

Preschool Environment Design Enhancing Neuroplasticity

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Abstract

In preschool settings, the environment plays a fundamental role in children's cognitive, physical and psychological development. Early childhood is recognized as a critical period for neuroplasticity, when the brain's ability to adapt and reorganize in response to environmental stimuli is at its peak. Neuroplasticity forms the foundation for the development of various skills, particularly fine motor skills, which involve the coordination of small muscle groups to perform precise and purposeful movements. This research examines the fundamental principles, methods and tools for designing and improving the physical environment of preschool institutions. The study aims to develop interior design modules for preschool settings that can serve as a universal model adaptable to various educational institutions. As a result of the research, a flexible spatial model is proposed for preschool institutions that adapts to specific layout conditions through the use of stable and modular systems, thereby creating an equitable educational environment for children. The implementation of the methodology developed in this study promotes children's psychological well-being and supports the development of fine motor skills and neuroplasticity. Furthermore, analytical research on environmental design provides a foundation for the optimal use of space and the inclusion of appropriate design elements, which underscores the relevance of this topic.

Keywords: Design for Children, Environmental Design, Fine Motor Skills, Neuroplasticity, Preschool Environment.

Introduction

Preschool education is widely recognized as a crucial period in human cognitive, emotional and social development, laying the foundation for an individual's future well-being and contribution to society. Early childhood education progresses through continuous stages of development and serves as a cornerstone of sustainable, equitable and inclusive education systems worldwide (1). Today, the sector remains in a dynamic phase of development, shaped by global trends and challenges that require innovative approaches and accessible policies. An analysis of recent studies indicates that, alongside state-run kindergartens, numerous private institutions operate with varying approaches to spatial design and educational management programs, resulting in unequal educational conditions. This study aims to create a healthy and equitable learning and developmental environment that promotes fine motor development and neuroplasticity in children. An adaptive environment, organized and designed in accordance with contemporary requirements, can positively influence the formation of a child's personality, enhance

educational outcomes and address various psychological and physical challenges. The principles of the proposed conceptual framework, particularly the application of a modular system, enable the implementation of improvements within existing preschool infrastructures, thereby underscoring the relevance of this research. The physical environment plays a fundamental role in early childhood development, particularly during the period when the brain demonstrates the greatest capacity for adaptation (2). Well-designed preschool environments support fine motor development and neuroplasticity by providing opportunities for exploration, manipulation and sensory engagement, thereby strengthening the cognitive and physical foundations required for lifelong learning. Modular and adaptable learning environments offer several educational advantages. They promote hand-eye coordination, precision, dexterity and neuroplasticity through flexible play scenarios; encourage creativity by allowing children to modify and participate in shaping their surroundings; support emotional and social development alongside fine motor skills;

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accommodate different age groups through adaptable spatial configurations; enable cost-effective maintenance through replaceable modules; and facilitate the integration of innovative educational approaches, including STEAM (Science, Technology, Engineering, Arts and Mathematics) and activity-based learning. Fine motor skills involve the precise control of the small muscles of the hands and fingers and are essential for activities such as writing, drawing and object manipulation. Neuroplasticity, defined as the brain's ability to reorganize and establish new neural connections in response to experience, is particularly pronounced from birth to approximately six years of age (3, 4). Together, these developmental processes provide the foundation for children's cognitive, physical and academic growth. Preschool environments that incorporate accessible materials, varied textures, interactive activities and flexible functional zones encourage independent exploration, strengthen motor control and stimulate sensory and cognitive development (5). Studies have shown that children exposed to environments rich in fine motor activities demonstrate enhanced development across physical, cognitive, language and socio-emotional domains (6). Adaptable furniture, open layouts and natural elements such as sand, water and plants further stimulate exploration and support neuroplasticity by providing diverse sensory experiences. However, the implementation of such environments remains challenging due to spatial and financial limitations and the lack of professional training for educators in development-oriented environmental design (7). Addressing these challenges through innovative design strategies, appropriate resource allocation and professional development can improve children's learning experiences while fostering creativity, problem-solving, adaptability and overall well-being (8, 9). To address the identified research gap, this study is guided by the following research question: How can an adaptive modular preschool environment be designed to support children's fine motor skill development and neuroplasticity while ensuring flexibility, sustainability and equitable learning conditions across different preschool settings? Accordingly, the objectives of this research are to: analyze international literature and best practices concerning preschool environmental design,

neuroplasticity and fine motor skill development; identify the key architectural, ergonomic, educational and sustainability principles applicable to adaptive preschool environments; and develop a conceptual modular design framework that can be adapted to different spatial configurations and educational requirements (10). Rather than testing a predefined hypothesis, the study synthesizes multidisciplinary evidence to establish a design framework that can serve as a foundation for future empirical validation and implementation.

