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Design of a 3D Playground Layout Animation as a Reference for Children's Play Areas

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Children's holistic development requires outdoor play activities. This design aims to design a 3D playground layout animation as an interactive visualization media that can create an adaptive play space that supports children's cognitive, physical, and social development, while reducing the negative impacts of digital device use. Methodology This research uses a research and development (R&D) method with a qualitative descriptive approach through needs analysis, conceptual design, development of 3D layout animation prototypes (SketchUp, Enscape, DaVinci Resolve), and evaluation. The result is a 3D layout animation prototype with a nature adventure theme with real-time ray-tracing simulation for natural lighting and child-friendly materials. This design fulfills three pillars: physical safety, multidimensional stimulation, and interactive appeal, as well as modular zoning (play zone 217.53 m²) that is adaptive to children's age and interests. The first-person perspective visualization and customization of game elements (such as obstacle complexity) increase user engagement.
Keywords: 3D Layout Animation, Playground Design, Interior Design.

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1. Introduction

From childhood, individuals engage in various activities to foster enthusiasm and optimize their personal potential. The developmental process encompasses holistic aspects, including social, physical, emotional, intellectual, and linguistic dimensions [1]. Play activities, while often viewed merely as a form of entertainment, play a crucial role in supporting a child's holistic development. Therefore, facilities such as playgrounds are essential as learning environments that support children's growth [2].

Children are in a crucial developmental phase where play serves as a foundation for cultivating essential skills, such as motor abilities, creativity, and social interaction. Every experience at this stage not only shapes character but also contributes to instilling moral values that underpin future behavior [3]. Unfortunately, modern lifestyle trends have altered traditional play patterns which once involved physical activity and environmental exploration shifting them toward increased indoor time spent with digital devices. This shift potentially limits children's opportunities to experience the benefits of outdoor play.

In line with this, playground designs for children must adhere to fundamental principles such as safety, comfort, and accessibility [4]. Play facilities in public spaces need to feature equipment that stimulates children's fundamental development during play [5]. However, many playgrounds still employ conventional designs and fail to utilize technology or modern design approaches, making them less competitive against other forms of entertainment that are increasingly popular among children.

Digital device addiction in the modern era has emerged as a significant issue with negative impacts on children's physical and mental health, particularly due to reduced time for social activities essential to the development of their fundamental skills [6]. The use of technology in playground design such as the application of 3D animation for layouts can serve as a tool for academics and practitioners to visualize

physical space design concepts in greater detail and interactivity [7]. This innovation not only enhances the effectiveness of playground design but also provides visualizations that closely resemble real-world conditions, enabling the final design to adapt to children's changing needs as they grow and their interests evolve.

Based on this background, the author aims to develop a project titled "3D Playground Layout Animation Design as a Medium for Children's Play," emphasizing 3D layout animation as an interactive visualization tool to realize an adaptive playground concept that ensures safety, comfort, and accessibility within the context of modern childhood. By integrating technology, this design seeks to rekindle children's interest in outdoor activities which has declined due to the influence of digital devices while simultaneously meeting the need for adaptive, contemporary design. The resulting design is expected to provide interactive visuals aligned with the developmental stages and interests of children, thereby supporting holistic learning and mitigating the negative impacts of digital device usage on children's physical and mental health.

This project highlights the importance of playground designs that foster holistic child development amidst the challenges posed by rising digital device usage. Three key issues have been identified: a lack of interactive visualization in playground design, minimal integration of play elements, and limited variety in play activities suited to children's developmental needs. To address these issues, the project involves exploring 3D layout animation methodology as an interactive design visualization tool, developing techniques to integrate play elements using animation technology, and analyzing criteria for diverse play activities that adapt to children's changing ages and interests. The objective is to create an innovative strategy for 3D animation-based playground visualization, optimize the integration of play elements, and produce a prototype that combines safety, cognitive physical social stimulation, and interactive appeal to reduce children's reliance on digital devices. From an academic perspective, this project contributes to the development of technology-based visual architectural design methodologies. Practically, the final output is intended to serve as a guide for designers in creating play spaces that are relevant to the digital era, balancing physical social interaction and bridging traditional concepts with the contemporary needs of children.

