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The logic of construction: The evolution of design philosophy in educational construction toys

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Abstract. The purpose of the study was to reconstruct the genealogy of design philosophies that transformed construction toys from closed instructional systems to open platforms and, ultimately, to socially engaged artefacts. The study employed a qualitative historical design using multiple-case comparative analysis based on primary sources (patents, designers' and educators' writings), historical commercial materials, and key educational and philosophical texts, supplemented by contemporary scholarly and industry sources. The analysis was structured around two dimensions – systematicity (connection mechanisms, materials, modular logic) and didacticism (educational philosophies, cultivated skills, and encoded cultural values) – to trace the evolution of educational construction toys. Each case was analysed along these axes: systematicity (materials, connection mechanisms, modular logic) and didacticism (educational philosophy, skills cultivated, cultural values). A clear evolutionary trajectory emerged. In the early period (1840s – early 20th century), construction toys functioned as closed systems designed to transmit philosophical or engineering knowledge. During the industrial-modernist stage (early 20th century – 1980s), supported by innovations such as LEGO "clutch power", construction toys transformed into open platforms enriched by narrative and systemic approaches. In the contemporary era (1990s – present, 2026), the design logic diversified to address social and environmental challenges, including gender representation and sustainable materials. The study provided evidence that construction toys act not merely as playthings but as educational artefacts encoding worldviews, pedagogical strategies, and social values. The results may be useful for educational toy designers, educators, and researchers of material culture as a methodological foundation for creating and applying construction toys that align technological design, pedagogical goals, and cultural context

Keywords: toy design; systemic design; modular platforms; material culture; pedagogical artifacts; educational tool

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INTRODUCTION

As cultural artefacts, toys embody the pedagogical ideals, technological capabilities, and societal values of their time. Understanding the design evolution of these objects offers a unique lens for examining the changing relationship between education and material culture. However, while their role in child development is widely acknowledged, the specific evolution of design logic remains under-researched. Recent research has extensively examined the relationship between toy design, cognitive development, and user interaction. According to H. Saikia *et al*. (2023), the visual design elements of educational toys, such as colour, pattern, and structure, are critical factors that directly influence visual perception and the subsequent development of reading and mathematical skills in early childhood.

Building on the connection between physical form and cognition, Ç.İ. İleri *et al*. (2023) argued that construction toys offer unique affordances that elicit spatial language and gestures, suggesting that variation in design mechanics is essential for fostering mental folding and perspective-taking skills required for STEAM fields. I. Gryshchenko *et al*. (2024) examined how design education integrates research and creative activity across science, art, and engineering, showing that interdisciplinary learning strengthens professional competence. This perspective on cultivating systematic and constructive thinking in design students resonates with the evolving design philosophy of educational construction toys, in which the logic of construction itself serves as both a pedagogical tool and a reflection of broader design principles.

Shifting the focus from educational outcomes to the design process, researchers seek to categorise how these objects are conceived and used. According to J.F. Legaard & H.M. Skovbjerg (2024), construction toys possess distinct functional and narrative affordances, and the central challenge for designers lies in balancing structured instructions with the freedom of open-ended play to maintain children's engagement. A. Codner & C.A. Lauff (2024) investigated the prototyping phase of toy development, showing that the fidelity of a prototype – whether it prioritises form or function – considerably influences how children provide feedback, thereby highlighting the complexity of translating educational theories into physical products. In parallel with these functional studies, other researchers have explored the cultural and technological context of toys.

According to V. Komis *et al*. (2021), the field experienced a paradigm shift towards "smart toys", where the focus changed from developing transversal skills such as symbolic thinking to specific 21st-century skills, including computational thinking. However, a counter-narrative re-examines traditional craftsmanship. According to Y. Yan *et al*. (2024), traditional systems such as the Chinese mortise and tenon structure can be revitalised through "emotional design" frameworks, which connect historical cultural values with modern consumer needs at instinctive and reflective levels. Similarly, N. Yang & O. Yezhova (2025) analysed the Phoenix Stamp to demonstrate how traditional Luban lock structures can be reinterpreted as modern educational toys that preserve the mathematical complexity of ancient craftsmanship while offering engaging structural challenges. Taking a historical perspective, M. Mindrup (2023) indicated how architectural toys and models function not merely as playthings but as affective objects that shape societal concepts of domesticity and space. Despite these diverse perspectives on cognition, prototyping, and technology, a lack of genealogical research persists on how the underlying logic of construction has evolved over the last two centuries.

The purpose of this study is to reconstruct the genealogical evolution of design philosophies in educational construction toys from the 1840s to the present (2026), analysing the trajectory from closed didactic systems to open, socially engaged platforms.

MATERIALS AND METHODS

This study employed a qualitative historical research design, using a multiple-case comparative analysis to trace the evolution of design philosophies in educational construction toys. The data are drawn from a systematic review of diverse historical materials. These include primary sources such as key product patents – most notably LEGO's 1958 "stud-and-tube" coupling system (Kirk, 1961) and the 1920 Lincoln Logs "Toy Cabin Construction" patent (Lloyd, 1920) – as well as original writings by designers and educators, for example, Froebel's discussions of gifts (Provenzo, 2009). Commercial and marketing materials, such as Meccano Ltd.'s "Engineering for Boys" advertisement (The Brighton Toy and Model Museum, 2022), LEGO's gender-inclusive campaign (The LEGO Group, 2021), and early Lincoln Logs packaging slogans (Mindrup, 2023), were also examined. The corpus further includes seminal educational and philosophical works, including M. Montessori's (1912) method and S. Papert's (1980) "Mindstorms", along with contemporary scholarship, design critiques, relevant cultural studies, and authoritative news reports documenting significant industry decisions.