Methodology

Research Design

This research is a design-based conceptual study that combines an integrative literature review with a comparative analysis of international preschool educational environments. Rather than collecting empirical data or conducting experimental testing, the study synthesizes multidisciplinary evidence from architecture, environmental design, developmental psychology, neuroscience, ergonomics, sustainability and education to develop a conceptual framework for adaptive preschool environments. An integrative review was selected because it enables the synthesis of theoretical, empirical and design-oriented knowledge across disciplines and is therefore appropriate for addressing the complexity of preschool environmental design.

The literature search included peer-reviewed publications indexed in internationally recognized scientific databases, as well as relevant international standards, educational guidelines and technical reports. The review focused on adaptive learning environments, neuroplasticity, fine motor development, environmental psychology, preschool architecture, ergonomic furniture, interactive educational technologies and sustainable design. Priority was given to recent peer-reviewed studies and internationally recognized standards to ensure the relevance and reliability of the evidence. A comparative analysis of international preschool environments, including kindergartens and child development centers, was conducted to identify common design principles, methods, technological solutions and educational strategies. Particular attention was given to environmental and educational factors that may support children's fine motor development and

neuroplasticity. The findings from the literature review and comparative analysis were synthesized to inform the proposed adaptive modular framework. The resulting framework provides a theoretical basis for future empirical validation and practical implementation.

Research Procedure

During the execution of the project, the following tasks were undertaken:

- a) Research and analysis of modern international experience in preschool institutions
- b) Design regulatory requirements for preschool institutions, mandatory infrastructure study
- c) Study of educational programs in preschool institutions, analysis of the justification of the importance of the environment from the perspective of the peculiarities of the process
- d) Determination of sustainable development principles in the design of fine motor and neuroplasticity development rooms in kindergartens
- e) The psychology of children of a given age group, identification of their interests and the main elements of creating an environment that promotes educational development
- f) Research and analysis of STEAM educational methodologies appropriate for preschool children
- g) Application of experience gained as a result of research work in the implementation of a conceptual project of adaptive environment design modules in modern preschool educational institutions

Development of the Adaptive Design Framework

The proposed adaptive preschool environment model was developed through a sequential process based on the synthesis of multidisciplinary research findings. First, the main factors influencing children's development in educational environments were identified, including spatial organization, sensory stimulation, ergonomic conditions, educational flexibility and sustainability. Second, existing preschool design approaches and international educational models were comparatively analyzed to identify common environmental requirements and effective design strategies. Based on these findings, the model was structured into four interconnected adaptive layers: spatial adaptation, sensory-environmental adaptation, multifunctional furniture adaptation

and interactive educational modules. Spatial adaptation addresses flexible room layouts and modular organization according to different preschool activities. Sensory-environmental adaptation incorporates adjustable lighting, temperature, color and material characteristics (11). Furniture adaptation comprises multifunctional modular chair-table systems designed according to children's ergonomic requirements (12). Interactive educational modules include transformable flooring, tactile walls and activity-based elements that support fine motor development and cognitive engagement. Together, these layers form an integrated adaptive environment in which architectural, educational and technological elements can be applied independently or combined according to the spatial conditions, educational objectives and available resources of different preschool institutions.

Environmental adaptation in the proposed design is based on the room configuration, dimensions and arrangement of modular elements, children's activities, sensory conditions such as lighting and temperature, adaptive furniture and interactive floor transformation. Spatial adaptation involves developing alternative layouts that accommodate different group sizes and activity types while maintaining appropriate levels of comfort, safety and usability. The spatial organization of preschool environments considers children's physical needs, movement patterns, safety, educational activities, circulation, accessibility, furniture arrangement and educator visibility. An allocation of approximately 3 m² of usable activity space per child is used as a planning reference, reflecting the importance of providing sufficient space for movement, play, individual activities and interaction (13). The proposed modular system therefore follows the principle of adaptable spatial allocation rather than a fixed layout, allowing the environment to be reorganized according to group size, activity type and institutional requirements. This flexibility enables modular components to be rearranged while maintaining functional circulation and appropriate conditions for active, collaborative and individual activities. Such spatial adaptability can reduce overcrowding, improve the functionality and usability of the environment and support diverse educational scenarios.

