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CASE STUDY RESEARCH PAPER

An Analysis of the Components of the Mobility Cycle and Naturalism in the Architectural Design of Educational Spaces in Girls' Schools (Case Study: Lower Secondary Schools, Tehran city, Iran)

Mina Gheisari[1], Saeed Azemat[2*], Gholamhossein Naseri[3], Hossein Moradinasab[1]

1 Department of Architecture, Se.C., Islamic Azad University Semnan, Iran

*2*Department of Architecture, ET.C., Islamic Azad University, Tehran, Iran*

3 Department of Architecture, Da.C., Islamic Azad University Damghan, Iran

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A B S T R A C T

Nowadays, many educational environments designed with a child-centered approach especially in girls' elementary schools face significant functional challenges. Inefficient educational spaces that lack flexibility, spatial diversity, and compatibility with children's scale and psychological characteristics cannot provide an appropriate context for improving the quality of education. The aim of this study is to explain the role of design components of child-centered educational spaces based on enhancing mobility and nature-orientation in girls' elementary schools (first cycle) in Tehran city. The methodological approach of the study is survey-based, and data collection was conducted in two stages: first, through library research and a review of literature related to mobility, nature-orientation, and child-centered educational design; and second, through a field study using a closed-ended questionnaire. The statistical population consisted of 290 principals, teachers, and staff members of selected schools with more than five years of work experience. Participants were selected through cluster random sampling. The sample size was determined based on Klein's formula (2 to 5 participants for each questionnaire item). Data analysis was performed using factor analysis in R, Pearson correlation test, and structural equation modeling in AMOS software. The findings indicate that in the cycle of designing child-centered educational spaces, "mobility" and "nature-orientation" play key and determining roles. Designing dynamic spaces enriched with natural elements can enhance spatial diversity, social interaction, and physical movement. Accordingly, focusing on the creation of multi-functional, flexible spaces inspired by nature can increase opportunities for movement, experience, active learning, and environmental exploration among children.

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*Corresponding Author:
Email: *Azemati@iau.ac.ir*
Phone: 00989124091689
ORCID: https://orcid.org/0000-0002-6410-6491

INTRODUCTION

In recent years, the quality of educational spaces has been recognized as an influential factor in children's learning, cognitive development, mental health, and social behaviors. Elementary schools are among the most important spaces where children spend a significant portion of their time, and these spaces are not merely places for formal education but also shape part of their daily experiences, social interactions, physical mobility, and creativity development (Razmi & Gholami, 2024). However, many elementary schools, especially in common design patterns, still have static and classroom-centered structures (Esmaili et al., 2021) and lack desirable mobility, nature-orientation, and appropriate responsiveness to children's motor, emotional, and perceptual needs. This issue is particularly important in the first cycle of elementary education because children at these ages experience learning not only through hearing and seeing but also through movement, play, discovery, and direct interaction with the environment. In Iran, one of the main challenges of elementary schools is the dominance of traditional and one-sided approaches to space design; closed classrooms, purely connective corridors, low-quality yards, and spaces lacking identity limit diverse activities and active learning. Consequently, reduced mobility, decreased motivation, mental fatigue, and weakened learning quality follow. Therefore, designing child-centered educational spaces can transform elementary schools into active environments in the learning process environments that provide opportunities for free movement, choice, interaction, play, experimentation, and meaningful presence of the child (Salawu et al., 2024). It is worth noting that in child-centered educational spaces, mobility is not limited to physical displacement but refers to the possibility of smooth movement between spaces and experiencing learning in various paths and arenas. Furthermore, nature-orientation in these spaces plays a key role in improving children's cognitive development and learning. This approach, aiming to redefine classrooms as part of the ecosystem, enables children's direct interaction with the natural world (Scarlett et al., 2023). In general, nature-orientation in child-centered educational spaces creates physical continuity between interior space and the yard, facilitates exploration, and strengthens physical connection with nature. On the other hand, transferring part of the educational process to green spaces takes learning out of its abstract state and gives it a practical dimension (Marcella et al., 2023).

Therefore, attention to the components of mobility and nature-orientation in girls' elementary schools (first cycle), due to the importance of this period in personality development, socialization, and the formation of children's attitudes toward learning, plays an effective role in improving the quality of comprehensive education for students. Accordingly, examining the design components of child-centered educational spaces based on enhancing the level of mobility and nature-orientation is an effort to redefine the child-centered educational space of the school as a dynamic environment appropriate to children's developmental needs. Numerous studies have been conducted in the field of the present research at international levels, categorized into three groups: studies focused on mobility, studies focused on nature-orientation and interaction with the environment, and studies focused on participation, safety, and user accessibility. Radun et al. (2025), in a study titled "Comparison of Open, Flexible, and Enclosed Learning Spaces Teaching Staff's Experiences and Activity Sound Exposure" using experimental research methods, showed that the type of spatial organization in schools can affect the quality of teaching experience, environmental comfort, and the way space is used. This study emphasizes the component of mobility as a factor not limited to students but also affecting teachers' professional experience. In the same year, Arndt (2012), in their study titled "Exploring Spatial Design Preferences for Learning Spaces in Primary Schools: A Child-Centered Approach Using Generative AI," stated that spatial preferences for primary school learning spaces are respectively spatial flexibility, nature-orientation, layout, and physical factors. This study emphasizes that nature-orientation is the second priority in designing child-centered educational spaces after mobility. Azemati et al. (2024), in their study titled "Evaluation of Influential Components in Child-Centered Spaces Based on Enhancing Children's Creativity from Experts' Perspectives," stated that factors such as mobility, social interactions, and playability are effective components in enhancing children's creativity in child-centered educational spaces. Sun and Firzan (2024), in their study titled "Investigating User Feedback for Learning Space Design in Primary Schools of Shandong Province, China" using survey research methods, stated that primary school users evaluate learning spaces as desirable when they have features such as flexibility, comfort, functional diversity, safety, appropriate accessibility, and interactivity. This study introduced safety and accessibility as independent and essential components that serve as the foundation for the realization of other components. Vaishnavi and Vera (2023), in their study titled "Spatial Design Recommendations for Early Childhood-Oriented Educational Spaces," showed that the design principles of child-centered educational spaces are play-centeredness, mobility, collective activities, and participation, especially in classrooms and open spaces. From these researchers' perspective, the nature-orientation component is one of the design pillars, and open space and connection with nature have great importance in children's learning. Chierichetti and Lembo (2022), in their study titled "Children's Participation in the Design of Learning Environments" using survey research methods, showed that child-centered design is effective when children are considered not merely as end-users but as real participants in the spatial decision-making process. Therefore, the participation component as a sub-component of flexibility, mobility, and nature-orientation in child-centered educational spaces is important for improving children's learning and education. Kariippanon et al. (2018), in their study titled "Perceived Interplay Between Flexible Learning Spaces and Teaching, Learning and Student Wellbeing" using quantitative research methods and questionnaire tools, concluded that flexible learning spaces are generally associated with creating a favorable space for more positive interactions between students and teachers, and students in these environments experience a greater sense of value, which can contribute to their emotional and social wellbeing. Overall, this research introduced attention to mobility in child-centered educational spaces as the foundation and basis of these spaces. (Tab. 1)