The data analysis was structured around the two core concepts – systematicity and didacticism. For each historical period, the selected cases were examined from two analytical dimensions. First, systematicity analysis was used to investigate the toy's core connection mechanisms (e.g., bolts, grooves, clutch power), material properties (wood, metal, plastic), and modular logic (whether it replicates real-world structures or enables open-ended creation), to define the boundaries and characteristics of its "system". Second, didacticism analysis was used to investigate the dominant educational philosophy embedded in the toy (e.g., idealism, pragmatism, constructivism), the key skills it is intended to cultivate (e.g., abstract thinking, mechanical principles, systems thinking), and its encoded cultural values and ideologies (e.g., national myths, gender roles, environmental responsibility.

RESULTS AND DISCUSSION

Early designs as closed systems – from philosophical encoding to engineering models (1840s –early 20th century). In the early lineage of educational construction toys, from the 1840s to the early 20th century, the core design philosophy was not oriented toward open-ended creativity. Instead, designers focused on creating "closed systems" with explicit educational objectives. The intention was to "encode" a specific worldview or skill set through a predetermined set of rules and components, guiding users to decode them. From F. Froebel's philosophical educational tools to Meccano's engineering models, these early designs exhibited a strong didactic character through meticulous control over materials, forms, and connection methods. In the 1840s, Friedrich Froebel designed a series of educational toys introduced in sequential order, known as "gifts" (Fernsebner, 2003) (Fig. 1). The system introduced components in a strict sequence: starting from a uniform woollen ball (the first gift), followed by spheres and cubes representing opposing concepts (the second gift), and then progressing to divided cubes illustrating the relationship between parts and the whole (gifts three to six). This progression constituted a one-way path from simple to complex and from concrete to abstract. The systematicity and educational sequencing of this design were elaborated in detail by F. Froebel in the periodicals he founded. Each component's form carried carefully designated symbolic meanings (Morgenstern, 1882). The sphere represented unity, while the cube symbolised stability. Through these geometric shapes, the designer materialised abstract philosophical concepts. F. Froebel's three modes of play – the "forms of life," the "forms of beauty," and the "forms of knowledge" – functioned as predefined contexts for this design language. The success of this design lay in its ability to guide users' thinking, such as that of architect Frank Lloyd Wright, towards abstract structural reasoning.

M. Montessori's design approach advanced further by integrating the role of the teacher into the objects themselves. Her system of educational materials achieved the clear functional goal of self-education through two core design principles. First, each material focused on a single, isolated physical attribute, such as size or colour, to maximise informational clarity and avoid cognitive confusion. For example, the Pink Tower was intentionally designed with uniform colour and texture, retaining only "size" as the variable (Fig. 2). The second principle was the physical implementation of "error checking", representing a key innovation. This innovation was the most critical one. The designer embedded a feedback mechanism within the objects themselves, making the material the source of information. In the cylinder blocks with sockets, incorrect matches produced physical incongruities (either failing to fit or wobbling). This immediate, non-judgemental physical feedback replaced traditional correction provided by adults. As M. Montessori (1912) explained in the first English exposition of her method, this design choice aimed to directly guide user behaviour through the physical properties of the objects, fostering independence and concentration.

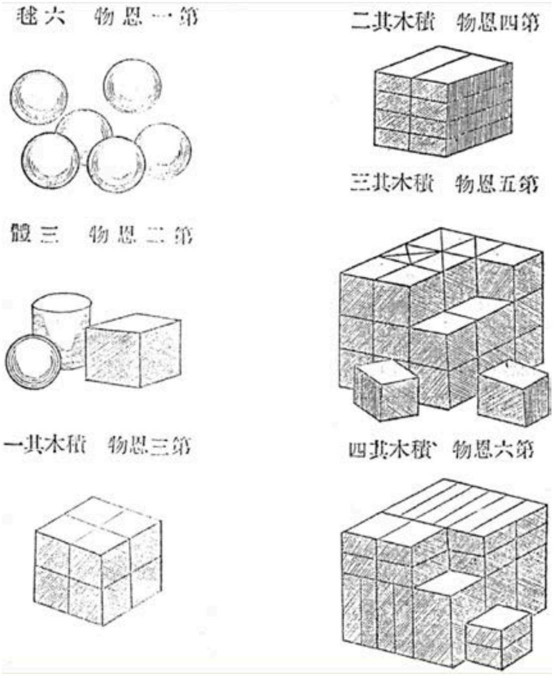

Figure 1. Diagram of Froebel's gifts offered by the Shanghai Kindergarten Society (1909)
Source: S.R. Fernsebner (2003)

Figure 2. Montessori Pink Tower
Source: M. Esta (2017)

With the advent of the industrial era, Meccano Ltd. embodied another type of closed-system design logic – direct simulation of real-world technology (Guijarro, 2021). Its design language was directly borrowed from contemporary engineering. Reusable metal strips, angle girders, plates, nuts, and bolts were miniaturised representations of construction methods used for bridges, cranes, and other large-scale structures. Meccano's design intent was explicit: as repeatedly emphasised in its early 20th-century advertisements under the slogan "Engineering for Boys", it functioned as a tool for imparting practical technical knowledge. Rather than aiming to stimulate unrestricted imagination, the design enabled users, through simulation, to understand and internalise dominant engineering principles and societal values of the period (Gök & Sürmeli, 2022) (Fig. 3).

* This is Meccano Outfit No. 5 costing 67/9 (inc. tax)

A whole world of miniature engineering is within the grasp of a boy the moment he opens his Meccano Outfit and commences model-building. Meccano today is better than ever. Outfits from No. 0 to No. 6 in this fascinating hobby are now fitted with moulded trays, partitioned and shaped to hold the parts. This neat modern storage means easier selection, speedier construction and less risk of damage to parts.

Figure 3. Meccano advertisements "Engineering for Boys"
Source: The Brighton Toy and Model Museum (2022)

During this period, the design of educational construction sets focused on creating closed systems with clearly defined learning objectives. Toys from this era promoted the development of specific skills and knowledge through a strictly organised sequence of elements and forms. They were designed to convey certain ideas or concepts through the physical properties of objects, particularly through interaction with them, thereby enabling specific educational outcomes. This approach promoted systematic thinking and structured learning, guiding users towards specific goals.