Depending on the regions, the areas allocated to kindergartens and the buildings, the rooms provided may have different sizes and shapes of layouts. In this case, modular system solutions can

create favorable conditions for the environment to become comfortable. Options for environmental adaptation depending on changes in layouts are presented in Figure 1.

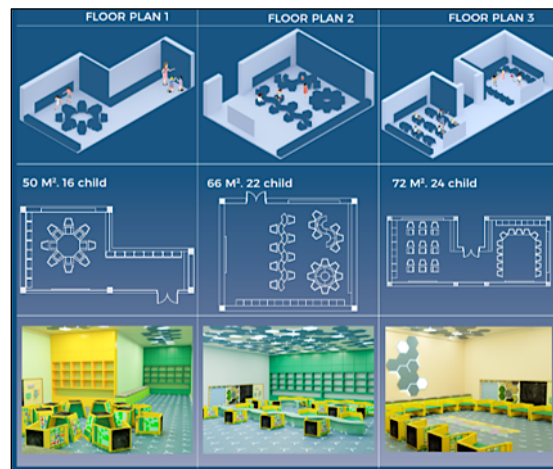


Figure 1: Module Combination Options, Types of Adaptation Depending on the Size and Shape of the Environment, Three-dimensional Images of Application Options

The lighting is regulated by a special system that provides the most appropriate level of lighting for children at a given moment. The lighting is uniform throughout the room; however, as numerous scientific studies prove and a person knows from his own experience, that when performing various tasks, the type of lighting plays an important role in a person's rational work. In this case, if children are actively engaged in the learning process, a lesson is being conducted, the lighting should be cold, because it creates alertness in children and during such lighting, children are more focused and attentive to the actions to be performed. If children are in an active play scenario, they need to be provided with slightly softer lighting in the room, as it weakens the impression of the lesson process and creates a more relaxed environment. The warmest lighting in the environment can and is encouraged to be used when, at the teacher's discretion, children have a break time or are listening to a fairy tale and are more free-form entertainment. A more intimate and comfortable environment for children can provide warm and cozy lighting, which will relieve children's tension and remove them from active play phases. The adaptive lighting strategy was developed considering quantitative lighting parameters appropriate for preschool environments. Illuminance levels should be adjusted according to the type of activity performed in the space, with higher levels recommended for focused

educational activities and lower levels for relaxation and rest periods. For example, general preschool learning environments typically require approximately 300–500 lux for educational activities, while softer lighting conditions may be appropriate for relaxation areas. The proposed lighting system also considers correlated color temperature (CCT) as an important factor influencing children's perception, attention and comfort. Cooler light conditions (approximately 4000–5000 K) may support alertness and concentration during structured learning activities, while warmer light conditions (approximately 2700–3000 K) can contribute to a calmer atmosphere during rest periods, storytelling and less intensive activities. In addition to visual comfort, the adaptive lighting concept incorporates principles of circadian lighting, recognizing that exposure to different light characteristics throughout the day can influence human biological rhythms, attention and well-being [14]. Therefore, the proposed system allows variation in lighting intensity and color characteristics according to activity type and time of day. From a sustainability perspective, energy-efficient LED technologies with adjustable intensity and color temperature provide advantages through reduced energy consumption, longer service life and improved environmental control. The integration of sensors and automated regulation systems can further optimize energy

use by adapting lighting conditions according to occupancy, daylight availability and educational requirements.

By the same principle, when we consider the ambient temperature, it is also important, since in the above options the activity of children was divided into 3 types: educational, playful and rest. Naturally, the physical activity of children also differs sharply during these 3 scenarios; therefore, the same temperature in the room can be appropriate for a maximum of two scenarios. If the

temperature is always high, children will have body temperature fluctuations and sweating, which can lead to deterioration of their health. If the temperature is always low, children will freeze in the rest and educational scenarios, as they will have a physically passive state, which will cause discomfort, a feeling of cold and unpleasantness. Based on these questions, as well as studies of norms, an appropriate temperature scale was developed, which was included in Figure 2.

