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Exploring modular systems and construction logic through practice-based design of a constructive block toy

Nurul Fitriana Bahri [a,1,*], Ica Ramawisari [a,2], Evilya Meyliana Purwanto Putri [a,3], Asep Sufyan Muhakik Atamtajani [a,4]

[a] Desain Produk, Telkom University, Jl. Telekomunikasi. 1, Terusan Buah Batu - Bojongsoang,, Indonesia
[1] nurulfitrianabahri@telkomuniversity.ac.id*; [2] ramawisari@telkomuniversity.ac.id; [3] evilya.mpp@gmail.com;
[4] krackers@telkomuniversity.ac.id
* Corresponding Author

ABSTRACT

This article presents a practice based research in product design focusing on the exploration of modular form systems and construction logic through the design process of a constructive block toy. Creative practice is positioned as the primary mode of inquiry, where knowledge is generated through iterative making, form exploration, and material experimentation. A qualitative descriptive approach is employed within a practice-based research framework to examine design decisions emerging through iterative form exploration, prototyping, and material experimentation. Data are collected through visual analysis of existing products, literature review, exploratory sketching, physical prototyping, and reflective documentation. The resulting design artifact demonstrates how a limited set of modular elements can generate diverse spatial configurations through systematic construction rules. This research identifies how proportional variation, construction rules, and material-dependent connection tolerances interact to support formal variation while maintaining structural stability.

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1. Introduction

Research in art and design increasingly recognizes creative practice as a mode of knowledge production in which inquiry can occur through designing, making, testing, and reflecting on material outcomes. In design practice research, the design activity is not treated solely as a means of producing an artifact, but as a situated process through which research questions can be investigated and knowledge can be articulated [1]. Kaszynska and Kimbell emphasize the importance of distinguishing design practice research from design practice alone by identifying the conditions under which practice becomes research and the forms of knowledge and outcomes that emerge from it [2]. Similarly, recent discussions of creative practice research highlight the need to clarify the relationship between research questions, design processes, methods, and contributions to knowledge [3].

This positioning is particularly relevant to product design, where decisions concerning form, proportion, material, and construction frequently develop through iterative cycles of sketching, making, testing, and refinement. Constructive block toys provide a relevant context for such an inquiry because their design is fundamentally based on relationships among discrete elements, connection mechanisms, and possible configurations. Rather than functioning as isolated objects, constructive toys establish systems in which individual components can be repeatedly combined to produce different spatial arrangements. Recent research has examined construction toys from several perspectives.

Legaard and Skovbjerg, for example, investigated the relationship between toy affordances and play experiences, emphasizing how the properties of construction toys influence the actions and possibilities available during play [4]. Akdemir and Sevimli-Celik examined preschool children's spatial and architectural design skills during constructive play, demonstrating the relevance of construction activities to spatial exploration [5]. These studies provide important insights into the experiential and developmental dimensions of constructive toys, but their primary focus is on what users can do with construction systems rather than on how the modular form and construction system itself can be developed through design practice.

A related body of research examines modularity from the perspective of product architecture. Product modularization has been studied as a means of structuring products into relatively independent modules and managing relationships among components, interfaces, and systems [6]. Mertens *et al.* identify the increasing importance of system architecture within contemporary product modularization research, while Monetti and Maffei show that assembly considerations are increasingly incorporated into product architecture during conceptual design [7], [8].

More recent approaches have also proposed structured methods for identifying modules and their relationships during early product development [9], [10]. These studies establish modularity as a systematic approach to organizing product architecture and assembly. However, they primarily address modularity in relation to product development, functional decomposition, assembly, and system complexity rather than the exploration of formal variation in constructive toy systems through iterative design practice.

The intersection between these two areas remains comparatively under-articulated. Existing research provides substantial understanding of construction toys as systems that afford particular forms of play and spatial activity, while modular product research provides established concepts for understanding modules, interfaces, assembly, and system architecture [11]. What remains less explored is how iterative design practice can be used to investigate the relationship between modular form transformation, construction logic, and material behavior in the development of a constructive block toy.

In particular, there is limited articulation of how design decisions concerning the geometry and proportion of modules are connected to the rules governing their assembly, and how those relationships are subsequently refined through physical prototyping and material experimentation. From a practice-based research perspective, this issue is important because the knowledge generated during such iterations may not be fully represented by the final artifact alone; it also resides in the documented relationships between design problems, material responses, design modifications, and resulting configurations [12].

This study therefore addresses the following research question: How can practice-based design exploration generate knowledge about the relationship between modular form, construction logic, and material behavior in the development of a constructive block toy? The study does not investigate the pedagogical or developmental effects of constructive toys, nor does it evaluate user performance. Instead, the inquiry focuses on the design process through which modular forms are explored, construction rules are established, and physical prototypes are iteratively refined. User-related considerations are treated as design constraints concerning module scale, handling, and ergonomic relevance rather than as the primary object of empirical investigation.