Transition to open design – from narrative layering to system empowerment (early 20th century-980s). Entering the 20th century, especially in the post-World War II era with the rise of the mass market, the design philosophy of educational construction toys underwent a pivotal shift. This period can be characterised as the Industrial-Modernist stage – a time when designers relied on industrial production, standardised materials (metal, wood, plastic), and modernist ideas (rationality, functionality, systematicity). The focus moved away from closed systems with clearly defined goals towards open platforms offering richer possibilities. This evolution manifested in two key design strategies: first, the "narrative layering" approach, exemplified by Lincoln Logs, which built cultural stories on top of existing functional designs; and second, the "system empowerment" approach, exemplified by LEGO, in which core technological innovations enabled platform-based design.

The success of Lincoln Logs stands as a classic example of "dual-layer design", clearly demonstrating how a toy's physical functionality and its cultural narrative can be independently designed and selected. The toy's core construction principle – the interlocking log-beam structure – was derived from its inventor, John Lloyd Wright's experience working on the earthquake-resistant design of the Imperial Hotel in Tokyo, Japan. This functional and highly purposeful design, aimed at developing children's building instincts, was patented as a "toy-cabin construction" in 1920 (Fig. 4).

On the marketing side, however, the designer chose not to highlight this story of modern international engineering. Instead, he engaged in a notable act of brand storytelling by naming the product Lincoln Logs. By overlaying a national myth about President Abraham Lincoln's log-cabin childhood and reinforcing it with the packaging slogan "Interesting playthings typifying the spirit of America", the product was imbued with cultural values such as pioneering spirit and self-reliance (Mindrup, 2023). This deliberate separation of physical and narrative layers demonstrated that the meaning of a toy can be intentionally designed as an element independent of its physical functionality – significantly enhancing its market appeal.

If Lincoln Logs represent a straightforward combination of function and narrative, the rise of LEGO exemplifies their integration at a higher level. Through a single but transformative technological innovation, LEGO empowered an overarching design philosophy and created a truly open-ended platform. In response to the prevailing problem of a toy market lacking a coherent system, company leader Godtfred Kirk Christiansen articulated a strategic design vision: to create an integrated system of play. Its core principles – such as "unlimited imagination" and "suitable for all ages" – established open and inclusive goals for the platform.

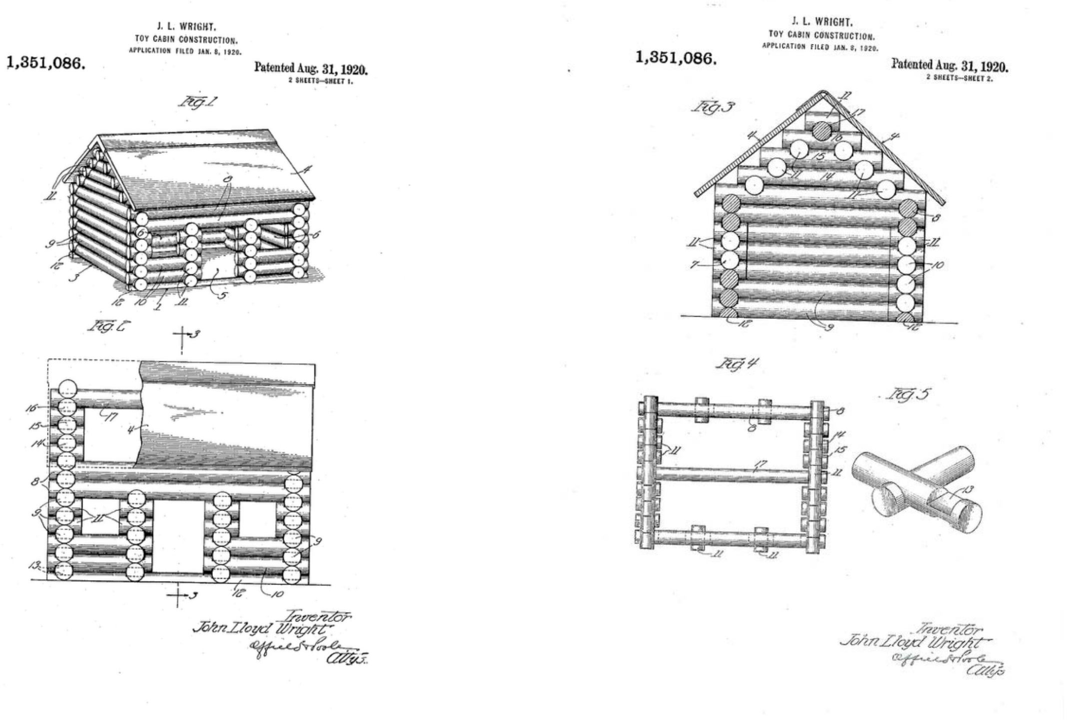

Figure 4. Lincoln Logs' patented "Toy-Cabin Construction" design
Source: W.J. Lloyd (1920)

The core technological innovation was clutch power. This ambitious philosophy could not be realised without a corresponding technical solution. The patented stud-and-tube coupling system of 1958 (Kirk, 1961) became the physical foundation of this vision. By precisely matching the hollow tubes on the underside of a brick with the studs on top, the design produced stable and reliable clutch power. This seemingly simple innovation solved the fundamental instability of earlier bricks, enabling any brick to connect securely with any other. In this way, it activated the potential of the system philosophy (Fig. 5).

LEGO's system eventually converged with S. Papert's (1980) educational theory of Constructionism. In his seminal work "Mindstorms", S. Papert advanced the idea of learning by making, which provided a strong theoretical articulation for LEGO's open-ended platform. This fusion of commercial design and academic theory culminated in the LEGO Mindstorms series, combining physical bricks with programmable digital technology. In this form, LEGO evolved from a construction toy into a cognitive exploration tool – one that enables users to construct ideas and bring them to life. Ultimately, LEGO's design logic underwent a transformation from pedagogical guidance to user empowerment (Komis *et al*., 2021).