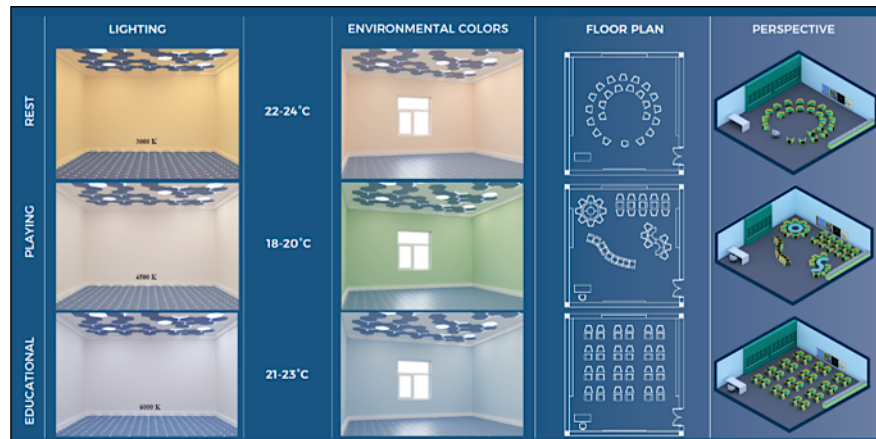


Figure 2: Types of Adaptation Depending on the Type of Children's Activity, According to Lighting, Temperature, Color of the Environment, Plans of Module Combination Options and Three-dimensional Images of Application Options

An adaptive environment, through lighting, temperature, color and spatial structure, encourages active sensory engagement in the child, which is vital for the development of fine motor skills and neuroplasticity. When the environment responds to the child's changing activity—for example, the light dims during rest or brightens during learning—the child's neurological system learns to recognize, differentiate and adapt to external stimuli. These processes promote the formation of synaptic connections, brain plasticity and neurological flexibility. The educational environment of a kindergarten should be multi-layeredly adaptive to respond to children's different activities, psychosomatic needs and developmental stages. The interrelated adaptation of light, temperature, color environment and spatial organization is not only a means of comfort but also a stimulus for development, contributing to the formation of neuroplasticity (15).

The combined adaptation of all these elements forms the flexible environment necessary to fully stimulate the cerebral, sensory and motor

development of children aged 2-6, especially in areas where it is necessary to create multifunctionality with limited resources.

Results and Discussion

The use of a modular system in preschool institutions is not only an innovative solution but also of vital importance. It provides a flexible, safe and comfortable environment that is easy to adapt and improve according to the needs of children and educators. The use of a modular system in various industrial elements that contribute to the organization of an adaptable environment is one of the main ideas of the design proposal. It allows creating similar and equal conditions in rooms of different sizes and features. Modular flooring is suitable for spaces that have changing classroom structures or that regularly reorganize the space. During the creation of the adaptive environment flooring module, several planar images were studied, which, after going through development stages, formed the final module. It is presented in Figure 3.

The module was developed taking into account the easy attachment of the repeating modular joint and the option of endless repetition, which allows the module to be used in everything from the smallest to the largest rooms. The modules are fastened together with a magnetic loop, which allows for very quick and secure fastening. The module has a

magnetic layer on all sides, which allows the modules to be connected to each other from all sides when repeated. The module has a light layer that turns on when desired, but can only start working when connected to another part. This mechanism allows the parts to work in a chain connection. It is presented in Figure 4.



Figure 3: Phased Path of Module Formation

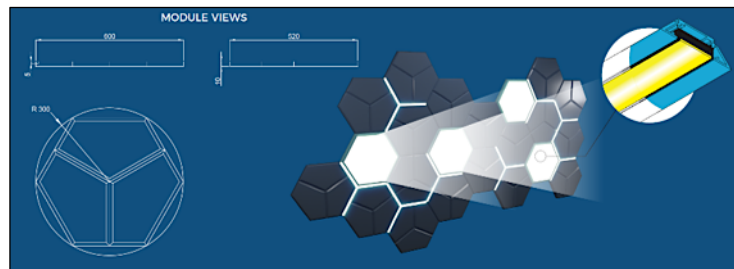


Figure 4: Views of the Ceiling Module, Light Installation Connection Node, Three-Dimensional Image

The interactive flooring system is designed as a modular, transformable surface composed of interconnected units that can be rearranged according to the spatial requirements and educational activities of the preschool environment. Each module functions as an independent element while maintaining compatibility with adjacent modules through the integrated connection system. This allows educators to modify the configuration of the floor according to different scenarios, including movement activities, sensory exploration, collaborative games and quiet learning areas. From an educational perspective, the interactive floor supports children's sensory, motor and cognitive development by creating opportunities for active exploration. Changes in texture, surface characteristics, lighting responses and spatial patterns encourage children to interact physically with the environment, improving balance, coordination, spatial awareness and fine motor-related activities. The modular approach also allows educators to select specific configurations according to children's developmental needs and educational objectives. Safety considerations were integrated into the design concept through the selection of child-appropriate materials, stable modular connections, non-toxic surfaces, rounded edges and slip-resistant characteristics. The

transformation mechanism is intended to operate gradually and safely without sudden changes that could create discomfort or risk during children's activities. For maintenance and long-term use, the modular structure provides practical advantages compared with conventional flooring systems. Individual damaged elements can be replaced without removing the entire floor, reducing maintenance costs and extending the service life of the system. The use of durable, recyclable and easily cleanable materials is also essential for maintaining hygiene requirements in preschool environments.