Table 1: Literature Review Summary

No.	Author(s)	Year	Topic	Components
1	Radun et al.	2025	comparison of open, flexible, and enclosed learning spaces - teaching staff's experiences and activity sound exposure	Environmental comfort, space usage, acoustic conditions, sound control, flexibility
2	Chinmay & Charu	2025	Exploring spatial design preferences for learning spaces in primary schools: A child-centered approach using generative AI	Spatial flexibility, Nature-Orientation, layout, mobility, physical factors (color, dimensions, proportions, openings)
3	Sun & Firzan	2024	Investigating user feedback for learning space design in primary schools of Shandong Province, China	Flexibility, comfort, spatial and functional diversity, appropriate accessibility, playability
4	Vaishnavi & Vera	2023	Spatial design recommendations for inclusive early childhood learning spaces	Play-orientation, mobility, collective activities

5	Chierichetti & Lembo	2022	Children's participation in the design of learning environments	Real needs, spatial perception, interests, children's behavioral patterns, sense of belonging, learning experience, participation, flexibility
6	Azemati et al.	2024	Evaluation of influential components in child-centered spaces based on enhancing children's creativity from the perspective of specialists	Evaluation of influential components in child-centered spaces based on enhancing children's creativity from the perspective of specialists
7	Kariippanon et al.	2018	Perceived interplay between flexible learning spaces and teaching, learning and student wellbeing	Flexible learning spaces, open space, Nature-Orientation, emotional and social wellbeing

Based on the literature review, it was determined that previous studies generally show that educational space design is most effective when based on the real needs of users, especially children and teachers, and can provide conditions such as flexibility, spatial diversity, environmental comfort, social interaction, playability, participation in design, and enhancement of learning experience. However, the distinction of the present research lies in its focused examination of the components of child-centered educational space design with an emphasis on mobility and nature-orientation in the context of girls' elementary schools (first cycle) in Tehran, whereas most previous studies addressed aspects such as acoustics, general flexibility, children's participation, or creativity, and less specifically examined the relationship between mobility, nature-orientation, and improving the level of education in a specific educational and spatial context. Figure 1 presents the timeline of studies conducted in the field of the present research. According to this diagram, which shows the chronological review of previous studies and the evolution of research attention to the field of architectural design of child-centered educational spaces, it can be acknowledged that early studies (Kariippanon, 2018) focused solely on mobility. Then participation (Chierichetti & Lembo, 2022), nature-orientation (Vaishnavi & Vera, 2023), and finally safety and accessibility (Sun & Firzan, 2024) were gradually added to the set of components. The most recent studies (Chinmay & Charu, 2025; Radun, 2025; Azemati et al., 2024) have also confirmed these four components as the main pillars of child-centered educational space design. (Fig. 1)

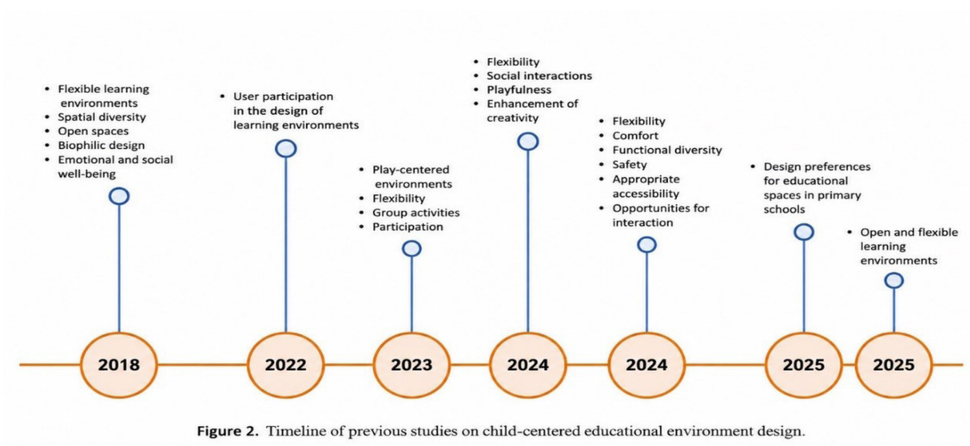

Figure 1: Literature Review Timeline

MATERIALS AND METHODS

Child-centered educational space is a modern approach in designing educational environments in which the needs, interests, abilities, and learning styles of the child are placed at the center (Dudek, 2005). In these spaces, the child is considered an active learner, and his/her developmental, physical, psychological, and social characteristics are incorporated into environmental design. Flexibility, nature-orientation, and playability are the main components of this approach, and spatial layout and furniture are designed to be changeable and adaptable to different learning needs (Louro, 2019; Chinmay & Charu, 2025). Furthermore, in these spaces, children are given the opportunity to choose their learning style, tools, and activity scheduling, and safety, accessibility, and connection with nature are also particularly important (Etra et al., 2012; Craig et al., 2024). In general, child-centered educational spaces are dynamic and evolving environments that, in addition to learning, provide the groundwork for socio-emotional development, self-confidence enhancement, and improvement of children's education quality (Wang et al., 2025). The concept of mobility in architectural design means spatial flexibility in response to users' movement needs. This feature is particularly important in child-centered educational spaces that must respond to children's psychological and physical needs (Barrett et al., 2015). Various dimensions of spatial flexibility, including variability, adaptability, expandability, and changeability, should be designed in such a way as to prepare the environment for children's active movement and learning (Uline & Tschannen-Moran, 2008). Traditional approaches to educational space design, which focused more on stability and spatial control, are now being replaced by flexible and dynamic designs in which mobility and physical interaction are prioritized. This shift in approach not only improves the quality of education but also contributes to students' physical and mental health (Evans, 2006). In general, mobility in child-centered educational spaces not only helps children's physical movement but also provides the groundwork for enhancing social interactions, increasing motivation, and improving their academic performance. Numerous studies have shown that educational environments with high mobility lead to increased physical activity, reduced anxiety, and improved concentration in children, ultimately resulting in improved learning processes (Barrett et al., 2015).