The evolution of construction toys from closed systems to open platforms reflects changing approaches to learning and creativity in design. At the beginning of the 20th century, design focused on clearly defined goals and strictly structured rules that promoted the development of specific skills, such as spatial thinking or technical knowledge. Over time, toys became more flexible and open, providing opportunities for creative self-expression. Open construction systems, such as LEGO, began to combine physical construction with innovation and cultural narratives, allowing children not only to build but also to develop critical and systematic thinking. This transition indicates a shift in focus from formal learning tools to more intuitive and multifunctional systems.

The multidimensional turn: Contextualising the system (1990s – present, 2026). Since the 1990s, the design philosophy of construction toys has ceased to follow a single linear evolutionary path. Instead, it has undergone a multidimensional turn. Systematicity is no longer confined to the internal logic of connection; it has diversified into distinct approaches to construction that facilitate different cognitive outcomes and interaction modes. This period is characterised by three distinct shifts: a structural divergence from static volumes to dynamic skeletons, an interface innovation towards intangible connections, and a digital overlay that transforms toys into cyber-physical systems. Since LEGO established its dominance with stacking logic, the market has evolved into a pluralistic landscape; a new wave of systems has emerged that prioritises skeletal engineering.

Systems such as K'NEX (introduced in 1992) and VEX Robotics utilise flexible rods, connectors, and beams to create spatial frameworks. Unlike brick-laying logic, these systems mimic real-world structural engineering, prioritising force transmission, equilibrium, and kinematics (Fig. 6). This shift fundamentally alters the cognitive demands placed on the user. Interaction evolves from static spatial arrangement (sculpting form) to dynamic systemic thinking (engineering motion), requiring the child to predict movement and structural forces. Recent academic designs extend this logic further. For instance, K. Kshirsagar *et al.* (2025) introduced MorphBlox, which utilises kinetic tessellations – modular blocks that move and transform – to help children explore complex mathematical concepts through dynamic manipulation rather than static building. This transition from static volume to dynamic skeleton reflects a broader pedagogical shift from spatial visualisation to systems thinking.

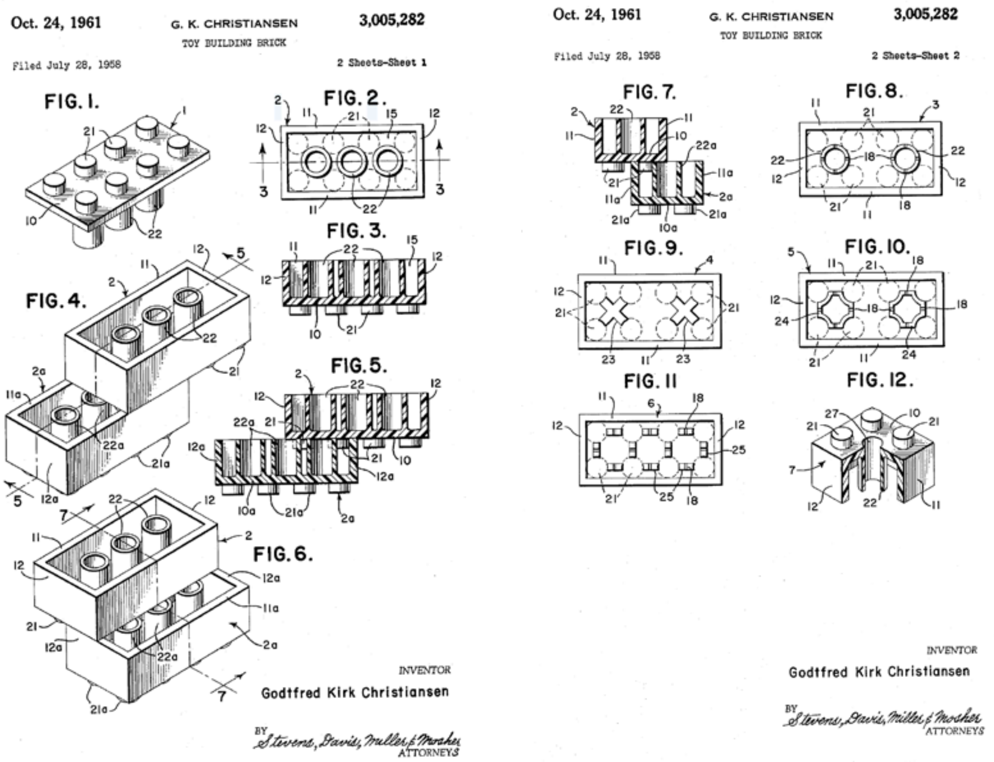

Figure 5. Schematic diagram of the stud-and-tube structure in LEGO’s patented brick system
Source: C.G. Kirk (1961)

Figure 6. K’NEX 3-in-1 classic amusement park building set
Source: Basic Fun (n.d.)

Figure 7. Fischertechnik robotic model
Source: Fischertechnik official website (n.d.)

Fischertechnik is a high-precision modular engineering system that uses a groove-and-pin connection method. It enables students to simulate complex mechanical functions and mechatronic systems, allowing them to construct and understand the principles of dynamic, non-assembled machinery (Fig. 7).

Various construction systems, such as K'NEX, VEX Robotics, and Fischertechnik, offer new approaches to creating dynamic structures that promote the development of systematic thinking and motion prediction. A comparative analysis of the basic logic of these systems is presented in Table 1.

Table 1. Comparative analysis of the core logics of three construction systems

System	Core components	Interlocking mechanism	Primary construction logic	Related cognitive skills
Lego	Rectangular bricks	Stud-and-tube, clutch power	Stacking, surface creation, volume filling	Spatial reasoning, schematic construction
K'Nex	Flexible rods and connectors	Axial snap-fit	Linear, skeletal frameworks, dynamic structures	Structural engineering, kinematics
Fischertechnik	Grooved sliding blocks, electromechanical components (motors, sensors, etc.)	Groove-and-pin +plug-and-socket	Functionality-oriented construction, precision assembly, mechatronic integration	Mechanical engineering, robotics modelling

Source: compiled by the authors

While conventional mechanical systems become increasingly complex, a parallel design trend aims to lower the barrier to entry through intangible connections. The introduction of magnetic construction toys, such as Magformers, Magna-Tiles, and academic prototypes like Magnetact animals, represents a clear shift (Fig. 8). The design logic moves from physical interlocking (which demands fine motor strength and precision) to effortless magnetic interaction.