The modular floor is made of shape memory polymer, which is a smart material that is able to return to its original shape from a deformed state, which is affected by external factors, such as temperature changes (16, 17). At a certain temperature range, the material is strong and hard, which makes the floor more solid. When the room temperature changes and warms up, the floor becomes a little softer, which becomes pleasant for children's feet. The interaction of the material is carried out gently and gradually, therefore it does not allow for abrupt changes in environmental conditions and abrupt changes in children's conditions and reactions. If the game scenario involves passive participation, for example, reading a fairy tale, a break, or listening to music,

then the temperature in the room will be higher so that the children feel more comfortable and warm. The material already undergoes some change at given temperature conditions, getting a softer surface but not so much as to create an unstable environment (18, 19). The soft surface will allow children to sit on the ground and feel comfortable. Shape memory polymers have high resistance to scratches, impacts and pressure. They are able to change hardness and softness, adapting to the user's gait or posture. Polymers with a special composition can absorb sound and vibrations, which is especially useful for active zones in kindergartens. In recent decades, alternative and renewable sources of energy storage and use have been proposed. Among such sources of generation, mechanical movement is one of the most discussed types. Piezoelectric absorbers provided in the modular floor are located in each module, allowing the adaptive environment to obtain internal energy, which can be used for lighting located in the module itself. Energy generation through impacts is beneficial in children's environments, since they are very active during the day and can run and jump nonstop (20). Physical exercises, which are also carried out through training, will also allow you to accumulate energy. Lighting can make the environment more interactive and adapt to the program for a given age group. Similar to the flooring module, relief modules can be produced with different shapes and surfaces. Their types can be diverse, but five options are presented in the design project.

The presented relief floors are designed for the sensory, motor and cognitive development of children. They create a variety of physical, sensory and educational experiences. When a child walks, the muscles of the feet work while moving on different surfaces. This is important for balance and the correct formation of the feet. Children learn to walk, run, jump and balance on different

types of floors, which strengthens the muscles. Relief floors create new sensory impulses that the brain processes, helping to form neural connections. Different tactile surfaces stimulate the nervous system, increasing sensitivity. Uneven surfaces force the child to maintain balance. This helps the child walk more steadily, adapt to moving in different areas and avoid falling. Tactile stimulation of the feet helps with blood circulation, the formation of correct gait and even the prevention of foot problems. This is similar to reflexology, which is used in children's physical therapy. They activate the muscular system, especially the muscles of the feet, calves and core of the body, help prevent foot deformities such as flat feet and strengthen the stability of the body by affecting posture. This is especially important for children aged 2-6, when neuroplasticity is most active. The design proposal is based on the idea that it should have a sectional application in the room so as not to cause an obstacle during normal walking, but if desired and necessary, it is possible to turn it into a main module and cover the entire room with similar reliefs. The relief floor modules presented in the design proposal are made of a bio-based flexible material (Bio-based flexible material) derived from natural sources (plants, bioplastics, waste materials) and have high flexibility, elasticity and comfort for various applications. The material is mainly obtained from plants (cellulose, agar, alginate), fungi, or biodegradable polymers. They can be soft, elastic, or deformable without rigidity. They are mainly biodegradable or recyclable. Despite their softness, many have high mechanical strength (21, 22). The use of the material in kindergartens is important because it is safe, does not produce toxic substances, is soft and contributes to the creation of an ecologically clean and interactive environment. The flooring modules are illustrated in Figure 5.