2. Literature Review

Three-dimensional (3D) animation is a technique for creating moving images featuring objects that possess volume, spatial depth, and realistic lighting within a digital environment [8]. The history of 3D animation began in the 1960s with the development of computer graphics at institutions such as the Massachusetts Institute of Technology (MIT) and Stanford University. The film Tron (1982) pioneered the use of 3D graphics in the entertainment industry, followed by the major revolution brought about by Pixar with Toy Story (1995) the first fully produced 3D animated film. Advances in software such as Autodesk Maya and Blender and increased computing power have made 3D animation increasingly accessible and versatile; its applications now extend to education and interactive simulations, making it highly relevant for the development of digital-based play media for children.

A playground is defined as a public area specifically designed to facilitate children's play activities through various physical structures, such as slides, swings, and exploration zones. The history of the modern playground began in the late 19th century in Europe and the United States, driven by social reform movements that emphasized the importance of child health and urban open spaces [9]. In the early 20th century, the concept evolved with the introduction of structured play equipment by the Playground Association of America (1906). Following World War II, playgrounds evolved to become more inclusive, incorporating materials and designs that prioritized safety while supporting children's motor and social development [10].

Interior design is a discipline focused on spatial planning to create environments that are functional, aesthetically pleasing, and aligned with user needs. The roots of this discipline can be traced back to Egyptian and Roman civilizations, which utilized ornamentation and symbolic spatial arrangements to reflect social status [11]. Its development became evident during the Renaissance with an emphasis on proportion and symmetry, later evolving in the 20th century through the modernist movement, which prioritized function and minimalism. In the contemporary era, interior design encompasses not only visual aspects but also considers the interaction between humans and space through environmental psychology approaches and the integration of digital technology.

Previous research on children's playground design has explored various aspects of implementing play spaces that foster creativity and comfort. The journal Interior Design of Creative and Imaginative Playground in Jakarta discusses zoning, furniture ergonomics, material selection, and color schemes tailored to the needs of children aged 3 to 9, as well as the integration of spatial circulation concepts to optimize functionality [12]. In the realm of technology, the journal Development of 3D City Park Animation Using SketchUp and Lumion Software examines the creation of 3D city park animations using the multimedia development life cycle method; it demonstrates the effectiveness of 3D visualization in realistically representing designs while facilitating budget planning [13]. Meanwhile, the journal *Quality of Child-Friendly Play Spaces (RBRA) in City Parks in Central Surabaya highlights safety, comfort, and health criteria as key elements in both physical design and user perception [4]. Additionally, the journal *Design Concept for a Child-Friendly Playground at Kapten Mudita Field, Bangli proposes a design concept based on site analysis and the synthesis of child-friendly city policies, emphasizing the importance of government collaboration in implementation [14]. These four studies serve as the foundation for designing a playground based on 3D layout animation, integrating aesthetic and technical aspects with standards for inclusive and educational play spaces.

Framework

A conceptual framework is a structure that explains the relationships between variables in the development of a final project [15]. In the context of this design project, the framework serves to analyze and provide relevant solutions to the identified problems. Through a systematic approach, it integrates key definitions, design methodology, and data collection techniques to achieve the primary objective: producing a 3D playground layout animation as a solution to contemporary playground design challenges.