The research employs a qualitative descriptive approach within a practice-based research framework. The inquiry proceeds through comparative analysis of existing constructive block toy systems, exploratory sketching and geometric transformation, physical prototyping, material experimentation, and reflective evaluation. Through these activities, the study examines how a limited set of modular elements can be transformed and combined through defined construction relationships, and how material and dimensional characteristics affect the resulting system behavior. The practice-based orientation allows the design process itself to function as an investigative site, while the qualitative descriptive approach provides a means of documenting and interpreting the design decisions and observable changes that emerge across iterations.

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The contribution of this study is therefore threefold. First, it articulates a practice-based process for transforming basic geometric primitives into a coordinated modular form system through proportional variation, subtraction, extension, and orientation. Second, it identifies stacking, slotting, and passive interlocking as construction relationships through which modular elements can generate varied spatial configurations while maintaining a coherent system. Third, it provides practice-derived insights into the relationship between connection tolerance, material properties, and structural stability, demonstrating how these factors influence subsequent design decisions during physical prototyping. Rather than proposing universal principles for all constructive toys, the study positions these findings as design knowledge derived from the development and evaluation of the specific constructive block toy system investigated in this research.

2. Method

2.1. Methodological Position

This study employs a qualitative descriptive approach within a practice-based research framework. The qualitative descriptive approach is used as the primary research approach to describe and interpret the observations, design iterations, prototype outcomes, and material responses generated throughout the development process. The practice-based research framework positions the design practice itself as a site of inquiry, in which designing, making, testing, and reflecting are used to investigate a research question and generate design knowledge [13]. Practice-based research differs from design practice conducted solely for professional or creative purposes because the design activities are undertaken as part of a structured inquiry and are accompanied by the articulation of the knowledge generated through practice [14].

In this study, the artifact is therefore not considered the sole research output. The documented process of exploring forms, developing construction mechanisms, testing materials, evaluating prototypes, and modifying design decisions constitutes the empirical basis of the inquiry. The emphasis on designing, making, and reflecting also acknowledges that aspects of design knowledge may emerge through direct engagement with materials and artifacts and may not be fully articulated in advance. This tacit dimension of knowledge is relevant to practice-based inquiry because understanding can develop through the act of making and responding to material and prototype conditions [15].

The qualitative descriptive approach and practice-based research framework serve complementary functions. Practice-based research establishes the methodological position of designing and making as a means of inquiry, while qualitative description provides an approach for systematically presenting and interpreting the observable conditions and outcomes generated during the process [14]. This combination is appropriate because the research question concerns how relationships among modular form, construction logic, and material behavior can be investigated through iterative design development. The study does not seek to measure user behavior or establish statistically generalizable relationships; instead, it examines how design decisions develop in response to observations obtained through product analysis, sketching, prototyping, and material experimentation.

2.2. Practice-Based Research Operationalization

Practice-based research was operationalized through an iterative sequence of existing-product analysis, form exploration, construction-system development, material experimentation, prototype evaluation, and reflection. These activities were not treated as independent stages, but as interconnected activities in which observations from one activity informed subsequent design decisions. The research process began by examining selected constructive block toys to identify their formal characteristics and construction mechanisms. The resulting observations were used as references for exploring alternative modular forms through sketching and geometric transformation. Selected forms were subsequently developed into physical prototypes to investigate their construction behavior.

Prototype testing then provided observations concerning connection fit, dimensional tolerance, stability, and configuration, which informed modifications to the form and construction features. Material trials were conducted in parallel to examine how material characteristics affected fabrication and connection performance. The operational relationship between design practice and research inquiry was therefore structured as in Fig. 1.

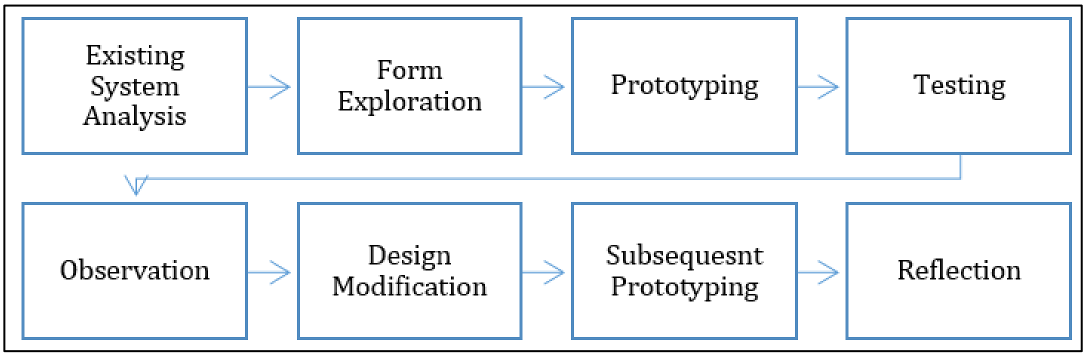

Fig. 1. Operationalization of Practice-Based Research in the Development of the Modular Construction System

Each iteration provided an opportunity to examine a design condition, introduce a modification, and observe its consequences in the following prototype. The design process thus functioned as an iterative inquiry through which design knowledge concerning modular form, construction logic, and material behavior was progressively articulated [2].