The nature-orientation component in the design of child-centered educational spaces refers to the importance and impact of nature on children's learning processes and cognitive development. This approach attempts to transform learning environments into spaces connected with nature where children directly interact with the ecosystem. Key dimensions of this approach include individual and collective participation in planting; where children become familiar with responsibility toward nature and learn how to participate in gardening projects individually or in groups. Also, direct access to yards and terraces not only allows children to explore natural parts but also strengthens the physical dimension of connecting with the environment (Scarlett et al., 2023). Outdoor classroom activities as an effective learning method help children learn scientific and social concepts in a natural and practical context. In this regard, community gardens as spaces for collaboration between children and adults increase collective identity and sense of responsibility. Designing large windows facing nature also allows children to feel more connected to their environment through visual perception of the relationship between indoor and outdoor space (Marcella et al., 2023). Furthermore, integrating nature with interactive technology, such as using digital tools to record plant growth or teach environmental topics, not only makes learning more attractive but also teaches children how they can use technology for the benefit of nature.

Based on the theories presented in the above table regarding mobility and nature-orientation in elementary child-centered educational spaces, the conceptual model of the research presented in Fig.2 was formed.

Table 2: Summary of Mobility Components and Characteristics in Child-Centered Educational Spaces

No.	Component	Key Components Mentioned	Source
1	Mobility	Open and flexible spaces, obstacle-free spaces, movable walls	Barrett et al, (2019); Katherine et al, (2024)
2		Various corridors and paths, non-linear paths, exploratory spaces	Ritonga, (2022)
3		Movable furniture	Chierichetti & Lembo (2022)
4		Safe movement activities within classrooms	Chierichetti & Lembo, (2022)
5		Increased creativity, reduced mental fatigue	Zhu et al., (2024) Zanele (2024)
6		Multi-functional spaces, children's participation	Scarlett et al. (2023)
7	Nature-Orientation	Easy access, safety and accessibility	Matthew & Alessandro (2019); Sri Een & Akemi (2019)
8		Child's connection with the environment and green space, increased participation and creativity	Sri Een & Akemi (2019); Scarlett et al)2023)
9		Participation in creating green space, individual and collective participation in planting, invitation to participate in design and space modification	Scarlett et al. (2023)

Nevertheless, based on mobility and nature-orientation of children in child-centered educational spaces, two factors, safety and accessibility, and participation can play mediating roles in the mobility and nature-orientation cycle. As shown in Table 2, safety and accessibility are key components of nature-orientation in child-centered educational spaces (Scarlett et al., 2023), and participation in nature-orientation and flexibility is a key component from researchers' perspectives (Sri Een & Akemi, 2019; Scarlett et al., 2023; Zhu et al., 2024; Zanele, 2024) in child-centered educational spaces. Therefore, these two components are examined further. Safety and accessibility in the design of child-centered educational spaces are recognized not merely as a set of protective standards but as a foundation for creating "self-confidence and cognitive independence" in children. The main goal of this perspective is to create an environment in which children can explore the world around them without the need for constant adult assistance (Malinin & Parnell, 2012). In this regard, the perspective of Rose and Meyer (2002) emphasizes that space should be designed so that all children with different abilities have equal and safe access to learning opportunities (Rose & Meyer, 2007). Also, in child-centered educational spaces, participation is designed purposefully and in accordance with children's developmental, psychological, and social needs to respond to their needs for mobility, solitude, interaction, and diverse experiences. In this regard, researchers point out that opportunities created for children's participation in child-centered educational spaces can contribute to improving the level of education (Sun & Firzan, 2024). To achieve a coherent framework for analyzing the components of the mobility and nature-orientation cycle in the architectural design of educational spaces in first-cycle girls' schools, the process of extracting components was conducted in two steps using directed content analysis. In the first step, concepts were extracted from theoretical foundations and research literature. In this step, all concepts related to child-centered educational space design from theoretical sources (Dudek, 2005; Barrett et al., 2015; Scarlett et al., 2023) as well as keywords present in the research literature (Tabs. 1 and 2) were extracted. These initial concepts included 17 key phrases:

flexibility, nature-orientation, playability, furniture changeability, barrier-free spaces, non-linear paths, multi-functional spaces, access to yard and terrace, participation in planting, large windows facing nature, safety, equal access, participation in spatial decision-making, social interactions, sense of belonging, emotional wellbeing, and environmental comfort. Then, in the second step, categorization and combination of concepts were carried out in the form of four main components, and according to semantic overlap and conceptual relationships among these phrases and based on theoretical approaches in the literature (especially perspectives related to the "mobility cycle" and "nature-orientation"), the initial concepts were organized into four main semantic categories. Table 3 clarifies the process of this categorization.

Table 3: Process of Extracting and Categorizing Key Research Components

No.	Main Component	Primary Concepts Integrated into the Main Component	Basis of Combination (Source or Theoretical Logic)
1	Mobility	Flexibility, obstacle-free spaces, movable walls, non-linear paths, movable furniture, safe movement spaces within classrooms, multi-functional spaces	These concepts all indicate the capability of physical movement and spatial changeability and were categorized under "mobility" (Barrett et al., 2015; Uline & Tschannen-Moran, 2008; Barrett et al., 2019; Katherine et al., 2024; Celeste, 2025; Wing et al., 2023; Singer, 2015)
2	Nature-Orientation	Easy access to green space, child's connection with the environment, large windows facing nature, outdoor classroom activities, participatory gardens	These concepts are organized around direct or visual connection with natural elements and were analyzed in research (Scarlett et al., 2013; Marcella et al., 2023; Matthew & Alessandro, 2019; Sri Een & Akemi, 2019)
3	Participation	Individual and collective participation in planting, invitation to participate in design and space modification, participation in spatial decision-making, collective activities, sense of belonging	These concepts emphasize the child's active role in creating and changing the environment. This characteristic is introduced as "participation" in the mobility and Nature-Orientation process (Chierichetti & Lembo, 2022; Sun & Firzan, 2014)
4	Safety and Accessibility	Security, easy access, safe paths, safe play spaces	This component is formed from the combination of Rose and Meyer's (2007) perspective on "universal design" and Malinin and Parnell's (2012) view on "safety as a foundation for independence," and is also considered as one of the sub-components of Nature-Orientation in child-centered educational spaces (Sri Een & Akemi, 2019; Scarlett et al., 2023)