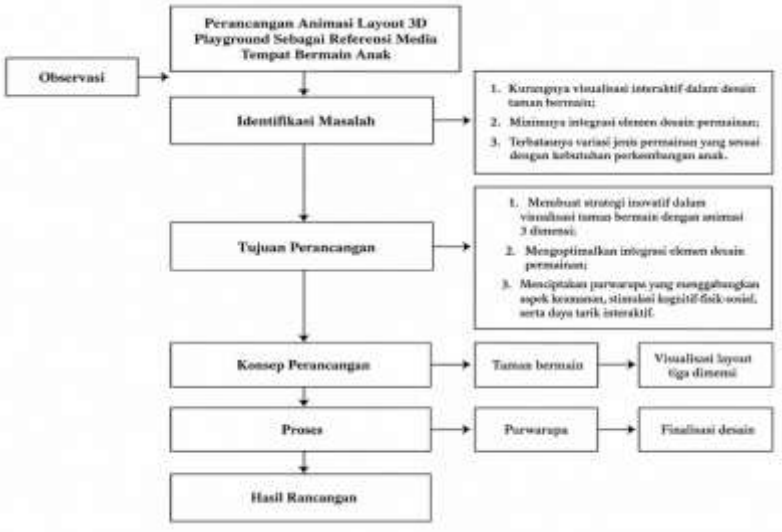

Fig. 1. Framework of thinking

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3. Method

This design project employs the Research and Development (R&D) method with a qualitative descriptive approach to design a children's playground utilizing 3D layout animation. The qualitative descriptive methodology was selected to gain deeper insight into the phenomena of conventional playground design, the challenges associated with digital tools, and the need for interactive visualization. The R&D approach was executed through stages comprising needs analysis, conceptual design, 3D layout animation prototype development, and evaluation, ensuring the design adhered to principles of safety, comfort, and adaptability to children's changing ages and interests.

The literature review for this design drew upon credible academic sources including journals, books, and articles regarding playground design, child development, and 3D layout animation technology focusing on keywords such as "playground design principles," "child development in the digital era," and "3D animation for spatial visualization." The author referenced research by Tuzzahra et al. on child-friendly play space criteria [4], Votinov & Smirnova on technology integration in physical design [7], and Suarna et al. on the application of 3D animation for playground visualization. The findings from this review served as the foundation for formulating the design concept and technical animation parameters [16].

The author conducted field observations and an industrial internship at Happy Play Indonesia a company specializing in children's playgrounds to evaluate contemporary designs, focusing on facility safety, play variety, and accessibility. Data were collected through visual documentation, informal discussions with the design team, and participation in daily operations. These data validated the literature review findings and helped establish development priorities, such as integrating fine motor skill stimulation and adaptive social interaction zoning.

Mind mapping was utilized as a method to represent ideas through images and text, illustrating the relationships between various concepts [17]. In this design process, the mind map serves to categorize and map out key aspects such as user needs, design elements, and technical parameters thereby establishing a structured approach to developing the 3D playground layout animation.