2.3. Data Sources and Collection

The empirical material was generated through the design practice undertaken throughout the research process. It consisted of selected constructive block toy products, exploratory sketches, physical prototypes, material trials, and documentation of design iterations, which were used to examine the development of modular forms, construction mechanisms, and material behavior.

1) Comparative Analysis of Existing Products

Three existing constructive block toy systems were examined as references for the development of the proposed system. The selected products represented different construction approaches, namely gravity-based stacking, magnetic connection, and magnetic edge connection. The products were selected based on their relevance to the research focus on constructive systems and their ability to demonstrate distinct relationships between discrete modules and construction mechanisms.

The analysis focused on form characteristics, module relationships, construction mechanisms, and configuration possibilities, particularly the dominant geometric forms and proportions, relative dimensions and orientations of modules, methods of connecting individual elements, and the ways in which these mechanisms enable elements to be combined and rearranged. The purpose of this analysis was not to evaluate the commercial products or user preferences, but to establish design references for subsequent exploration of modular form and construction logic.

2) Form Exploration

Form exploration was conducted through iterative sketching and geometric transformation. The exploration began with basic geometric forms that were modified through changes in proportion, subtraction, extension, and orientation. The sketches were assessed according to their potential to function as components within a modular construction system.

Particular attention was given to the relationship between the geometry of each element and its potential connection with other elements. Forms that did not provide meaningful construction relationships or produced undesirable spatial conditions were not developed further. Selected forms were subsequently translated into physical prototypes, allowing the formal exploration to be examined beyond two-dimensional representation.

3) Construction-System Development

The construction system was developed through physical prototyping. Three construction mechanisms were explored: stacking, slotting, and passive interlocking. The prototypes were repeatedly assembled and disassembled to examine the interaction between module geometry and connection features. The evaluation focused on connection fit, dimensional tolerance, assembly behavior, and structural stability.

Observations obtained during these trials informed modifications to the dimensions, proportions, and connection features of the modular elements. This process allowed construction logic to be examined concurrently with form development rather than being treated as a separate technical consideration.

4) Material Exploration

Material experimentation was conducted using ABS, PLA, and wood. These materials were selected to examine how different material characteristics affected the fabrication and construction behavior of the modular system. The material trials focused on observable differences in dimensional precision, surface interaction, connection fit, and structural response.

The results were compared across prototypes to inform subsequent material and dimensional decisions. The material investigation was therefore not intended as a comprehensive material-performance study. Instead, it functioned as part of the design development process by revealing practical implications of material selection for the proposed construction mechanisms.

5) Prototype Evaluation and Reflective Documentation

Prototype evaluation was conducted through repeated assembly and disassembly and through observation of different configurations produced by the modular elements. The evaluation considered fit, tolerance, stability, and consistency of connection. Observations were documented throughout the iterative development process. When a prototype produced an undesirable connection, unstable configuration, or fabrication problem, the relevant design characteristic was reconsidered and modified in the subsequent iteration.

The reflective documentation therefore established a traceable relationship between observed condition, design problem, design modification, and prototype outcome. This relationship constituted an important source of evidence for identifying the design knowledge generated through practice.

2.4. Data Analysis

The collected material was analyzed through comparative analysis, iterative design analysis, and reflective interpretation, consistent with the qualitative and practice-based orientation of the study [2]. Rather than applying a predefined coding or thematic analysis procedure, the analysis focused on identifying relationships between observations generated during the design process and the design decisions that followed. This approach is consistent with practice-based research, in which knowledge can emerge through the iterative relationship between designing, making, observing, and reflecting [6]. The analysis began with a comparison of the three existing constructive toy systems based on their form characteristics, module relationships, construction mechanisms, and configuration possibilities.

This comparison established design references and helped identify characteristics relevant to the development of the proposed modular system. The exploratory sketches and physical prototypes were then examined across successive iterations by tracing changes in form, proportion, orientation, connection features, and dimensions. These changes were considered in relation to the conditions observed during prototyping to determine how specific observations informed subsequent design decisions. The material trials were similarly examined by comparing observable differences in fabrication quality, dimensional precision, connection fit, and structural behavior.