Based on the presented material and the conceptual model of the research, the selection of the "mobility and nature-orientation cycle" in child-centered educational spaces as the main cycle of this research is based on theoretical and empirical reasons. According to the literature review and since both mobility and nature-orientation have dynamic, interactive, and bidirectional natures, the child in interaction with mobile space and natural space is not only affected by the space but also influences it (Barrett et al., 2015; Scarlett et al., 2023). This feature, which represents a kind of feedback, is what embodies the concept of cycle in the present research. It is worth noting that the safety and accessibility component has a static and infrastructural nature, and the participation component refers more to social processes (Dudek, 2005; Evans, 2006). Therefore, these two components are considered as mediating components as well as complementary and prerequisite components necessary for the realization of the mobility and nature-orientation cycle in this research. Thus, the main purpose of this research is to identify the role of design components of child-centered educational spaces based on enhancing the level of mobility and nature-orientation in girls' elementary schools (first cycle) in Tehran. The research question is: What are the components of child-centered educational space design based on enhancing mobility and nature-orientation in girls' elementary schools (first cycle) in Tehran? (Fig. 3).

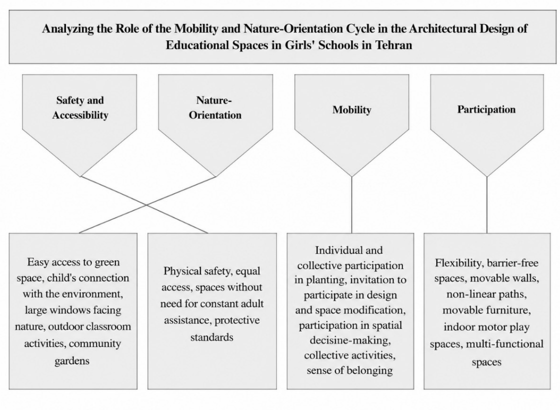

Figure 2: Research Conceptual Model

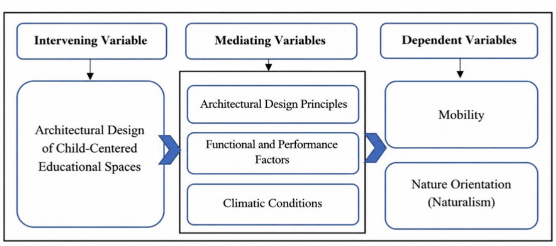

Figure 3: Initial conceptual model of the research and the relationships among the research variables.

Methodology

The research method is applied-fundamental in terms of purpose and cross-sectional in terms of time horizon. In terms of method, it is quantitative. It is worth noting that because the research method is based on correlation, this research has no hypotheses. In the user survey phase, according to the research purpose, the statistical population of respondents consisted of all principals, teachers, and users of selected first-cycle girls' schools in Tehran, including Salam Girls' School (District 4), Shahed School (District 1), Sama School (District 5), Saba School (District 4), and Gam Aftab School (District 5) who have been working in these schools for more than 5 years or have complete familiarity with the architectural design principles of these schools. The sampling method from the statistical population was cluster random sampling, and sample size determination was based on Klein's formula (2 to 5 people per questionnaire item). Accordingly, the sample size in the user survey phase was 290 people, and in addition to the 290 distributed questionnaires, electronic questionnaires were also made available to users to ensure the reliability of the results, and ultimately the same 290 questionnaires were entered into the software. It should be noted that the research questionnaire questions were designed with a 10-point Likert scale. In fact, this scale directs people to choose a specific direction among the options. To assess the validity of the questionnaire, face validity was used, and in this regard, the opinions of experts specializing in the research topic were applied, and group consensus was reached for the face validity of the questionnaire. Also, to assess face validity and to ensure that respondents correctly understood the survey options and accurately understood the researchers' intent, several users of first-cycle girls' schools in Tehran were asked in person to explain their understanding of each question so that the researcher could ensure correct and easy comprehension of the questions by the statistical population. Some unclear questions were revised after this process. Cronbach's alpha coefficient was used to measure reliability. Tab. 4 presents the results.

Table 4: User Questionnaire Reliability Confirmation Using Cronbach's Alpha

Factor	Composite Reliability	Number of Items	Cronbach's Alpha	Factor
1	0.945	7	0.942	Mobility
2	0.936	6	0.933	Safety and Accessibility
3	0.949	8	0.947	Nature-Orientation
4	0.953	7	0.951	Participation

To identify and categorize the main research components, factor analysis in R was first used to classify the questionnaire items into meaningful and coherent constructs (four components: mobility, nature-orientation, participation, and safety and accessibility). Based on the theoretical foundations, the results of this stage confirmed the four-factor structure, and based on that, the "mobility and nature-orientation cycle" was designated as the selected research cycle due to the highest internal consistency and the highest common factor loading. In the next step, to examine the prerequisites for modeling, Pearson correlation test and multiple regression analysis were performed among the components of the selected cycle. The Pearson correlation test was used because this research seeks to examine the direction and strength of linear relationships among variables, and this test, considering the interval and relatively continuous measurement level of the data, is the most suitable option for determining the presence or absence of significant relationships among components. After confirming the existence of significant correlations among variables, multiple regression analysis was performed to determine the contribution of each component in predicting the dependent variable. It should be noted that these steps (factor analysis, correlation, and regression) are considered initial prerequisites for structural equation modeling (SEM); in such a way that factor analysis provides construct validity, Pearson correlation examines the existence of relationships, multiple regression determines the contribution of each variable, and ultimately structural equation modeling will be able to test the entire conceptual model simultaneously with control of measurement error. Also, to ensure the adequacy of latent variable measurement and the appropriateness of items for measuring the relevant constructs, a confirmatory measurement model for the four components of the selected cycle was evaluated. Subsequently, to test causal and cyclical relationships among the model variables, structural equation modeling was used in AMOS software. This method was employed to assess model acceptability, examine fit indices, test the significance of relationships between factors, and determine the direct and indirect effects of variables. Finally, the relational network of research components was explained in the form of a modified model to clarify how variables affect each other within the framework of the selected cycle.

