### *Psychological and Educational perspectives on toys*

Toys have historically been recognized as vital tools in children's learning and development, serving as mediating objects that support cognitive, social, and physical growth [14]. From a developmental psychology standpoint, toys support children's active construction of knowledge through engagement with their surroundings. Piaget's theory of cognitive development argues that children acquire knowledge through object manipulation and self-reflection, especially during the shift from preoperational to concrete operational thought that defines the primary years [15]. This phase involves direct interaction with physical materials, promoting reasoning on cause-and-effect relationships, structures, and systems as basic elements of engineering cognition [16][17].

Vygotsky's sociocultural theory categorizes toys as cultural instruments that facilitate learning via social interaction and cooperative engagement. This perspective argues that play enables children to function within their zone of proximal development, facilitating learning through collaboration with peers, educators, or more knowledgeable individuals [18][19]. Toys serve as shared reference points that render abstract concepts concrete, enabling communication, negotiation, and working together to solve problems [20].

Recent perspectives extend constructivist views by situating children's interactions with toys within broader ecological, cultural, and pedagogical systems. Bioecological theory emphasizes that learning emerges from reciprocal interactions among the child, material objects, and the social environments in which play occurs, highlighting the influence of classroom practices, family contexts, and the cultural meanings attached to technological artifacts [21]. Contemporary sociocultural constructivist approaches further argue that learning occurs through guided participation in shared activities, in which toys serve as mediating tools that structure collaboration, communication, and problem-solving [22]. Complementary pedagogical traditions such as Montessori [23], Reggio Emilia [24], and Waldorf [25] education underscore the importance of material design and open-ended resources, viewing physical materials as languages for expression, tools for self-directed exploration, and catalysts for imagination. From this integrated perspective, construction toys, mechanical components, and modular kits do more than support embodied reasoning; they organize participation, enable shared meaning-making, and foster the development of engineering thinking within socially situated learning environments.

### *Toys as Educational Tools in Engineering Education*

In elementary engineering education, toys are increasingly seen as learning tools rather than mere playthings [26]. Learning technologies are tools explicitly designed or adapted to support educational goals, structure learner interactions, and facilitate knowledge acquisition [12]. Toys used in engineering contexts, such as construction kits, mechanical toys, and robotics platforms, align with this description by incorporating engineering principles into their materials and design constraints [27]. Prior studies indicate that toy-based activities promote engagement with essential engineering processes, such as problem identification, solution development, prototype creation, and design assessment [5][12]. Their physical characteristics facilitate the connection between abstract engineering principles and children's daily experiences. Toys play a substantial role in shaping young learners' perceptions of engineering. By portraying engineering as enjoyable, imaginative, and investigative, toy-based activities reduce perceptions of engineering as unattainable or excessively technical [28].

## Method

This systematic literature review adapts the methodological guidance of Borrego, Foster, and Froyd [13] for conducting systematic literature reviews in engineering education and emerging interdisciplinary fields. Following this framework, the review employed comprehensive search procedures across multiple databases, predefined eligibility criteria, a multi-stage screening process, structured data extraction using coding protocols, and thematic synthesis to evaluate prior research, identify trends, and detect gaps relevant to elementary engineering education.

### *Database and Search Strategy*

Literature for this work-in-progress review was retrieved from Academic Search Complete, APA PsycArticles, APA PsycInfo, ERIC, Science Reference Source, Psychology and Behavioral Science Collection, Education Source, and Education Full Text (H.W. Wilson) via EBSCOhost, as well as the Web of Science Core Collection. These databases were selected to ensure coverage across engineering education, psychology, and general education research.

The search strategy combined three conceptual domains (toys, engineering, and elementary education) using Boolean operators and database-specific subject terms. The following search string was adapted for each database:

*toy AND (engineering OR STEM) AND ("elementary school" OR "primary school" OR "grade school" OR "elementary education" OR "K-5" OR "K-6")*

Searches were conducted in titles, abstracts, and keywords. Filters were applied to include peer-reviewed publications in English published between 1 January 2010 and 31 December 2025.

*Eligibility Criteria*

1. Publication and study type. Peer-reviewed journal articles published in English between 1 January 2010 and 31 December 2025 that report empirical research (quantitative, qualitative, or mixed methods) based on a described implementation and data collection.
2. Population. Participants are elementary-aged children (approximately ages 5–11; grades K–5/6). Mixed-grade studies are included when elementary students are analyzed separately or constitute the primary/majority participant group.
3. Intervention (toys). The intervention centers on a “toy” or toy-based tool as described by the study authors, used as the primary learning medium in a structured educational activity. Toys may be physical, digital, or hybrid; the toy modality (physical/digital/hybrid) is coded during data extraction.
4. Outcomes. The study reports empirical outcomes related to engineering learning (e.g., engineering knowledge/concepts, design/problem-solving practices, engineering-related skills, engagement, attitudes, motivation, interest, or self-efficacy toward engineering).