These observations were interpreted in relation to the corresponding prototype configurations to identify their implications for subsequent material and construction decisions. The analysis therefore did not treat material testing as an isolated technical assessment, but as part of the iterative design inquiry. Finally, observations generated throughout the design process were interpreted through reflection on their relationship with design decisions and prototype outcomes. Rather than treating each observation as an isolated result, the analysis traced how an observed condition led to the identification of a design problem, informed a modification in form, construction, or material, and subsequently affected the prototype outcome. The relationship between these analytical stages is illustrated in Fig. 2 [9].

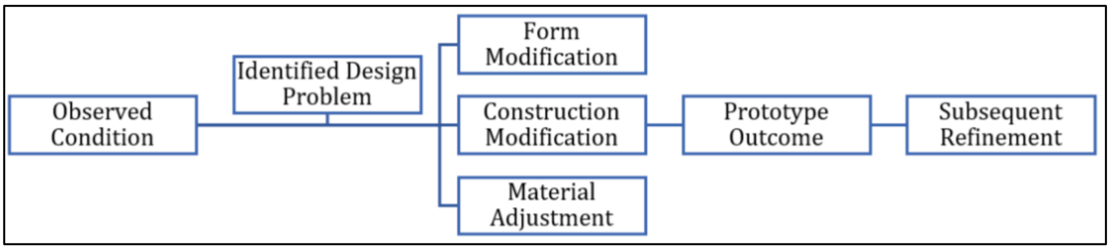

Fig. 2. Analytical Process for Tracing Design Decisions and Prototype Outcomes

This analytical sequence enabled the study to trace the development of design decisions across successive iterations and to identify how prototype outcomes informed subsequent refinement. In this way, the analysis moved beyond documenting the design activities themselves and focused on the knowledge generated through the relationships between observation, design modification, and making [9].

2.5. Research Process

The research process was structured as a sequence of interconnected activities that operationalized the practice-based orientation of the study as illustrated in Fig. 3.

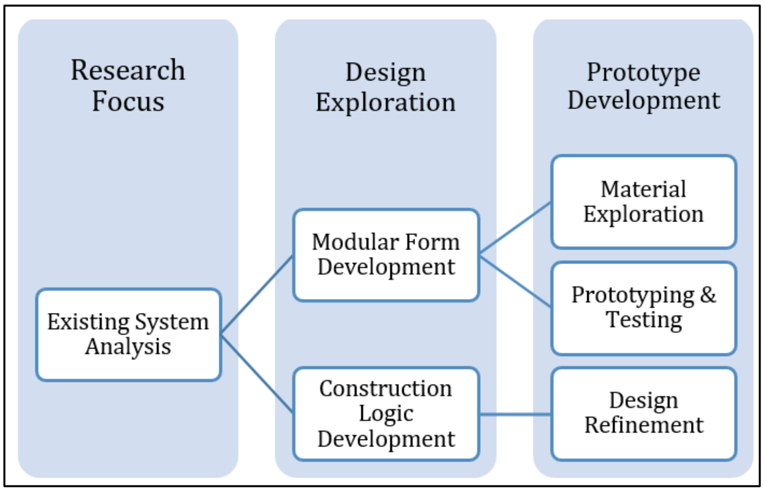

Fig. 3. Research Process for the Practice-Based Development of the Modular Construction System

The process was iterative rather than strictly linear, as findings from prototyping and testing informed subsequent design refinement. Existing-system analysis established the initial design references, while form and construction exploration translated these references into alternative modular configurations. Material exploration and physical prototyping then provided empirical observations of fabrication quality, connection fit, dimensional precision, and structural behavior. These observations were used to refine the design and guide subsequent iterations. User-related considerations were treated as design constraints concerning the scale and handling of the modular elements rather than as independently measured user outcomes [16].

3. Results and Discussion

3.1. Findings from Existing Constructive Toy Analysis

To understand the dominant form systems and construction logic found in existing constructive block toys, a comparative analysis was conducted on three selected commercial products. The analysis focused on form characteristics, module relationships, construction mechanisms, and configuration possibilities, providing a design reference for the subsequent development of the proposed modular system.

These dimensions are relevant to constructive toys because the relationship between physical elements and their modes of connection influences how children can assemble, manipulate, and reconfigure the system [4], [5]. Based on Table 1, the comparison identified

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differences in how form and construction mechanisms determine the possible relationships between individual elements. The wooden city block set primarily uses basic geometric solids, including cubes, rectangular prisms, and cylinders, with stacking and gravity-based assembly.

This system provides stable configurations, but the resulting forms depend largely on the accumulation and repetition of individual blocks. In contrast, the magnetic block with ball-and-rail elements uses spherical connectors to establish relationships between modular frame elements, while the magnetic building block system uses planar geometric modules with magnetic edge connections.