Figure 8. Magformers Basic Plus 26PC
Source: Magformers official website (n.d.)

In these systems, the connection is immediate and self-correcting. Instead of focusing on the structural rigidity of the final object, the design encourages intuitive exploration of topology – specifically, understanding how 2D planes can fold into 3D forms. By removing physical resistance in mechanical assembly, these toys allow users to focus purely on geometric logic. As K. Yasu & M. Ishikawa (2021) demonstrated, such magnetic kinetic kits enable children to construct complex structures with variable motions without the frustration of precise mechanical alignment. This effectively democratises the experience, making the construction of dynamic mechanisms accessible to a much wider audience.

The most radical disruption in the modern era is the integration of computation as a fundamental building block. Toy systems transitioned from purely physical objects into cyber-physical systems, a trend that began with LEGO Mindstorms and later developed into modular electronic kits such as LittleBits and Makeblock. The computational block system, exemplified by littleBits, encapsulates complex electronic functions (such as input sensors, logic gates, and output signals) within simple, colour-coded magnetic modules. This approach fundamentally shifts the assembly logic from "shaping forms" to "shaping behaviours". A block is no longer defined solely by its physical geometry, but by its function. Consequently, children can construct complex interactive systems using the same familiar logic as building with static blocks (Fig. 9).

Figure 9. Littlebits STEAM+ Coding Kit
Source: Littlebits official website (n.d.)

Researchers highlight the expanded definition of construction. Z. Chen *et al.* (2024) illustrated this through "Softy's Magic Touch", showing how modular interactive components can be attached to ordinary objects (such as plush toys) to endow them with digital behaviours. Similarly, Y. Lyu *et al.* (2024) argued that modern play is characterised by the "4Rs" – recallable, relaxing, repayable, and reconnected – where digital overlays bridge the gap between tangible interaction and virtual feedback. Ultimately, the "logic of construction" now extends into the logic of programming, effectively treating code as an intangible material that binds physical parts together. The evolution of construction toys from conventional mechanical systems to systems with magnetic connections and integrated computing represents a significant shift in design, increasing accessibility for a wider audience. A comparative analysis of physical and computational block systems was presented in Table 2.

Table 2. Comparative analysis of physical versus computational block systems

System type	Core components	Interlocking mechanism	Primary construction logic	Related cognitive skills
Physical blocks	Standard passive bricks, plates, structural beams	Mechanical interlocking e.g., stud-and tube friction/ clutch power	Stacking, volume filling, Static modeling	Spatial reasoning, structural balance, schematic construction
Control logic	Microcontrollers (CPUs), sensors, motors, smart bricks	Electronic interfaces, magnetic data-snaps, wireless connectivity	Defining behaviours, programming logic	Computational thinking, mechatronic logic, system-level problem solving

Source: compiled by the authors

Beyond technical and digital integration, contemporary design logic expanded to address socio-cultural challenges, particularly gender representation. A noteworthy case is the introduction of LEGO Friends (Fig. 10), which marked a strategic shift from a universal but often male-centric system towards a design language tailored to diverse social play patterns. While controversial, this approach demonstrates how modern construction toys function as socially engaged artefacts, encoding values of inclusivity and cultural diversity into modular systems.

Figure 10. LEGO Friends
Source: The LEGO Group (2021)

The evolution of construction toys demonstrates a shift from conventional mechanical systems to open platforms that integrate digital and computational technologies. Open construction systems such as LEGO and K'NEX changed approaches to learning, allowing children not only to create physical structures, but also to develop programming and systems thinking skills. The use of magnetic and computational blocks, such as Magformers and LittleBits, considerably simplifies the construction process, opening new opportunities for creativity and scientific development. These changes also reflect social and cultural trends, including inclusivity and diversity in contemporary toy design.

Discussion of the evolution of construction toy logic in contemporary research. Findings on the "closed system" logic of early educational toys align with and extend contemporary research on the evolution of pedagogical artefacts. According to F. Finlay *et al.* (2023), the 19th-century focus on toys with specific educational purposes resulted from the Enlightenment, which redefined childhood as a distinct developmental stage requiring structured play tools. This historical context is reinforced by M. Mindrup (2023), who identified building kits such as Froebel's gifts as structured instruments designed to cultivate order and spatial awareness through precise micro-architectural models. While H. Saikia *et al.* (2023) emphasised the importance of visual perception in toy design for cognitive development, this study demonstrates that early designers specifically employed "visual isolation" – as seen in Montessori's materials – to direct attention towards isolated physical attributes.

Furthermore, the intricate structures of traditional systems highlighted by J. Fu & J. Chen (2021) can be interpreted as a deliberate mechanism of closed instruction guiding the user towards a single, predetermined outcome. This differs from the multi-faceted visual and communicative system of interaction described by N. Skliarenko *et al.* (2023); while contemporary researchers view these objects as broad cultural systems, the original design philosophy analysed in this study was intentionally linear and restrictive. Moreover, G. Du *et al.* (2023) noted that structural innovations in traditional toys can promote spatial imagination and cultural identity; however, this study clarifies that early systems such as Meccano prioritised technical simulation and mechanical precision over open-ended imagination. Thus, the early period of educational construction toy design is characterised by the creation of closed systems that translated complex philosophical and engineering ideals into physical form. By embedding prescriptive rules and feedback mechanisms directly into toys, designers decentralised the role of the teacher, allowing the physical logic of the object to guide the pedagogical path. This era established a foundational design grammar focused on encoding specific worldviews through structural stability and restrictive, goal-oriented interaction.