FINDINGS AND DISCUSSION

In this research, factor analysis in R was used in the first stage of data analysis. After performing factor analysis, the adequacy indices were examined, and the KMO value in this stage of the research was 0.752, indicating very appropriate adequacy of the sample size for conducting factor analysis, and in the Bartlett test, the significance level (Sig) of 0.000 indicates the correctness of Varimax rotation, thus confirming the appropriateness of the data for factor analysis. The results are presented in (Tab. 5).

Table 5: KMO and Bartlett's Test of Sphericity for Examining Sample Size Adequacy

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.752
Bartlett's Test of Sphericity	Chi-Square	3018
	Df	666
	Sig	0.000

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Table 6: Total Variance Explained for Factors

Factor	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Cumulative percentage	Variance	Total	Cumulative percentage	Variance percentage	Total	Cumulative percentage	Variance percentage	Total
1	28.64	18.56	18.56	28.64	18.56	18.56	13.45	8.71	8.71
2	15.43	10.00	54.67	15.43	10..00	54.67	8.56	5.55	30.17
3	12.78	8.28	62.95	12.78	8.28	62.65	10.92	7.07	37.24
4	10.21	6.62	69.57	10.21	6.62	69.57	9.87	6.39	43.63

Tab. 7 presents the rotated data matrix, including the factor loading for each factor after rotation. User grouping in each category was based on the factor loading amount. Thus, in each column, each expert with a factor loading greater than ±0.3 was assigned to that group, and this process continued for the next group. In this table, a factor loading of 0.3 indicates that 9% of the variable's variance is explained by that factor. This amount of explained variance is considerable, and the factor loading can be considered significant. According to the mentioned points and examination of the factor loading table, the following can be observed. (Tab. 7)

Table 7: Rotated Data Matrix and Factor Loading for Each Item

No.	Component	Item	Factor 1	Factor 2	Factor 3	Factor 4
1	Mobility	Dynamic curved paths	0.187	0.09	0.112	0.134
2		Ergonomic movable furniture	0.176	0.087	0.098	0.121
3		Temporary partitions	0.201	0.112	0.134	0.156
4		Integration with movable walls	0.145	0.123	0.145	0.167
5		Learning through movement	0.156	0.098	0.123	0.145
6		Wheeled furniture	0.167	0.087	0.112	0.134
7		Safety	0.089	0.156	0.145	0.123
8	Safety and Accessibility	Easy access	0.112	0.589	0.145	0.134
9		Path safety	0.123	0.564	0.156	0.145
10		Safe play spaces	0.156	0.526	0.178	0.167
11		Educational stairs	0.134	0.167	0.912	0.156
12		Safe materials	0.145	0.178	0.867	0.167
13		Cozy shelters	0.178	0.183	0.838	0.178
14	Nature-Orientation	Participation in planting	0.201	0.156	0.779	0.201
15		Access to yard	0.189	0.145	0.688	0.189
16		Activity in green space	0.212	0.167	0.681	0.212
17		Community gardens	0.223	0.178	0.591	0.223
18		Large windows	0.178	0.134	0.522	0.178
19		Integration with technology	0.389	0.345	0.412	0.478
20	Participation	Multi-functional spaces	0.245	0.189	0.201	0.473
21		Light partitions	0.234	0.178	0.189	0.446
22		Active child intervention	0.256	0.201	0.212	0.453
23		Open plans	0.223	0.167	0.178	0.403
24		Multi-purpose flooring	0.112	0.223	0.256	0.399
25		Geometric breaks	0.134	0.303	0.301	0.567
26		Planning boards	0.398	0.412	0.423	0.413

Based on the rotated matrix in Table7, the extracted factors have been able to provide an appropriate factor structure for the research items. In Factor 1 (Mobility), items such as temporary partitions (0.201), dynamic curved paths (0.187), and movable furniture (0.176) have the highest factor loadings. In Factor 2 (Safety and Accessibility), easy access (0.589), path safety (0.564), and safe play spaces (0.526) have the highest factor loadings. Factor 3 (Nature-Orientation) is formed with items such as participation in planting (0.779), access to yard (0.688), and activity in green space (0.681). Factor 4 (Participation) is formed with components such as geometric breaks (0.567), multi-functional spaces (0.473), and active child intervention (0.453). Table 8 presents the rotated factor matrix. (Tab. 8)

Table 8: Rotated Factor Matrix

Factor	1	2	3	4
1	1.000	0.523	0.589	0.634
2	0.523	1.000	0.567	0.556
3	0.589	0.567	1.000	0.623
4	0.634	0.556	0.623	1.000

According to Table 9, these indices show that the model fits the sample size of 290 and has good generalizability. Table 9 presents the descriptive indices of the factors extracted from factor analysis in R.

Table 9: Factors Extracted from Factor Analysis in R

Row	Factor	Count	Mean	Deviation Standard	Minimum	Maximum
1	Mobility	290	4.15	0.69	1.00	5.00
2	Safety and Accessibility	290	3.87	0.65	1.00	5.00
3	Nature-Orientation	290	3.98	0.74	1.00	5.00
4	Participation	290	4.12	0.71	1.00	5.00

Subsequently, before structural equation modeling, the correlation test among the four components of the selected cycle was performed. The results of the correlation test are presented in Table 10. According to the results in Table 10, it can be acknowledged that there is a positive and strong correlation between most components at the significance level of 0.01. This means that these components are in close interaction with each other, and improvement of each can lead to improvement of other components. The variable "mobility" showed a strong and significant correlation with all components except safety. Also, the strong relationship between "mobility" and "participation" with a coefficient of 0.698 (Sig = 0.001) is important. This means that the more students have the opportunity to move and navigate in space, the more their social interactions and participation with each other in group activities increase. Movable spaces create more opportunities for face-to-face encounters and collaboration among students. The relationship between "mobility" and "nature-orientation" (0.742) is also strong and significant, indicating that these concepts are in an interconnected chain and their separation is not possible. The variable "nature-orientation" showed significant and mostly strong correlations with all components. (Tab. 10)

Table 10: Correlation Test Among Sub-Components of the Mobility and Nature-Orientation Cycle in the Architectural Design of Educational Spaces in Girls' Schools in Tehran

Components		Mobility	Safety and Accessibility	Nature-Orientation	Participation
Mobility	Correlation coefficient	1	0.234	0.742	0.698
	Significance probability	-	0.025	0.001	0.001
	N	290	290	290	290
Safety and Accessibility	Correlation coefficient	0.234	1	0.310	0.280
	Significance probability	0.025	-	0.001	0.002
	N	290	290	290	290
Nature-Orientation	Correlation coefficient	0.742	0.310	1	0.599
	Significance probability	0.001	0.001	-	0.001
	N	290	290	290	290
Participation	Correlation coefficient	0.698	0.280	0.599	1
	Significance probability	0.001	0.002	0.001	-
	N	290	290	290	290

Evaluation of the Measurement Model of the Mobility Cycle in Nature

After the initial extraction of components through factor analysis in R and selection of the selected cycle based on the components (mobility, safety and accessibility, nature-orientation, and participation), and considering the correlation test and prior to testing causal/structural relationships among constructs, it is necessary to evaluate the measurement model. To prevent data dispersion and focus on the "specified cycle of the 4 mentioned components," these factors were subjected to confirmatory evaluation in the form of a measurement model. The purpose of this stage was to ensure that the items correctly measure the latent constructs of the cycle. The results of the measurement model evaluation are presented in Tab. 11.