These connection mechanisms allow elements to be oriented and combined in a wider range of configurations. The comparison also indicates that construction mechanisms influence the degree of configurational flexibility available within a constructive toy system. Stacking-based assembly relies primarily on positional stability, whereas connector-based systems establish more defined relationships between modules and allow alternative orientations. This observation is consistent with previous research emphasizing the role of construction mechanisms and affordances in shaping the ways construction toys can be assembled and explored [4], [5].

Table 1. Comparative Analysis of Existing Constructive Block Toy Systems

Product Type	Dominant Form System	Construction Logic	Visual and System Characteristics
Wooden city block set 	Basic geometric solids such as cubes, rectangular prisms, and cylinders	Stacking and gravity based assembly	Stable but limited formal variation, repetition of basic forms
Magnetic block with ball and rail 	Modular geometric frames combined with spherical connectors	Magnetic connection enabling flexible assembly	High configurational freedom, emphasis on linear and structural composition
Magnetic building blocks set 	Planar geometric modules such as triangles and squares	Magnetic edge connection	Enables complex structures, strong emphasis on geometric abstraction

From the perspective of the present design development, the analysis revealed an opportunity to investigate a system in which geometric form variation and construction logic are developed as interconnected design parameters. Rather than introducing a connection mechanism only to join predetermined forms, the subsequent design exploration therefore examined how changes in geometric form could generate different module relationships and construction possibilities.

3.2. Modular Form Exploration

Following the existing system analysis, modular form exploration was conducted through iterative sketching and geometric transformation. Basic geometric primitives were used as starting points and subsequently transformed through operations such as subtraction, extension, and rotation. This exploration was intended to investigate how geometric forms could be developed into constructive toy elements while maintaining possibilities for combination and rearrangement [17], [18]. As can be seen in Fig. 4.

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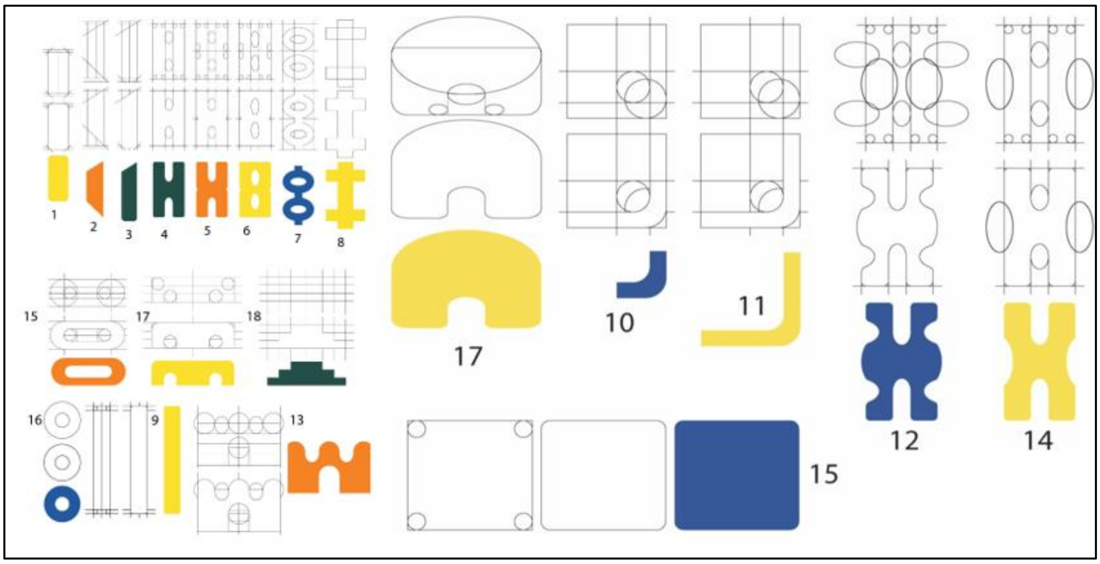

Fig. 4. Early Sketch Exploration of Modular Form Variations

Through sketching, multiple module configurations were explored, compared, and selectively developed before being translated into three-dimensional forms. Variation was generated primarily by manipulating proportion, orientation, and geometric relationships, allowing different configurations to be derived from a consistent geometric basis. The exploration therefore focused on expanding the possibilities of constructive form without introducing unrelated form types [17].

The selected forms were subsequently examined as potential modular components. Particular attention was given to their relative dimensions and orientations, which established the basis for further development of the construction system. At this stage, the exploration remained focused on form generation, while the feasibility of connecting and combining the resulting elements was examined through subsequent prototyping. As can be seen in Fig. 5.