The transition from the rigid, instruction-based systems of the 19th century to the open-platform logic of the mid-20th century represents a paradigm shift in how design mediates the relationship between play and learning. This evolution is rooted in what J.F. Legaard & H.M. Skovbjerg (2024) defined as the expansion of functional and narrative affordances. While early toys provide a singular path of interaction, the design of Lincoln Logs and LEGO creates a dual-layer logic, following which physical construction is decoupled from a specific ideological outcome. As identified in this study, the success of Lincoln Logs lies in its ability to layer a cultural myth onto a functional system – a strategy that A. Codner & C.A. Lauff (2024) suggested is critical in toy prototyping to ensure high interaction fidelity and play value. By separating meaning from mechanics, these designs maintain children's engagement through diverse narrative paths.

Furthermore, the emergence of the LEGO system of play provides a physical foundation for constructionist theories. Findings regarding clutch power as a technical enabler are strongly supported by the developmental psychology perspective of Ç.İ. İleri *et al.* (2023). Their study indicated that construction play offers unique affordances that elicit spatial language and gestures, facilitating the development of mental rotation and perspective-taking. By providing a stable, modular environment through high-precision coupling, LEGO design allows children to shift cognitive load from the basic stability of the structure to higher-order structural problem-solving. Long before the era of smart toys, the modular logic of the postwar era already trained children in symbolic thinking and iterative design. Unlike the wooden structures analysed by J. Fu & J. Chen (2021), which requires specific, exquisite, and ingenious unlocking methods rooted in embodied cognition, the LEGO system moves towards a universal, abstract logic. This universalism prioritises individual agency over fixed craftsmanship. Thus, openness in this period represents a deliberate design choice that transforms toys from pedagogical tools into creative laboratories, with the most effective designs providing tools for "how to build" while instilling a belief in "what can be built". It is therefore justified that the postwar evolution of construction toys marks a definitive move from prescriptive tools towards open-ended systems of creative empowerment. By integrating narrative flexibility with high-precision modular technology, designers successfully transform toys into cognitive platforms capable of supporting diverse learning paths. This transition establishes the system as the primary unit of design, shifting educational value from the completion of a specific model to the mastery of an infinitely adaptable creative language.

The analysis of the contemporary period highlights a fundamental fragmentation in the logic of construction. Unlike the unified trajectory of the modernist era, current design philosophies are pulling in opposing directions: towards high-tech complexity and towards intuitive simplicity; towards physical permanence and towards digital fluidity. A comparative analysis of recent studies revealed three critical tensions defining this era: the cognitive trade-offs of structural divergence, the democratisation of engineering through interface innovation, and the redefinition of play value in hybrid systems. The divergence between stacking (LEGO) and skeletal (K'NEX, VEX) systems is not only about visual style, but also changes how users think. While classic construction toys enhance mental rotation and spatial skills (İleri *et al.*, 2023), the introduction of dynamic, kinetic systems expanded this pedagogical scope. K. Kshirsagar *et al.* (2025) noted that kinetic construction kits such as MorphBlox provide specific affordances for embodied mathematics, allowing users to physically feel and manipulate geometric transformations that are difficult to grasp in static models. This suggests that construction evolved from representation (building a house) to simulation (building a machine). However, as emphasised by C. Bartneck & E. Moltchanova (2018), the increasing number of specialised parts can make systems difficult for beginners to learn. In contrast, new kinetic systems aim to bridge this gap by embedding complex mathematical rules into the physical behaviour of the blocks themselves, rather than requiring the user to engineer them from scratch.

The shift from mechanical interlocking to magnetic and intangible connections represents a democratisation of design authority. This aligns with findings by N. Talu *et al.* (2024) in Fab Lab environments, in which accessible prototyping tools allow students to bypass constraints of mass-produced commercial categories and engage in unstructured play that fosters deeper creativity. The integration of digital logic constitutes the most radical shift. The system is no longer contained within the physical box but extends into the digital realm. Y. Lyu *et al.* (2024) suggested that the future of toys lies in reconnected experiences, where the tactile benefits of physical toys are merged with the interactivity of digital layers. This is echoed by Z. Chen *et al.* (2024), whose study on modular interactive designs (Softy's Magic Touch) demonstrated that systematicity can now be applied to non-systematic objects (such as plush toys) through modular electronic add-ons. This suggests a paradigm shift based on which the toy is no longer a finished product but a platform for cyber-physical creation. However, this hybridisation requires careful balance.

The definition of systematicity expanded to include the ethical dimension of material lifecycles. C. Yadou *et* *al*. (2025) proposed a holistic sustainable design system that integrates life cycle assessment with modular manufacturing, arguing that the logic of construction must now extend beyond physical assembly to include the entire environmental footprint of the product from extraction to disposal. Complementing this macro-view with material innovation, M.J.M. Kamil & S.A. Shaukat (2023) indicated through the "Ebee" robot case study that biodegradable polymers such as polycaprolactone can successfully replace toxic plastics while retaining the complex, interchangeable modularity required for modern construction play. This shift confirms that contemporary toy systems are evolving from purely functional structures to environmentally responsive artefacts.

Thus, the modern construction toy system evolved from a single standard to a diverse ecosystem of logic. Through MorphBlox's kinetic geometry, Magnetact animals' magnetic interaction principles, and the digital integration of modern LEGO systems, the definition of a "construction toy" expanded considerably. It is no longer limited to assembling individual components, but extends to organising and manipulating complex systems that include structural, magnetic, or computational elements. Construction toys now not only promote the development of spatial and cognitive skills, but also open new opportunities for interactive and multidimensional learning. This transition requires users to think strategically and remain flexible in problem-solving approaches, ensuring a more comprehensive and dynamic educational process.