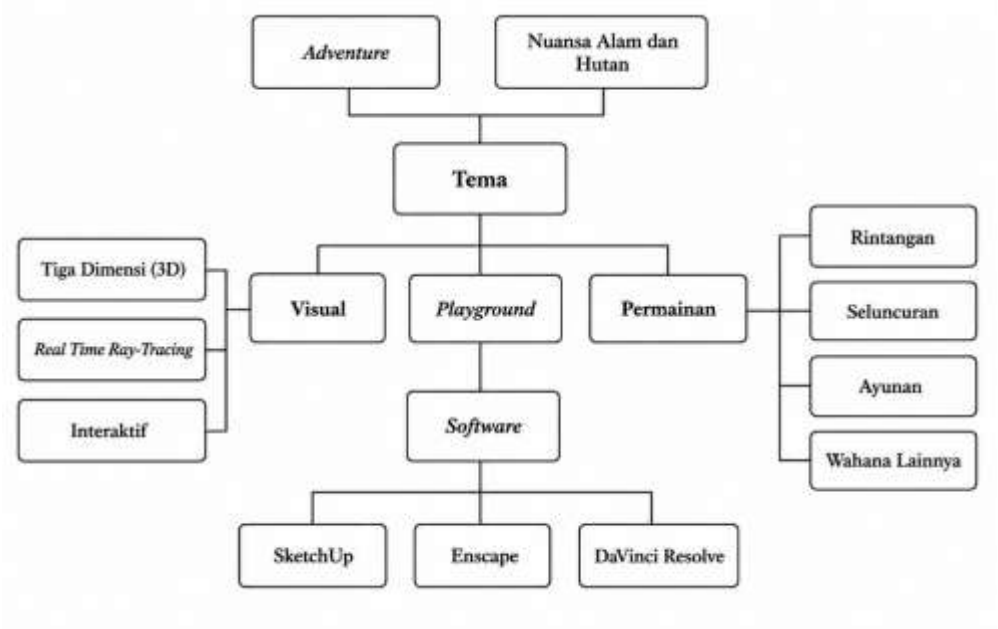

Fig. 2. Mind Map

Observations indicate that conventional playgrounds struggle to compete with digital gadgets and fail to fully meet children's holistic developmental needs. To address this, a concept based on three pillars was developed: physical safety assurance, multidimensional stimulation (cognitive, physical, and social), and

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interactive appeal. Applying zoning principles specific to children's play spaces [12], the area is divided into a buffer zone (waiting area, cashier, shoe racks) and a play zone. Visualizations created using SketchUp and Enscape software produced realistic simulations featuring child-friendly materials (non-toxic, anti-slip) and natural lighting that facilitated pre-construction evaluation. Immersive technology allows for the dynamic adjustment of playground equipment based on user needs such as modifying complexity and color palettes according to age thereby ensuring ongoing relevance [18].

The prototype's strength lies in its adaptability; the layout and types of play activities can be dynamically adjusted to suit different age groups (e.g., toddlers versus pre-teens) and specific children's interests [4]. Integrating 3D layout animation proved effective in creating a rich variety of play options within limited spaces and offering adaptive visualization capabilities superior to those of conventional playgrounds. Key challenges include the high cost of licensed software (such as SketchUp and Enscape) and the need for specialized training to address the lack of technical expertise among conventional designers. Through dynamic visualization and personalized play themes (e.g., nature themes for toddlers, adventure challenges for pre-teens), this concept aims to reduce children's reliance on gadgets by stimulating their interest in outdoor play.

From an academic perspective, this methodology enriches the approach to playground architectural design by integrating 3D layout animation as a tool for visualization and interactive simulation. In practical terms, the prototype serves as a reference for stakeholders in creating public play spaces that are inclusive, safe, and digitally relevant. Realistic visualizations facilitate the communication of concepts and pre-investment decision-making. Further design work is required to test physical implementation and measure long-term impacts on play behavior, social interaction, and the reduction of screen time. This empirical validation is crucial for ensuring the design's effectiveness in achieving holistic objectives.

4. Results and Discussion

Design Results

The design concept centers on an adventure theme featuring natural and forest-inspired elements, crafted to foster exploration and ignite children's imaginations. It incorporates nature-inspired color palettes such as leafy greens and earthy browns and play features modeled after outdoor adventure activities, creating an immersive play environment that shifts children's focus from digital devices to educational physical activities.

Fig. 3. Example of an outbound activity in the forest
Source: https://kopengtreetop.com/

The play activities are designed around multidimensional physical challenges, incorporating obstacle courses, slides, swings, and interactive features such as dynamic tunnels and ball pit zones. Each element is formulated to foster gross motor skills, sensory coordination, and problem solving abilities aligned with principles of holistic stimulation (cognitive, physical, and social) and is supported by age appropriate playground designs and activities aimed at promoting cognitive and motor development [19].

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Fig. 4. Example of an outbound obstacle
Source: https://garutdinoland.com