Table 11: Results of Measurement Model Evaluation

Constructs	Indicator (Label)		Factor Loading	Critical Ratio (c.R)	VIF	Significance Level
Mobility	MOB1	Dynamic curved paths	0.72	2.71	1.45	0.000
	MOB2	Ergonomic movable furniture	0.81	2.85	1.60	0.000
	MOB3	Temporary partitions	0.54	1.75	1.30	0.008
	MOB4	Temporary partitions	0.68	2.60	1.55	0.009
	MOB5	Learning through movement	0.85	3.25	1.70	0.000
Safety and Accessibility	SAF1	Easy access	0.84	3.35	1.78	0.000
	SAF2	Path safety	0.89	3.60	1.85	0.000
	SAF3	Educational stairs	0.55	1.90	1.32	0.057
	SAF4	Safe play spaces	0.82	3.15	1.70	0.000
	SAF5	Safe materials	0.78	2.85	1.60	0.004
	SAF6	Cozy shelters	0.71	2.60	1.55	0.009

Nature-Orientation	NAT1	Cozy shelters	0.77	2.95	1.65	0.000
	NAT2	Access to yard	0.72	2.70	1.58	0.007
	NAT3	Activity in green space	0.85	3.25	1.72	0.000
	NAT4	Community gardens	0.80	3.00	1.68	0.012
	NAT5	Large windows	0.69	2.50	1.52	0.028
	NAT6	Integration with technology	0.61	2.20	1.45	0.006
Participation	PRT1	Multi-functional spaces	0.74	2.75	1.60	0.045
	PRT2	Light partitions	0.59	2.00	1.38	0.000
	PRT3	Active child intervention	0.81	3.10	1.70	0.012
	PRT4	Open plans	0.66	2.50	1.52	0.021
	PRT5	Multi-purpose flooring	0.63	2.30	1.48	0.012
	PRT6	Geometric breaks	0.47	1.70	1.28	0.089
	PRT7	Planning boards	0.75	2.85	1.62	0.004

Structural Equation Modeling of the Mobility Cycle in Nature

In this stage, to explain how these factors influence each other in a cyclical and feedback-oriented system, structural equation modeling (SEM) was used to analyze the design process of girls' schools in the form of a cycle. In this section, after confirming the validity and reliability of the measurement model in the previous stage, causal and cyclical relationships among variables were tested. This cycle shows how "mobility" through "nature-orientation" and "safety" leads to strengthening "participation." In this cycle, nature-orientation is influenced by the model at 100%, mobility at 41%, participation at 37%, and safety at 29%. Details of direct and indirect relationships are presented in Table 12.

Table 12: Direct, Indirect, and Total Standardized Effects

Two-Variable Relationship	Direct Standardized Effect	Indirect Standardized Effect	Total Standardized Effect	Standard Error
Mobility → Safety and Accessibility	0.33**	0.16	0.49**	0.046
Mobility → Nature-Orientation	0.39**	0.11	0.50**	0.042
Mobility → Participation	0.37**	0.13	0.50**	0.044
Safety and Accessibility → Nature-Orientation	0.34**	0.10	0.44**	0.046
Safety and Accessibility → Participation	0.31**	0.12	0.43**	0.047
Nature-Orientation → Participation	0.44**	0.08	0.52**	0.042
*Significance at 99% level **, significance at 95% level *, no significance		P¹ < 0.01 = **, P < 0.05 = *, P > 0.05 = -		

Based on the findings presented in Table 12, structural relationships among all four research constructs have been examined. The results show that most of the examined relationships have been confirmed at 99% and 95% significance levels, confirming the explanatory power of the structural model. Mobility has significant direct effects on other variables. Safety and accessibility also have significant direct effects on nature-orientation (0.34) and participation (0.31). Nature-orientation shows strong direct effects on participation (0.44). Nature-orientation also has a negative effect on mobility with a coefficient of -0.10, which, although not significant, indicates a possible inverse direction. Participation also has significant direct effects on other variables, with the greatest effect on nature-orientation (0.41), mobility (0.39), and safety and accessibility (0.33**). Overall, from the total items examined for the four main constructs in the structural equation cycle of the research, 87% have factor loadings above 0.5 and 60% have factor loadings above 0.7, indicating good convergent validity and, in a considerable portion, very good model validity. In terms of construct differentiation, mobility, safety and accessibility, nature-orientation, and participation all have significant and relatively strong indicators, among which path safety and creative discoverable space stand out as the strongest items in the entire model. In summary, the results of causal modeling in AMOS software show that the components of design principles for child-centered educational spaces based on enhancing mobility and nature-orientation have a significant and considerable role in explaining the quality of education in first-cycle girls' elementary schools in Tehran. It is worth noting that the components of participation, safety, mobility, and nature-orientation interact with each other to form the mentioned cycle. In this cycle, safety and accessibility are influenced by the model at 29%, participation at 37%, mobility at 41%, and nature-orientation at 100%. In this cycle, the mobility component increases participation in the environment and external nature of the child-centered educational space, and safety and accessibility in these spaces also lead to increased mobility of students. The final modified model is presented in (Fig. 4).