CONCLUSIONS

The study demonstrated a clear evolutionary trajectory of educational construction toys, transforming from closed instructional systems to open, socially engaged platforms. First, analysis of early designs such as Froebel's gifts and Meccano showed that 19th-century toys functioned as closed systems. These artefacts prioritised the transmission of specific philosophical or engineering knowledge, where the design logic dictated a singular, correct outcome. Subsequently, the study indicated that the industrial-modernist era shifted this paradigm towards open systems. The case study of LEGO demonstrated how the innovation of clutch power acts as a physical enabler for system empowerment, decoupling mechanical construction from ideological instruction. The analysis showed that this shift allows toys to evolve from tools of replication into platforms for infinite creative expression, as seen in the separation of narrative and function in Lincoln Logs. In the contemporary era, results indicated a multidimensional divergence. The comparison between K'NEX's skeletal logic and LittleBits' digital overlays confirmed that modern systematicity expanded to include kinetic, intangible, and cyber-physical connections, reflecting a complexification of play. Future studies should extend this genealogical framework to explore cross-cultural variations in toy design, particularly in non-Western contexts. Furthermore, cognitive science experiments are recommended to quantify how these evolving construction logics – specifically the shift from static stacking to dynamic engineering – impact children's spatial reasoning and problem-solving strategies in real-time interaction.

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REFERENCES

[1] Bartneck, C., & Moltchanova, E. (2018). LEGO products have become more complex. *PloS One*, 13(1), article number e0190651. doi: 10.1371/journal.pone.0190651.

[2] Basic Fun. (n.d.). *K'NEX 3-in-1 classic amusement park building set*. Retrieved from https://www.basicfun.com/product/knex-thrill-rides-3-in-1-classic-amusement-park-building-set/.

[3] Chen, Z., Zhang, Z., Pan Ding, A., Wang, X., & Xin, Q. (2024). Softy's Magic Touch: Altering old toys into interactive friends! In *Companion of the 2024 ACM/IEEE international conference on human-robot interaction* (pp. 1217-1220). New York: Association for Computing Machinery. doi: 10.1145/3610978.3641275.

[4] Codner, A., & Lauff, C.A. (2024). Designing toy prototypes: An exploration of how fidelity affects children's feedback on prototypes. *Design Science*, 10, article number e33. doi: 10.1017/dsj.2024.42.

[5] Du, G., Du, Y., Yang, J., & Liu, X. (2023). Design and evaluation of children's assembled toys based on mortise and tenon structure and zodiac modeling. *Journal of Industry and Engineering Management*, 1(1), 44-53. doi: 10.62517/jiem.202303107.

[6] Esta, M. (2017). What is the Pink Tower... and why is it pink? *Capital Montessori School*. Retrieved from https://www.montessori.school.nz/blog-capital-montessori-parenting-early-childhood-education/2017/10/15/what-is-the-pink-towerand-why-is-it-pink.

[7] Fernsebner, S.R. (2003). A people's playthings: Toys, childhood, and Chinese identity, 1909-1933. *Postcolonial Studies*, 6(3), 269-293. doi: 10.1080/1368879032000162167.

[8] Finlay, F., Copsey, J., & Guiton, G. (2023). The history of toys. *Archives of Disease in Childhood*, 108(2), A246-A247. doi: 10.1136/archdischild-2023-rcpch.392.

[9] Fischertechnik official website. (n.d.). Retrieved from https://www.fischertechnik.de/en.

[10] Fu, J., & Chen, J. (2021). The intelligent redesign of traditional Chinese wooden toys from embodied cognition. In *2021 IEEE 12th international conference on software engineering and service science (ICSESS)* (pp. 239-242). Beijing: IEEE. doi: 10.1109/icsess52187.2021.9522284.

[11] Gök, B., & Sürmeli, H. (2022). The effect of scientific toy design activities based on the engineering design process on secondary school students' scientific creativity. *Asian Journal of University Education*, 18(2), 692-709. doi: 10.24191/ajue.v18i2.17987.

[12] Gryshchenko, I., Yezhova, O., Pashkevich, K., & Biryukova, Y. (2024). Research and creative activity in the design field: Intersections of science, art, and engineering. *Leonardo*, 57(3), 279-285. doi: 10.1162/leon_a_02521.

[13] Guijarro, V. (2021). Scientific and construction games in education and industry: Values and interactions in Spain (1920-1936). *History and Memory of Education*, 14, 511-546. doi: 10.5944/hme.14.2021.27412.

[14] İleri, Ç.İ., Erşan, M., Kalaça, D., Coşkun, A., Göksun, T., & Küntay, A.C. (2023). Malleability of spatial skills: Bridging developmental psychology and toy design for joyful STEAM development. *Frontiers in Psychology*, 14, article number 1137003. doi: 10.3389/fpsyg.2023.1137003.

[15] Kamil, M.J.M., & Shaukat, S.A. (2023). The implementation of polycaprolactone (PCL) as an eco-friendly material in toy design development. *Journal of Graphic Engineering and Design*, 14(1), 5-17. doi: 10.24867/JGED-2023-1-005.

[16] Kirk, C.G. (1961). *Toy building brick (United States Patent No. US3005282A)*. Retrieved from https://patents.google.com/patent/US3005282A/en.

[17] Komis, V., Karachristos, C., Mourta, D., Sgoura, K., Misirli, A., & Jaillet, A. (2021). Smart toys in early childhood and primary education: A systematic review of technological and educational affordances. *Applied Sciences*, 11(18), article number 8653. doi: 10.3390/app11188653.

[18] Kshirsagar, K., Quiterio, A.S., & Smith, M. (2025). MorphBlox: Bridging play and mathematics through kinetic tessellations. In *Proceedings of the 19th international conference on tangible, embedded, and embodied interaction* (article number 82). New York: Association for Computing Machinery. doi: 10.1145/3689050.3706001.

[19] Legaard, J.F., & Skovbjerg, H.M. (2024). Affordances of construction toys. *The Design Journal*, 27(2), 226-245. doi: 10.1080/14606925.2023.2265183.

[20] Littlebits official website. (n.d.). *STEAM+ Coding Kit. The ultimate classroom solution*. Retrieved from https://littlebits.com/kits/steam+coding.