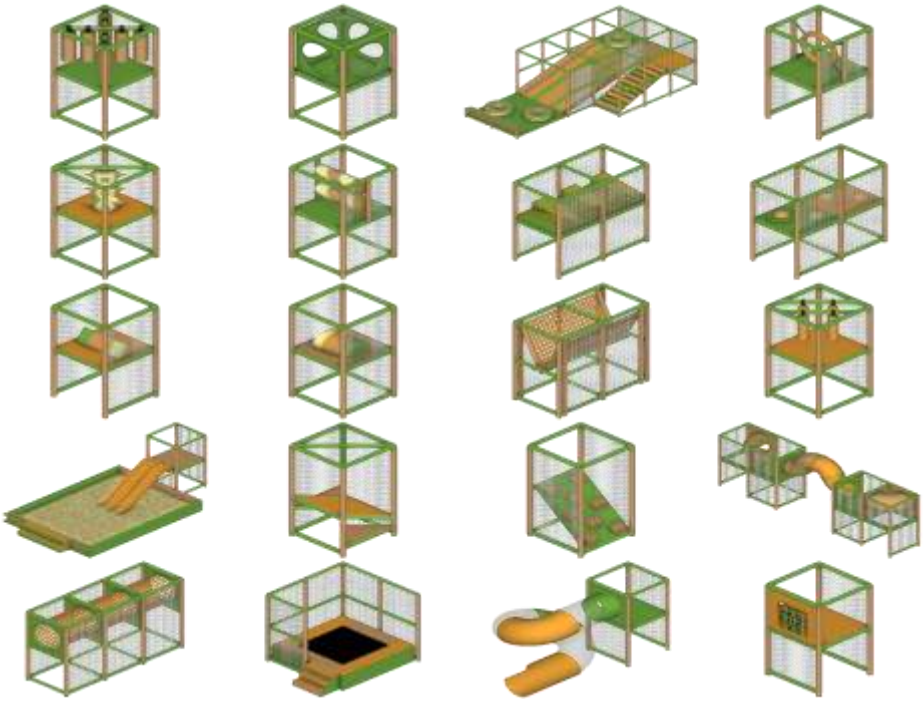

Fig. 5. Some Play Equipment for Playground Design

The visualization employs 3D layout animation with real-time ray tracing to simulate natural lighting, dynamic shadows, and child-friendly material textures (non-toxic, anti-slip). In this design, the flooring consists of simulated EVA (ethylene-vinyl acetate) foam mats featuring visual textures that mimic synthetic grass (grass pattern) and natural wood (wood grain), simulating a safe, natural, and anti-slip surface. Play structures such as obstacle frames and tunnels utilize simulated galvanized steel frameworks covered in protective foam padding, visualized via real-time ray-tracing-based texture mapping. These textures are optimized in Enscape to ensure a visual representation that meets physical safety standards for children (SNI 8128:2015). This interactive approach allows for visual adjustments based on the user's age such as modifying obstacle complexity and color palettes visualized from a first-person perspective to enhance emotional engagement while ensuring physical safety and comfort in accordance with child-friendly playground standards [20], [21].

The animation production process integrates SketchUp for 3D playground modeling, Enscape for real-time rendering and virtual simulation, and DaVinci Resolve for video post-production. This software integration ensures spatial representation accuracy and design iteration efficiency, aligning with the

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multimedia development life cycle methodology [13].