Based on Figure 4, it can be acknowledged that the direction of the relationship is from “nature-orientation” (C4 → C5) to “mobility.” In this regard, the theory of “play in nature” indicates that the presence of natural elements in educational spaces increases children’s motivation for movement, exploration, and discovery (Scarlett et al., 2023). In other words, nature-orientation acts as a platform for the realization of mobility. The direction of the relationship from “mobility” to “participation” in the model (C5 → C7) is considered. According to “active learning” theory, spaces that allow children to move, rearrange, and choose paths inspire a sense of ownership and responsibility in them, and this sense increases their participation in collective activities and spatial decision-making (Chierichetti & Lembo, 2022). In the present model, “safety and accessibility” is considered as a prerequisite and necessary condition for the realization of mobility; meaning the direction of the relationship is from “safety and accessibility” to “mobility” (C6 → C5). In this regard, Malinin and Parnell (2012) state that safety in child-centered educational spaces should be designed not merely as a limitation but as a platform for creating “self-confidence and cognitive independence” in children. Without ensuring safety and appropriate accessibility, a mobile space cannot be properly used by children (Rose & Meyer, 2007). Also, Sun and Firzan (2024) in their research explicitly introduced “appropriate safety and accessibility” as one of the main criteria for desirability of learning spaces that must be ensured before any mobility-oriented design. Also, the cycle shows the relationship between nature-orientation

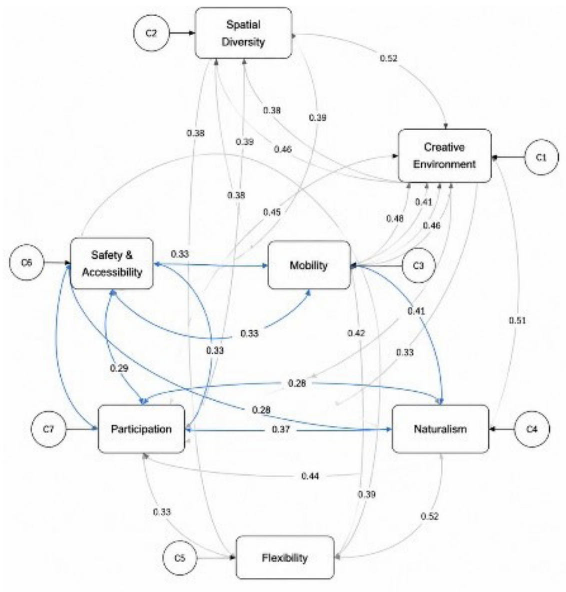

Figure 4: Structural Model (Mobility Cycle in Nature-Orientation)

and participation (C4 → C7), indicating that nature-orientation also directly affects participation. According to "place-based learning" theory, natural spaces, due to their informal and exploratory nature, increase children's collective participation and provide more opportunities for cooperation and interaction (Matthew & Alessandro, 2019). The most important feature of the present model is considering a bidirectional and cyclical relationship between mobility and nature-orientation (C4 ↔ C5). In this regard, the theory of dynamic learning environments shows that mobility and nature-orientation mutually and reciprocally reinforce each other. This means that nature-orientation increases mobility, and increased mobility deepens and makes more meaningful the child's experience of interaction with nature (Dudek, 2005; Barrett et al., 2015) Now, to examine the fit and acceptability of the model presented in Figure 2, fit and acceptability indices are presented in (Tab. 13).

Table 13: Model Acceptability and Fit Indices

	Index	Research Model	status	Excellent Fit	Good Fit
Absolute Fit Indices	Goodness of Fit Index (GFI)	1.000	Excellent Fit	GFI≥0/95	GFI≥0/90
	Adjusted Goodness of Fit Index AGFI))	.999	Excellent Fit	GFI≥0/95	GFI≥0/85
	Root Mean Square Residual (RMR)	0.012	Excellent Fit	RMR ≤ .05	RMR ≤ .08
	p-value	0.981	Excellent Fit	P≥0/05	-
	Chi-Square (CMIN)	0.038	Excellent Fit		
	Degrees of Freedom (DF)	2	Excellent Fit	-	-
	Chi-Square/Degrees of Freedom (CMIN/DF)	0.019	Excellent Fit	CMIN/DF<2/0	CMIN/DF<3/0
Proportional Fit Indices	Tucker-Lewis Index (TLI)	1.018	Excellent Fit	TLI ≥ .95	-
	Normed Fit Index (NFI)	1.000	Excellent Fit	NFI≥ 0/95	NFI≥0/90
Non-Centrality-Based Indices	Comparative Fit Index (CFI)	1.000	Excellent Fit	CFI≥ 0/95	CFI≥0/90
	Root Mean Square Error of Approximation (RMSEA)	0.00	Excellent Fit	RMSEA≤0/05	RMSEA≤0/08

According to Table 13, the goodness-of-fit indices show that the research model has very good and even excellent fit. The GFI value is 1.000 and AGFI is 0.999, both indicating excellent model fit. Also, the RMR value of 0.012 indicates very low estimation error. On the other hand, the CMIN value of 0.038 with 2 degrees of freedom and significance level of 0.981 indicates that there is no significant difference between the observed covariance matrix and the matrix predicted by the model. In addition, TLI with a value of 1.018 and NFI with a value of 1.000 also confirm the excellent fit and appropriate performance of the research model. Now, the coefficient of determination (effect size) of the model on the research variables is presented (Tab. 14)

Table 14: Coefficient of Determination (Effect Size) on Research Variables

Component	Adjusted R-squared (R^2)	Coefficient of Determination (R^2)
Mobility	0.866	0.867
Safety and Accessibility	0.840	0.841
Nature-Orientation	0.866	0.867
Participation	0.889	0.890

According to the results in Table 15, which shows the operational error estimation of variables and the significance of operational errors, it can be acknowledged that all operational errors for the research constructs are at a desirable level, with the lowest error related to participation at 0.110. In contrast, the highest operational error is related to safety and accessibility with a value of 0.159, indicating that part of the variance of this construct is not explained by the predictor variables. Also, C.R. values for all constructs are above 1.96 and in the range of 2.821 to 3.698, and the significance level P for all is less than 0.05; therefore, operational errors and unexplained variances are statistically significant and indicate that part of the variations in constructs remains outside the model. (Tab. 15)

Table 15: Variable Variances in the Final Model and Operational Error Estimation

Operational Error	Component	Estimate	Standard Error	C.R. (Critical Ratio)	P (Significance)
C1	Mobility	0.133	0.042	3.167	0.002
C2	Safety and Accessibility	0.159	0.043	3.698	0.000
C3	Nature-Orientation	0.133	0.041	3.244	0.001
C4	Participation	0.110	0.039	2.821	0.005

The final model shows that "mobility" is the driving engine of the cycle, which through improving "safety" and connecting with "nature-orientation" creates the highest level of "participation" in students.