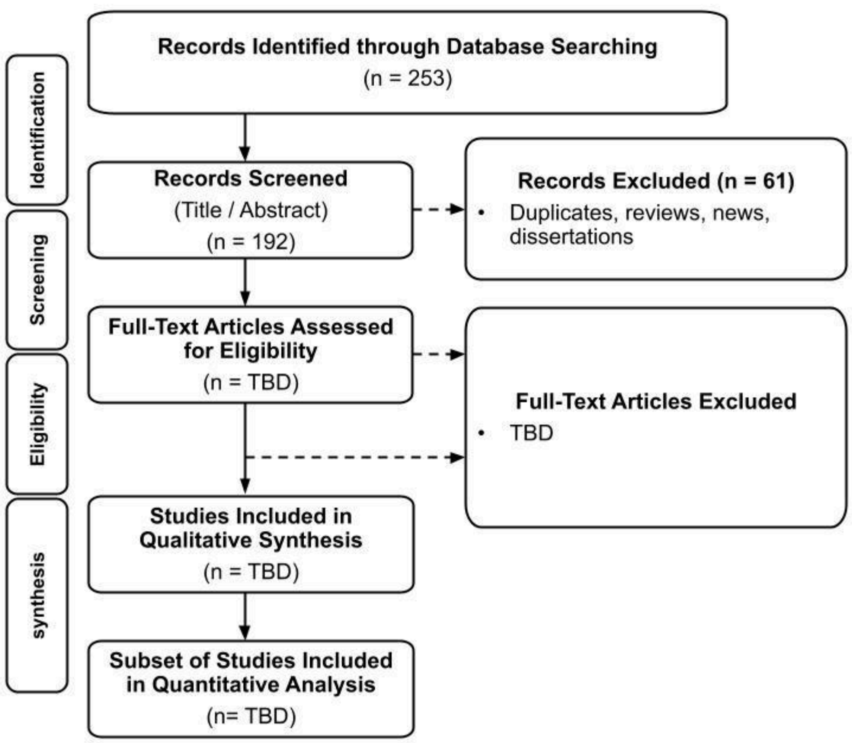


*Figure 1. SLR Flowchart: Adapted from Borrego et al. (2014)*

The search process yielded 140 records from EBSCOhost databases and 113 from the Web of Science Core Collection, for a total of 253. All records were exported in RIS format and imported into Zotero for management and screening. After consolidating the libraries and removing duplicates across databases, 192 unique records remained. An initial title-level screening was then conducted to verify publication type and obvious eligibility criteria, and records that did not meet peer-reviewed empirical study requirements were removed at this stage. This process is described in Figure 1. The dataset is currently organized and documented within Zotero to ensure traceability and facilitate subsequent data export and analysis.

**Initial Trends**

An LLM-supported content analysis using NotebookLM was conducted to identify overarching trends across the studies included in the qualitative synthesis. Current research strongly emphasizes early exposure to STEM concepts from preschool through elementary grades [29][30]. Engaging children with STEM toys at young ages is associated with the development of foundational capacities such as spatial reasoning and engineering habits of mind before stereotypes or academic anxieties emerge [31][32]. A growing trend integrates toys with literacy and storytelling to contextualize engineering challenges; programs such as PictureSTEM use narrative frameworks to connect abstract concepts with meaningful experiences [33][34][35]. Other approaches blur boundaries between physical and digital play through smart toys, augmented reality, and robotics that combine tactile manipulation with programming or simulation [36][37][38][39]. A parallel strand focuses on equity and participation, addressing gender stereotypes in toy use and leveraging game-based interventions to support students with disabilities [40][41][42][43].

Toy-based learning research encompasses a wide spectrum of physical and digital tools that support design thinking, physics reasoning, and computational skills [44][45]. Construction kits and building systems remain the most studied tools, particularly LEGO platforms used to teach engineering design, structural reasoning, and robotics [46][47][48], while systems such as K'NEX support understanding of forces and structures [49]. Open-ended "loose parts" materials promote creative recombination and symbolic reasoning [50], and circuitry kits such as Squishy Circuits introduce electrical concepts through conductive materials [29]. Robotics and coding toys support computational thinking through embodied interaction [37][38], while social assistive robots promote geometric reasoning and metacognitive awareness [51]. Board games, digital games such as Minecraft, augmented reality tools, and simple physics toys make abstract concepts visible and interactive [36][52][53][54][55].

Across studies, toy-based interventions are associated with cognitive, skill-based, and socioemotional benefits [29][41]. Evidence includes gains in domain knowledge such as forces, motion, electricity, and geometry [54][56][57], improvements in spatial reasoning [31][58][59], and enhanced computational thinking [48][60]. Construction play and robotics have been linked to improvements in communication and writing [61][62], while engagement in iterative design processes strengthens problem-solving and creativity [63][64][65]. Manipulation of small components supports fine motor coordination [66], and playful environments increase motivation, engagement, and flow-like experiences [67][68][69]. Early exposure to engineering toys supports STEM identity formation and may reduce gender gaps in interest [40][41][70]. Collaborative toy-based activities foster teamwork [71][72], and inclusive interventions show benefits for children with developmental disabilities in social attention, participation, and daily living skills [42][43][73].

## Future Work

To complete this systematic literature review and consolidate it into a fully developed systematic study, several key steps remain. The screening process must be finalized through abstract and full-text review, with documented exclusions and a definitive PRISMA flow diagram establishing a transparent and reproducible corpus. The coding framework should be stabilized and validated through inter-reviewer calibration and agreement procedures to ensure analytic consistency. Beyond classification, the analysis must deepen to interpret patterns across toy types, engineering domains, learning outcomes, and methodological approaches, while also evaluating the strength and limitations of the evidence base. Identifying research gaps and underrepresented populations or domains will further strengthen the study's contribution. Finally, conceptual coherence must be confirmed by aligning definitions, inclusion criteria, and findings, and the discussion should articulate implications for curriculum design, teacher preparation, and equitable access to early engineering learning. In summary, these steps will move the review from preliminary mapping to a rigorous synthesis that clarifies the field and guides future research and practice.

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