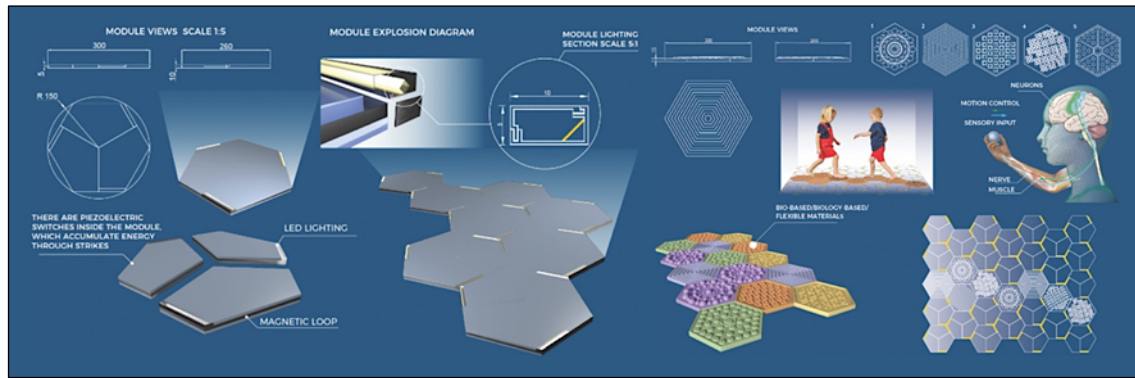


Figure 5: Views of the Flooring Modules, Constructive Connection Nodes, Three-dimensional Image of the Application Option

The application of the selected material for flooring can be carried out through 3D printing, which will further accelerate production and will be an innovation for this sector. The node is based on the principle of a basic modular system, which simplifies the assembly process and provides the opportunity for standardization. The latter allows for more affordable and efficient production. Color options are offered for the respective preschool institution, but the choice of colors provides a wide range of possibilities in the case of such a material. Certain types of textures and soft rubber surfaces can have a calming effect on children with low sensory input needs. They can also help develop attention, concentration and self-control. The activation of certain pressure points on the hands and soles of the feet, according to 'Foot and hand reflexology' approaches, is associated with various organs and the nervous system of the body. Although pediatric reflexology is not primarily used for classical therapeutic purposes, such stimulation can theoretically promote the balanced functioning of internal systems, especially the digestive, respiratory and nervous systems. The chair's design is uniquely multifunctional, which made it possible to have several entertainment games, each of which is located on each seat of the chair and has its own rules and principles of the game. The design of the modular chair-table system was developed according to internationally recognized ergonomic principles for preschool furniture. The dimensions and configuration of the chair-table system were developed according to age-specific anthropometric characteristics of preschool children and internationally recognized ergonomic principles for educational furniture. The main ergonomic parameters considered include seat height, seat

depth, backrest support, tabletop height, leg clearance and comfortable reach distance to learning materials. These factors are essential for maintaining appropriate sitting posture, supporting physical comfort and reducing unnecessary muscular strain during educational and play activities. In addition to ergonomic considerations, the proposed furniture system incorporates safety requirements appropriate for preschool environments. The design principles include rounded edges and corners, structural stability, durable connections, non-toxic and child-safe materials and surfaces resistant to intensive daily use. The modular configuration also allows adaptation to different activities and age groups, supporting independent interaction, creativity and fine motor skill development. The design approach follows established recommendations for preschool furniture, including the relationship between children's anthropometric measurements and furniture dimensions described in educational furniture standards such as EN 1729 and ISO 5970. The application is also calculated in the case of joint use of both. The chair-table is intended for children attending preschool institutions. Taking into account the age characteristics, the games were also selected in accordance with the interests and characteristics of children of that age (23). The selected games contribute to the development of fine motor skills and thinking in children.

The choice of material was made based on very detailed studies; the final choice was made on nylon thermoplastic, which is one of the most common types, strong, flexible, comfortable, durable, lightweight, multi-colored, environmentally friendly and recyclable. Nylon is a leading synthetic fiber in terms of safety, despite the

chemical composition of the material - it has no odor, does not emit toxic substances, therefore it is absolutely safe for children. The molding of the product involves injection molding; production by molding actually involves high costs, since the mold must be made of steel or aluminum, but in the case of mass production, it is possible to return the invested money in a very short period of time. The color selection was made taking into account the fact that the users are children and it should be attractive and cheerful colors. The adopted technology is the most effective and the molding can be carried out as close to the imagination as possible. There are 4 game options on the chair: a puzzle with geometric figures, a blackboard-shelf

with kinetic sand, an abacus calculator with its cards and a digital puzzle. The chairs are also modular, which can be connected to each other in different quantities. The chair-tables can also become another game option - a labyrinth, which is an active game option. If you remove the seat of the chair, only the base remains, which becomes a small tunnel when placed on a table position. If you glue several of them together and line them up one after the other, you can get tunnels of different lengths and directions, which create game variations for children. Chair-table modules, constructive connection nodes, three-dimensional images of application options are presented in Figure 6.