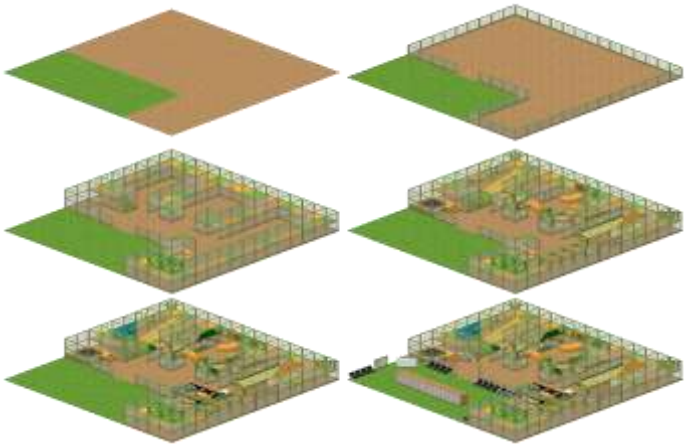

Fig. 6. Process of Playground Design

Applying zoning principles for children's playgrounds[12], the playground layout is divided into two zones. The buffer zone is designed as a rectangle measuring 12.03 meters in length and 6.03 meters in width (area: 72.6 m²), serving as a transition area for a parental waiting space, a cashier counter, and shoe storage. Meanwhile, the play zone is optimized in an inverted "L" configuration, measuring 17.03 meters in length with varying widths of 11 meters and 5 meters (total area: 217.53 m²). This asymmetrical play zone design allows for the modular integration of various play elements such as obstacle courses, spiral slides, and other activities tailored to children's developmental needs. These spatial dimensions enhance the utility of the 3D layout animation as an adaptive simulation, ensuring that the playground prototype meets requirements for physical safety, universal accessibility, and holistic stimulation (cognitive, physical, and social).

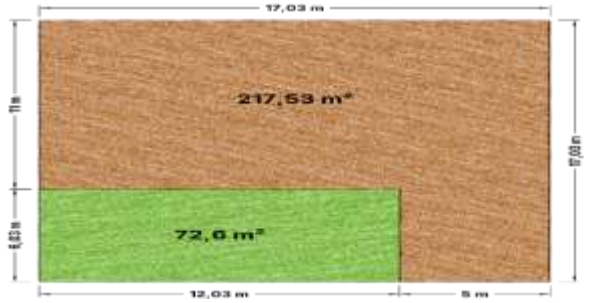

Fig. 7. Floor plan from Playground Design

Fig. 8. Color Palette with RGB Color Code for Playground Design

Children begin their adventure by climbing zig-zag stairs that develop leg coordination, then navigate "spike" obstacles (soft, spike-shaped barriers) to build agility. After turning right, they pass through semi-circular obstacles (curved structures) and a rolling obstacle (a rotating cylindrical tunnel) that test balance, followed by a "mini boxing" obstacle (a target-striking area) for gross motor stimulation. After another right turn, children descend via a donut slide into a new area. Here, they can climb a rolling staircase (with a wavy surface) and choose between two routes: (1) straight ahead to the X-O-X panel (an interactive symbol game) and a tube slide (enclosed slide), or (2) a right turn toward triangular obstacles (pyramid-like climbing structures), suspended tires, and a series of complex tunnels (featuring 90-degree turns and elevation changes) that hone spatial navigation skills. After navigating an inclined platform and making a right turn,

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children can choose to slide down into a ball pit or continue straight past a "big boxing" obstacle (large striking targets). The route concludes with a right turn through elastic bouncing obstacles, crossing a 2.4-meter bridge, entering a "time tunnel" (a multi-sensory tunnel), turning right through a square box with a clear dome (a transparent observation pod), and finally descending via triangular steps (a tiered triangular structure) back to the starting point. On the ground floor, there is a simulated street scene with toy cars for role-play, as well as twin swings and a trampoline equipped with safety netting. The modular play structure allows for dynamic configurations tailored to children's developmental stages and interests, reflecting the design's adaptive approach.

Fig. 9. Close-up shot of playground design

Close-up shots of the playground design clearly display the details of play elements such as the shapes of the structures, material textures, and safety surfacing. These visualizations serve to evaluate safety, comfort, and the suitability of child-friendly materials, while also showcasing the design theme and quality prior to physical implementation.