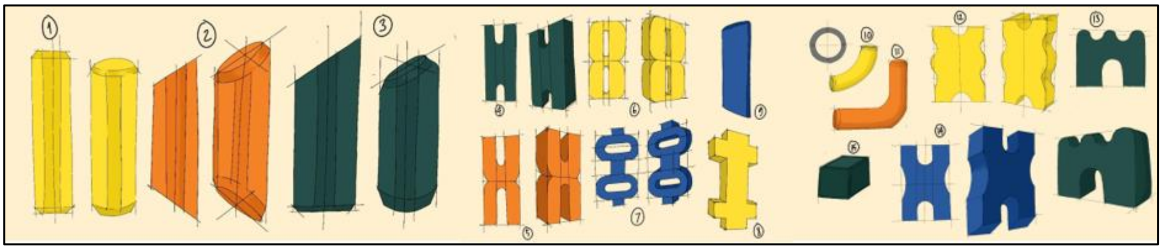

Fig. 5. Geometric Transformation from Basic Primitives to Modular Form Variations

The transformation process resulted in a set of selected modular forms with differentiated proportions and orientations while maintaining a common geometric basis. These forms were subsequently taken forward into physical prototyping to investigate how the developed geometries could be translated into viable construction mechanisms.

3.3. Construction-System Development

Following the modular form exploration, the selected forms were developed into physical prototypes to investigate how the modules could be connected and assembled. The development of the construction system considered the role of constructive toys as physical learning materials in which children interact with objects through manipulation, assembly, and configuration [19]. Previous studies on constructive block play have also examined how such activities provide opportunities for children to interact with and organize physical elements through play [20], [21]. In addition, block-based construction has been associated with opportunities for exploring mathematical concepts through the manipulation and arrangement of geometric elements [22]. These perspectives provided a broader context for considering the construction mechanism not only as a technical connection between modules, but also as a means of enabling repeated manipulation and configuration. As can be seen in Fig. 6.

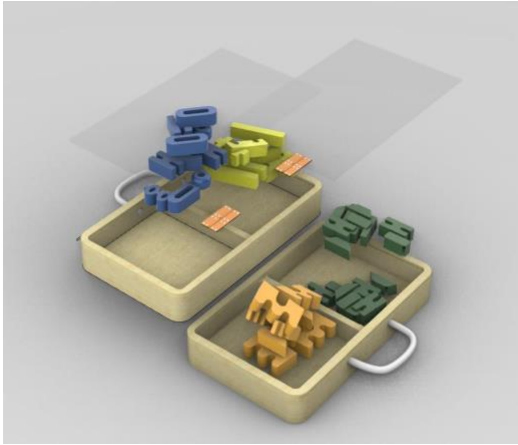

Fig. 6. Construction Logic and Assembly Rules Developed Through Stacking, Slotting, and Passive Interlocking Mechanisms

Based on the selected modular forms, the three mechanisms were developed as alternative ways of establishing relationships between the modules. Stacking relied on direct surface contact between elements, slotting introduced defined interfaces between complementary features, while passive interlocking integrated the connection directly into the module geometry. These mechanisms were subsequently examined through physical prototyping to identify differences in assembly behavior, connection fit, stability, and configuration possibilities.

1) Stacking

The first mechanism explored was stacking, in which modules were combined through direct contact between their surfaces. The prototypes were examined by varying the orientation and arrangement of the modules to observe how their geometric characteristics affected stability and configuration. The direct manipulation and arrangement of blocks are central characteristics of constructive play, in which children physically organize discrete elements to produce different configurations [19]. In the present exploration, stacking provided the most direct relationship between the module geometry and the resulting configuration.

2) Slotting

The second mechanism explored was slotting, in which complementary features were introduced to establish a more defined relationship between adjacent modules. The prototypes were examined by varying the dimensions and positioning of the slot and its corresponding connecting feature. This mechanism introduced a greater degree of constraint into the assembly process, requiring the user to align the elements before they could be combined. Such structured interaction remains relevant to constructive play, in which the manipulation and coordination of multiple elements can support children's collaborative activity [20], [21].

3) Passive-Interlocking

The third mechanism explored was passive interlocking, in which complementary geometries allowed the modules to retain one another without additional connectors. The prototypes were examined by varying the interlocking profile and the relative orientation of the connected elements. The mechanism provided a more integrated relationship between the geometry of the module and its construction behavior, allowing the connection to become part of the form itself. The resulting configurations also relate to the potential of block-based construction to support exploration of spatial and mathematical relationships through the manipulation and arrangement of geometric elements [22].

3.4. Material Exploration

Material exploration was conducted as part of the modular system development to examine how material and fabrication characteristics affected the realization of the developed forms and construction mechanisms. In modular product development, the relationship between individual modules, their interfaces, and the overall product architecture is an important consideration because changes at the component level can influence the behavior of the resulting system [7]. As can be seen in Fig. 7.