Figure 6: Views of Chair-Table Modules, Constructive Connection Nodes, Three-Dimensional Images of Application Options

Offering a similar chair model simplifies the process of organizing adaptive rooms and environments and allows children to be offered individual games in a standardized way and everyone can use any of their games at the same time, since each chair has a chair for each game. During classes, especially in preparatory and senior groups, discipline is very important. A chair-table combination can be an excellent option to create classroom conditions for them. During group classes or fairy tale readings, you can connect the chairs and get a warmer environment for children, which will contribute to ensuring a

successful model of an adaptive environment. The next game module is also similar in style to the others, as it again has a hexagonal shape at its base. The module is one, but the paths continue and connect in different positions of the hexagon. The path of the modular system is designed in such a way that it is possible to change the course of the game. The game provides different game scenarios so that children can create a path along which the stones will pass and reach the final result. Built-in wall modules, constructive connection nodes, three-dimensional image of the application are presented in Figure 7.

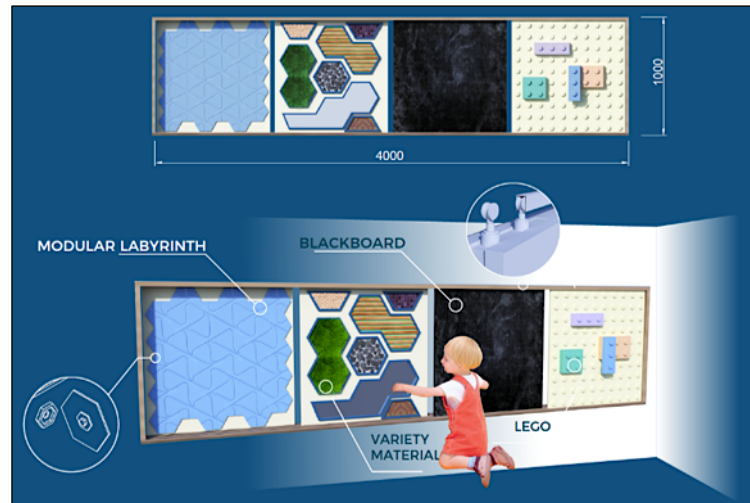


Figure 7: Views of Built-in wall Modules, Constructive Connection Nodes, Three-Dimensional Image of the Application

The module assembly is very simple, since the roads will be created by children, so the assembly should be appropriate for their age. The module has a protrusion inside, which is also hexagonal and there is a hexagonal hole on the wall. This simple assembly will help children always place the part so that the hexagon vertices are in a horizontal direction. The module is very light, made of a flexible polymer based on biomaterials and thanks to 3D printing it can also be hollow, which will give additional lightness. A wall made of different materials is one of the best options for developing fine motor skills. It allows children to touch different materials, which will cause different sensations, which in turn will affect the nervous system. There are both different materials and different games on the wall, which make the entire game process more interactive. The game module installed on the wall consists of sections made of different materials, which have various reliefs. Its surface is covered with soft areas like grass, smooth and shiny tiles, wooden sections of

different textures, as well as small mosaics or details embedded with tactile graphics. Each section offers a unique sensory experience, activating children's tactile perception. This play module stimulates children's fine motor skills by stimulating finger and hand movements. Touching different materials develops the sensitivity of the nerve endings and exploring uneven surfaces encourages finger flexibility and strength. The reliefs on the module promote tactile exploration and cognitive development, which is especially useful for preschool children. This play wall can be used in many different play scenarios, for example, exploration can be followed by a memory game, when the child, with his eyes closed, has to guess what surface he touched or can describe the physical properties of the material (at an older age) (24, 25). Adaptive, interactive and resource-rich spaces promote both motor accuracy and cognitive growth, laying a solid foundation for a child's overall development. Preschool educational environments are demonstrated in the Figure 8.



Figure 8: Three-dimensional Images of Preschool Educational Environments Using the Proposed Modules