[21] Lloyd, W.J. (1920). *Toy-cabin construction (United States Patent No. US1351086A)*. Retrieved from https://patents.google.com/patent/US1351086A/en.

[22] Lyu, Y., *et al.* (2024). Let go of the non-digital past: Embracing the 4Rs for a new life –recallable, relaxing, repayable, and reconnected experiences. In *Design, user experience, and usability: 13th international conference on human-computer interaction* (pp. 128-140). Verlag: Springer. doi: 10.1007/978-3-031-61362-3_10.

[23] Magformers official website. (n.d.). Retrieved from https://magformers.com/products/basic-plus-26pc-set.

[24] Mindrup, M. (2023). From doll's house to dream house. *Architectural Theory Review*, 27(2), 277-297. doi: 10.1080/13264826.2023.2205153.

[25] Montessori, M. (1912). *The Montessori method: Scientific pedagogy as applied to child education in "the children's houses" with additions and revisions*. New York: Stokes.

[26] Morgenstern, L. (1882). *Friedrich Fröbel: Commemorative publication marking the centenary of his birth*. Berlin: Walther & Apolant. doi: 10.3931/e-rara-87379.

[27] Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. New York: Stokes.

[28] Provenzo, E.F. (2009). Friedrich Froebel's gifts connecting the spiritual and aesthetic to the real world of play and learning. *American Journal of Play*, 2(1), 95-99.

[29] Saikia, H., Bhattacharyya, N., & Baruah, M. (2023). Review of educational toy design elements and their importance in child development from a cognitive perspective. *Pharma Innovation*, 12(5), 1030-1033. doi: 10.22271/tpi.2023.v12.i5n.20049.

[30] Skliarenko, N., Shkliaieva, N., & Pylypiuk, L. (2023). Ukrainian folk games and toys: Levels of integration into modern visual culture. *Art History and Criticism*, 19(1), 95-111. doi: 10.2478/mik-2023-0008.

[31] Talu, N., Yurt, C., & Çolak, C. (2024). Fab Lab toys from a second-grade industrial design studio: Expanding the boundaries of toy design. *International Journal of Designed Objects*, 18(2), 157-183. doi: 10.18848/2325-1379/CGP/v18i02/157-183.

[32] The Brighton Toy and Model Museum. (2022). *Category: Meccano*. Retrieved from https://www.brightontoymuseum.co.uk/index/Category:Meccano.

[33] The Lego Group. (2021). *LEGO® Friends and gendered play*. Retrieved from https://www.lego.com/cdn/cs/set/assets/blt286410a1ba5b807a/bits_n_bricks_s01e07_lego_friends_a_conversation_feature_and_transcript.pdf.

[34] Yadou, C., Shamsudin, R., Tawakkal, I.S.M.A., Me, R.C., & Basri, M.S.M. (2025). Analyzing product design system application children's toys based on sustainable materials and processes. *Entertainment Computing*, 54, article number 100947. doi: 10.1016/j.entcom.2025.100947.

[35] Yan, Y., Xu, Z., Zhu, L., & Lv, J. (2024). Innovative design model for the mortise and tenon structure. *BioResources*, 19(3), 5413-5434. doi: 10.15376/biores.19.3.5413-5434.
[36] Yang, N., & Yezhova, O. (2025). Designing educational construction toys with traditional Luban lock structures: A case study of "Phoenix stamp". In *Proceedings of VII international scientific conference "Topical issues of modern design"* (pp. 269-272). Kyiv: Kyiv National University of Technologies and Design.
[37] Yasu, K., & Ishikawa, M. (2021). Magnetact animals: A simple kinetic toy kit for a creative online workshop for children. In *CHI conference on human factors in computing systems* (article number 198). New York: Association for Computing Machinery. doi: 10.1145/3411763.3451533.

Логіка конструювання: еволюція філософії дизайну в розвивальних іграшках-конструкторах

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Анотація. Метою дослідження була реконструкція генеалогії дизайнерських філософій, що трансформували конструктори від закритих інструктивних систем до відкритих платформ і, зрештою, до соціально залучених артефактів. У цьому дослідженні використано якісний історичний метод з використанням порівняльного аналізу кількох прикладів на основі першоджерел (патентів, праць дизайнерів та освітян), історичних комерційних матеріалів та ключових освітніх і філософських текстів, доповнених сучасними науковими та галузевими джерелами. Аналіз структуровано навколо двох вимірів – систематичності (механізми зв'язку, матеріали, модульна логіка) та дидактизму (освітні філософії, культивовані навички та закодовані культурні цінності) – для простеження еволюції навчальних конструкторів-іграшок. Кожен приклад проаналізовано за двома вимірами: систематичність (матеріали, механізми з'єднання, модульна логіка) та дидактизм (освітня філософія, навички, що розвиваються, культурні цінності). Виявлено чітку траєкторію еволюції. У ранній період (1840-ті – початок XX ст.) конструктори функціонували як закриті системи, призначені для передачі філософських або інженерних знань. В індустріально-модерністський етап (початок XX ст. – 1980-ті), завдяки інноваціям, зокрема «силі зчеплення» LEGO, іграшки-конструктори трансформувалися у відкриті платформи, збагачені наративними та системними підходами. У сучасний період (1990-ті – дотепер, 2026) зафіксовано диверсифікацію дизайнерської логіки з орієнтацією на соціальні та екологічні виклики, зокрема гендерну репрезентацію й сталі матеріали. В роботі обґрунтовано, що іграшки-конструктори виступають не лише розвивальними іграшками, а й освітніми артефактами, які кодують світогляди, педагогічні стратегії та суспільні цінності. Результати можуть бути використані дизайнерами освітніх іграшок, педагогами та дослідниками матеріальної культури як методологічна основа для створення й застосування конструкторів, що поєднують технологічний дизайн, педагогічні цілі та культурний контекст

Ключові слова: дизайн іграшок; системний дизайн; модульна платформа; матеріальна культура; педагогічні артефакти; освітній інструмент