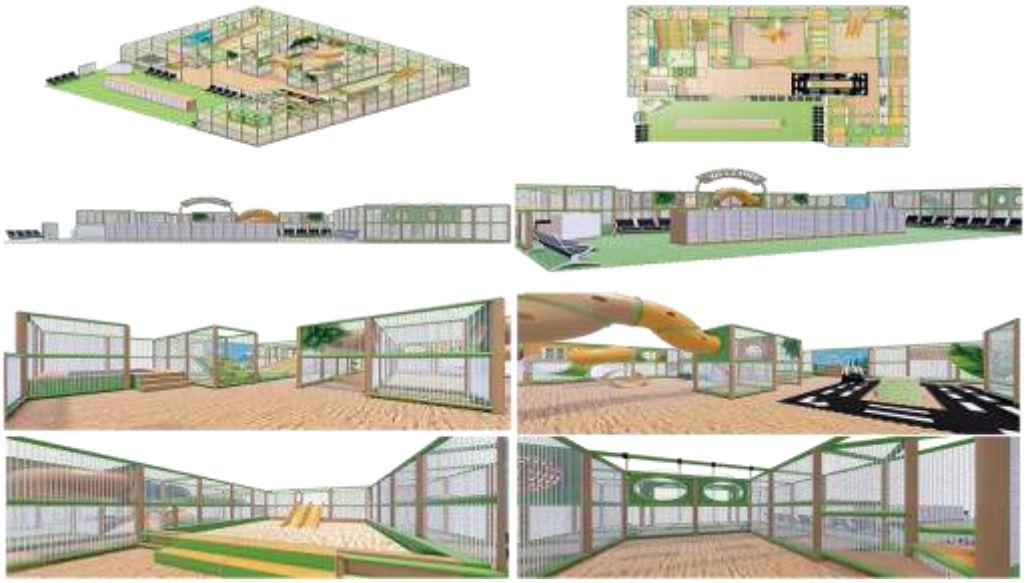

Fig. 10. Final rendering of the playground design

The final render of the playground design presents a 3D animated visualization that captures the entire design concept, including the spatial layout, play elements, lighting, and materials. This visualization offers a realistic depiction of the play area to serve as a design reference, while also facilitating the evaluation of safety, comfort, and appeal prior to the physical implementation stage.

Discussion

The 3D playground layout animation demonstrates that animation-based visualization effectively represents the design concept in its entirety, encompassing spatial layout, play elements, and the user experience. The resulting animation not only displays the playground's physical form but also simulates children's movement patterns, the relationships between zones, and the interactions among play elements within a cohesive spatial whole.

An "adventure in nature" design theme is realized through color composition, equipment shapes, and material selection that evoke a forest environment and encourage exploratory activity. The design effectively creates an immersive play atmosphere, stimulates curiosity, and fosters children's interest in physical activity. Play elements such as obstacle courses, spiral slides, tunnels, and climbing structures are arranged sequentially to create a continuous and challenging play flow without compromising safety.

Regarding spatial layout, dividing the space into buffer and play zones enhances functionality and organization. The buffer zone serves as a transition area that supports the comfort of parents and supervisors, while the play zone designed with a modular approach and an area of 217.53 m² accommodates a variety of play activities. An inverted "L" configuration allows for flexible equipment placement and facilitates design adjustments based on age requirements and the intensity of play.

The 3D animation, presented from a first-person perspective, provides a realistic impression of the spatial experience. This approach simplifies the evaluation of safety aspects, such as the spacing between equipment, obstacle heights, and children's movement circulation. Furthermore, natural lighting simulations using real-time ray tracing demonstrate an even, glare-free light distribution, thereby supporting visual comfort and child safety during play.

The results of this 3D playground layout animation project demonstrate that interactive visualization media can provide a comprehensive, safe, and engaging design reference for children's play spaces. 3D layout animations play a crucial role in providing a realistic visualization of the space, supporting design evaluation, and serving as a reference for designing playgrounds that adapt to children's development and interests.

5. Conclusion

Based on the overall design process, it can be concluded that integrating 3D layout animations into playground design successfully addresses the challenges of creating contemporary play spaces in the digital era. (1) 3D layout animations overcome the lack of interactive visualization by presenting the playground design in a realistic and dynamic manner, serving as a valuable reference tool. (2) The integration of play design elements was successfully achieved through the arrangement of zones, play flows, and the connectivity between play structures within a unified space. (3) The variety of play types designed to be modular and adaptive can accommodate children's developmental needs across motor, cognitive, and social domains. Regarding design limitations, technical constraints such as software licensing costs and the need for training for conventional designers should be noted for future development. For future research, physical implementation testing and the measurement of long-term impacts specifically regarding reduced gadget dependency and increased social interaction among children are required to validate the holistic effectiveness of this design.

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