CONCLUSION AND RESULTS

Child-centered educational environments are dynamic and multidimensional spaces designed with a deep understanding of children's developmental, motor, and psychological needs to transform learning from a static process into a living and interactive experience. In these spaces, elements such as mobility through movable furniture and curved paths, creating proportionate scales and soft forms, and flexibility with the possibility of quick rearrangement of layout all serve to foster children's creativity, independence, and physical and mental health. Inspired by leading educational theories, these environments break the fixed boundaries of classrooms and create a space where the child is not merely a passive receiver but an active, curious, and creative individual who, through direct interaction with the environment, understands concepts and strengthens cognitive and motor skills. The results of this section of the research are consistent with the studies of Zanele (2024), Chierichetti and Lembo (2022), and Salawu et al. (2024). The findings of factor analysis in R indicate that the research data follow a coherent multi-factor structure including mobility, safety and accessibility, nature-orientation, and participation, and this structure has good fit with empirical realities. Among these, the "mobility" factor, by explaining a significant percentage of the total variance, has established its central position in the design of child-centered educational spaces. In the mobility dimension, the presence of dynamic movement paths and the use of movable furniture play a key role, a finding consistent with the research of Sun and Firzan (2024), which emphasizes the necessity of aligning spatial changeability with children's needs. In contrast, in the "safety and accessibility" component, movable and modular elements have higher factor loadings, and "nature-orientation" is more closely tied to the presence of safe play spaces and the use of safe materials. Finally, the "participation" factor has less importance and factor loading compared to other main components, and this hierarchy of importance provides valuable guidance for prioritizing future designs. According to the mobility cycle in nature formed in the research model, it can be acknowledged that nature-orientation acts as the main foundation and key driver in child-centered educational environments based on the mentioned cycle. This deep connection with nature directly affects mobility and creates a dynamic space for movement and exploration. Simultaneously, increased mobility provides a suitable platform for greater participation, and on the other hand, adherence to safety and accessibility principles alongside nature allows children to move and engage in activities with greater confidence. Therefore, this cycle shows that the combination of "nature-centeredness" with "safety" is the driving engine of "mobility," which itself provides the groundwork for "participation" and ultimately the improvement of education quality.

In general, the modeling findings also showed that all identified constructs in the research have significant and positive effects on the quality of educational spaces, and no multi-collinearity problems were observed in the model. Based on the explanation of the direction of relationships in the conceptual model of the research, it can be concluded that the mobility and nature-orientation cycle acts as the central core of child-centered educational space design, in such a way that these two components through their bidirectional and feedback relationship reinforce each other and provide the groundwork for the formation of a dynamic learning environment. The results of this section of the research are consistent with the study of Scarlett et al. (2023). Safety and accessibility as a basic prerequisite are considered a condition for the realization of any effective mobility in space; because without ensuring it, not only the child's self-confidence and cognitive independence do not form, but the mobile space also loses its effectiveness. The results of this section of the research are consistent with the study of Malinin and Parnell (2012). Also, participation, which is influenced by both nature-orientation and mobility, plays a role as an intermediary and complementary link in this cycle; in such a way that nature-orientation through its informal and exploratory nature increases collective participation, and mobility by creating a sense of ownership provides the groundwork for the child's active presence in spatial decision-making. The results of this section of the research are consistent with the study of Matthew and Alessandro (2019). The findings from structural equation modeling showed that among the four research components, "mobility" and "nature-orientation" play the greatest role in the design of child-centered educational spaces, and the bidirectional relationship between these two components forms the central core of the design cycle. Therefore, a successful educational space is one in which child mobility and the presence of nature are considered simultaneously in the architectural design of spaces. These results are consistent with the view of Woolley (2021), which indicates that diversity in the external environment (which is a type of mobility) is essential for children's development, and the view of Wang and Kim (2025), who believe that space design should be based on children's movement patterns, not on fixed architectural forms. In this regard, when an architect combines movement paths in child-centered educational spaces with diverse vegetation, natural light, and views of green space, not only does it increase mobility but also deepens the child's experience of interaction with nature. In this regard, designing "winding exploration paths" that pass through multidimensional educational gardens can simultaneously reinforce mobility and nature-orientation in a cyclical manner. The findings also showed that "safety and accessibility" play a prerequisite and foundational role in the mobility and nature-orientation cycle; without which the mentioned cycle does not form. Therefore, in the architectural design of child-centered educational spaces, uniform and soft flooring, removal of physical barriers in paths to green spaces, installation of safe railings on windows facing nature, and scattering seating areas in high-traffic points can be used to maintain supervision while preserving the child's independence and self-confidence. It is worth noting that "participation" as a complementary component shows that natural and mobile spaces achieve maximum effectiveness when children have a role in creating and changing those spaces. The implication of this component in the architectural design of child-centered educational spaces can be the design of "decision-making points" on exploratory paths and the creation of large work tables in open spaces where children can change their arrangement. Based on the obtained results, Table 16 presents effective strategies for achieving the components of architectural design of child-centered educational spaces in improving the level of mobility and nature-orientation in first-cycle girls' elementary schools in Tehran city. (Tab. 16)

Table 16: Effective Strategies for Achieving Architectural Design Components of Child-Centered Educational Spaces in Improving Mobility and Nature-Orientation in First-Cycle Girls' Elementary Schools in Tehran

Effective Strategies for the Mobility and Nature-Orientation Cycle	
Participatory Capacity	Nature-Orientation
Implementation of collaborative activity stations within outdoor and semi-outdoor environments Integration of 'Exploratory Pathways' and spatial decision-making nodes	Integration of multi-dimensional educational gardens Development of pedestrian pathways featuring diverse vegetation and natural hardscape materials (stone or timber) Design of classrooms and interior spaces utilizing expansive glazing to facilitate visual connectivity with green environments Creation of semi-open transitional spaces (e.g., pergolas and canopies) to optimize exposure to natural ventilation and daylighting
Mobility	Safety and Accessibility
Provision of diverse exploratory and play-oriented circulation paths Design of dynamic movement pathways incorporating gentle topographical variation, short tunnels, small-scale timber or industrial bridges, and mildly sloped surfaces Use of creative, nature-based play structures	Provision of universally accessible circulation pathways Use of safe, slip-resistant, and uniformly treated flooring across the spatial environment Provision of distributed seating areas, particularly near high-activity zones, to support rest and enhance supervisory oversight Use of resilient, impact-absorbing floor materials Use of protective window coverings and safety guards

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