Fig. 7. Material Exploration of ABS, PLA, and Wood for Prototype Development

The material trials focused on observable differences in fabrication quality, dimensional precision, connection fit, and structural behavior. Particular attention was given to the accuracy of connecting features because the developed system required modules to maintain consistent relationships during assembly. This consideration is consistent with research on assembly-oriented modular architectures, which emphasizes the role of interfaces and assembly relationships in defining modular product structures [8]. The trials were conducted using prototype components incorporating the developed geometric forms and construction features. Differences in fabrication accuracy were examined in relation to the resulting fit of the connecting features. The observations showed that dimensional consistency was particularly important for slotting and passive interlocking, where small variations in the geometry of complementary features affected the ease of assembly and retention. The material trials therefore informed subsequent adjustments to module dimensions and connection tolerances. The exploration also demonstrated that material selection could not be considered independently from the construction system. The suitability of a material depended on its ability to reproduce the required geometry and connection features consistently. This finding is aligned with modular product architecture research, which treats the relationships among components and interfaces as integral to the development of modular systems [23], [24].

3.5. Prototype Evaluation and Iterative Refinement

The developed prototypes were evaluated through successive cycles of observation, design modification, and subsequent refinement. The evaluation focused on how changes in form, dimensions, connection features, and material conditions affected the behavior of the modular construction system. Rather than treating prototyping as a final validation stage, the evaluation was integrated into the design process, allowing observations from each prototype to inform subsequent design decisions. This iterative relationship between design practice, observation, and reflection is consistent with the practice-based research orientation adopted in this study [25]. The evaluation identified several conditions that required refinement during prototype development. Connection fit and dimensional tolerance were found to influence the ease of assembly and the stability of the constructed configurations. Minor adjustments to slot depth and module dimensions produced observable differences in how the elements engaged with one another. These observations led to modifications of the corresponding connection features, which were then examined through subsequent prototypes. As can be seen in Fig. 8.

Fig. 8. Physical Prototyping and Iterative Refinement of the Developed Modular Construction System

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The iterative process also showed that changes to connection geometry affected the resulting configuration of the system. Adjustments intended to improve stability could influence the orientation and combination of adjacent modules, indicating that construction performance was closely related to the geometric relationships established during form and construction-system development. The prototypes therefore served not only to realize the proposed design but also to reveal relationships between design decisions and material outcomes. The resulting prototype iterations demonstrated that refinement was achieved through repeated adjustment rather than through a single finalized design decision. Each observed condition provided a basis for identifying a design problem, modifying the relevant feature, and evaluating the resulting prototype outcome. The process consequently established a traceable relationship between observation, design modification, and prototype outcome, as represented in the analytical process presented in Fig. 2. In this sense, the evaluation contributed to the generation of design knowledge through practice rather than merely documenting the sequence of prototype development [25].

3.6. Configuration Possibilities of the Developed System

The developed modular system was further examined through the configuration possibilities generated by combining and rearranging the modules. The analysis focused on how the established module relationships, dimensional proportions, orientations, and construction rules enabled different spatial configurations while maintaining compatibility between elements. In modular product design, such relationships are fundamental because modular architectures organize products into relatively independent units while defining how those units interact within the overall system, see Fig. 9 [26], [27]. The configuration exploration further indicates that the established construction rules define the range of possible arrangements within the system. Modules can be combined in different orientations while maintaining compatibility between their interfaces, allowing formal variation without requiring additional component types. This finding demonstrates the role of modular architecture in enabling variation through the controlled relationships between modules [28], [29].

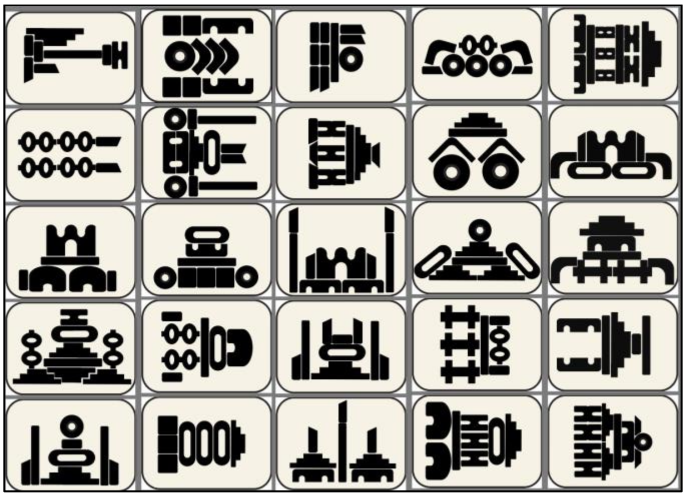

Fig. 9. Configuration Possibilities Generated Through Modular Combination and Rearrangement

The exploration also showed that configuration freedom was dependent on the consistency of the module interfaces. Modules with compatible connection features could be repositioned or combined in different orientations, whereas configurations that exceeded the established dimensional or connection relationships were constrained. Thus, the construction rules did not merely determine how individual modules were assembled; they also defined the design space within which alternative configurations could be generated.