The proposed adaptive modular framework shares several characteristics with internationally recognized approaches to early childhood education while introducing additional architectural flexibility. The Montessori approach emphasizes child independence, freedom of movement and carefully prepared environments that encourage self-directed learning (26). Similarly, the proposed modular system enables children to interact independently with adaptable furniture, tactile surfaces and multifunctional learning modules that support exploration and the development of fine motor skills. The framework also reflects principles of the Reggio Emilia philosophy, in which the physical environment is considered the "third teacher." Flexible spatial organization, natural materials, sensory experiences and opportunities for collaborative learning are central to both approaches (27). However, the proposed model extends these principles by incorporating adaptive modular components that allow rapid reconfiguration of the learning environment according to educational activities and spatial constraints. The proposed design further aligns with Scandinavian preschool design, which prioritizes child well-being, inclusive learning environments, natural lighting, sustainable materials and strong connections with nature. The use of environmentally friendly materials, modular construction and flexible layouts in this study supports these principles while emphasizing sustainability and efficient use of available resources. Finally, the proposed framework is consistent with evidence-based classroom design literature, which demonstrates that spatial flexibility, ergonomic furniture, adequate personal space, appropriate lighting conditions and multisensory learning environments positively influence children's cognitive development, engagement and psychological well-being. By integrating these established principles with adaptive modular technologies, interactive flooring and multifunctional furniture, the proposed framework contributes a comprehensive design strategy for contemporary preschool environments. Although the proposed framework is conceptual, it establishes a scientifically informed foundation for future implementation and empirical evaluation. Subsequent research should assess the effectiveness of the proposed modules through user-centered studies involving

educators, children and preschool administrators, together with post-occupancy evaluations of educational outcomes, usability and environmental performance.

Conclusion

The development of preschool education reflects the ongoing evolution of approaches aimed at supporting children's growth and development during their formative years. Modern educational methods emphasize the importance of a child-centered approach, integrating techniques that support both cognitive and motor development. International practice research demonstrates the value of using a variety of strategies tailored to the unique developmental needs of children, while maintaining a common commitment to fostering creativity, adaptability and fundamental skills. The use of targeted methods for the development of fine motor skills and neuroplasticity in preschool education emphasizes the connection between physical activity and brain development. By combining traditional pedagogy with innovative techniques, educators can maximize the benefits of early development.

The design part presents a complex concept of innovative solutions aimed at adapting the environment of preschool institutions using modern materials and technologies that stimulate the development of neuroplasticity and fine motor skills. One of the components is a modular floor made of memory polymer; the material is able to maintain its shape and respond to children's movements, which contributes to the development of balance and sensory perception. Solutions with light and piezoelectric absorbers allow children to explore the principles of energy conversion through physical interaction, while providing a safe and interactive environment. The relief floor, based on flexible materials with a biological composition, stimulates tactile perception and sensory integration, which is important for neurological development. This solution allows children to playfully explore the properties of different materials and develop muscle coordination. The furniture includes a multifunctional chair-table system that can be used in different ways, adapting to different scenarios, developing children's independence and creative skills. This solution allows preschool institutions to save space while offering

multifunctional use options. The modular maze and walls made of different materials are designed as interactive play systems that promote the development of fine motor skills and neuroplasticity. These elements allow children to practically explore spatial orientation, the sense of touch on different surfaces and problem-solving skills.

From an architectural perspective, the proposed modular system was evaluated using qualitative design criteria, including spatial flexibility, functional adaptability, ergonomic suitability, user safety, accessibility and efficient utilization of available floor area. These criteria guided the development of the conceptual framework and provide a basis for future quantitative assessment through user testing and post-occupancy evaluation in preschool settings. The presented project offers a comprehensive approach that combines the latest materials, technologies and game methodology to create an adaptive, functional and developmental environment for preschool institutions. It ensures the all-round development of children by combining interactive, safe and dynamic elements, contributing to the improvement of both physical and mental abilities. The environment plays an important role in achieving these results. A well-organized preschool environment, designed to stimulate exploration and engagement, significantly increases the ability of children to develop fine motor and neuroplastic skills.

The integration of modern educational methods and strategic environmental organization creates a comprehensive framework for preschool education. This approach not only supports children's cognitive and physical growth but also prepares them to cope with the complexities of future learning and life experiences.

The results of the study of design methods, principles and tools can be used to solve the problems discussed in the work, as well as serve as a basis for implementing design reforms in preschool institutions in the future.

Abbreviations

AB: Activity Based, STEAM: Science, Technology, Engineering, Arts, Mathematics.

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Author Contributions

Artashes Melikyan: Data Curation, Supervision, Anahit Petrosyan: Project Administration, Formal Analysis, Patrisia Karsyan: Conceptualization, Visualization, Software, Karen Melikyan: Literature Review, Validation, Tamara Sargsyan: Writing - Original Draft, Ani Atsharyan: Methodology, Tatevik Paytyan: Resources, Writing – Review and Editing.

Conflict of Interest

The authors declare no conflict of interest.

Data Availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Declaration of Artificial Intelligence (AI) Assistance

During the preparation of this work, the authors used ChatGPT in order to correct grammatical errors and improve writing style. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Ethics Approval

This article is based on theoretical analysis and publicly available sources; therefore, ethical approval was not required.

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