3.7. Design Knowledge Generated through Practice

The iterative design process generated several forms of design knowledge concerning the development of a modular construction system. These findings emerged from the relationship between form exploration, construction-system development, material experimentation, and prototype evaluation, rather than from the application of a predefined analytical model. In accordance with the practice-based orientation of the research, the resulting knowledge is

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therefore understood through the design decisions and prototype outcomes produced throughout the process [13]. The iterative design process generated several forms of design knowledge concerning the development of a modular construction system. These findings emerged from the relationship between form exploration, construction-system development, material experimentation, and prototype evaluation, rather than from the application of a predefined analytical model. In accordance with the practice-based orientation of the research, the resulting knowledge is therefore understood through the design decisions and prototype outcomes produced throughout the process [13]. The study demonstrates that modular variation can be generated through the controlled transformation of a limited set of geometric elements. Changes in proportion, orientation, and geometric articulation produced differentiated module forms while maintaining the relationships required for subsequent assembly. The resulting configurations further demonstrated that variation could be achieved by rearranging existing elements rather than continuously introducing new component types. This characteristic reflects the broader potential of modular product systems to accommodate modification and variation while retaining an established system structure [30]. Such an approach is further demonstrated by LEGO-inspired construction systems in which modular elements can be combined and rearranged to produce different configurations [31], [32].

This understanding was further developed through the construction-system experiments. Connection features functioned not only as joining mechanisms but also as determinants of assembly behavior and configuration possibilities. Stacking, slotting, and passive interlocking influenced how modules could be combined, oriented, and stabilized, while adjustments to connection geometry and dimensional tolerance produced observable changes in prototype behavior. The development process therefore established construction logic as an integral part of the modular system, with the resulting configuration possibilities depending on the relationships established between its elements. The role of physical prototyping further demonstrated how design knowledge emerged through direct engagement with the developing system. Observations concerning dimensional accuracy, connection fit, stability, material conditions, and configuration were obtained through physical interaction with the prototypes and subsequently translated into design modifications. The iterative nature of this process allowed conditions that were not fully apparent during conceptual exploration to become visible through making and testing. The use of sketching and iterative design activity as a means of developing and externalizing design ideas further supports the role of practice in progressively shaping design decisions [33]. Taken together, these findings position the developed constructive block system as a modular design system in which form, construction logic, material, and configuration are interdependent. The knowledge generated through practice lies not only in the resulting physical artifacts, but also in the relationships identified between geometric transformation, module interfaces, assembly behavior, and configuration. This understanding emphasizes the importance of considering how individual elements operate within a larger system and how their relationships influence the resulting design outcomes [34]. The findings therefore reinforce the practice-based position of the study, in which design knowledge is generated through the iterative process of making, observing, modifying, and reflecting [35].

4. Conclusion

This study explored modular systems and construction logic through the practice-based design of a constructive block toy. The design process combined comparative analysis of existing constructive toy systems with modular form exploration, construction-system development, material experimentation, and iterative physical prototyping. Through these activities, the study examined how geometric form, connection mechanisms, material conditions, and configuration possibilities interact in the development of a constructive modular system. The findings demonstrate that modular variation can be generated through the controlled transformation of a limited set of geometric elements while maintaining the dimensional and relational conditions required for assembly. The exploration of stacking, slotting, and passive interlocking further demonstrated that construction mechanisms function not only as means of joining components, but also influence how modules can be oriented, combined, and reconfigured. Material exploration and iterative prototyping additionally showed that connection fit, dimensional accuracy, material conditions, and structural stability need to be considered together in developing the modular system. The contribution of the study lies in the design knowledge generated through practice, particularly in establishing the interdependent relationship between modular form, construction logic, and configuration. The developed constructive block toy demonstrates how a limited set of compatible modules can support multiple configurations through defined geometric and connection relationships. Rather than generalizing these findings to constructive toys as a whole, the study contributes a practice-based account of how modular systems and construction logic can be explored, developed, and refined through iterative design and physical prototyping..

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Declarations

Author contribution	:	NFB: research idea, analyzed the data, and wrote the article; CRM, EMM, AFM: data collection, analyzed the data and wrote the article.
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Conflict of interest	:	The authors declare no conflict of interest.
Additional information	:	No additional information is available for this paper.

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