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Neuroarchitectural Design Element Implication on Student-Athlete School with Holistic Athlete Development

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The physical and cultural environment we create influences our thinking, emotions, and behavior. Architecture plays a role in shaping us as humans, contributing to human well-being. Architecture is a built environment inhabited by humans and engaged in activities within it. Architectural manifestations are always rooted in the physical body, and architectural design has the capacity to nurture, stimulate, or even destroy these through the influences that emerge from/impact human perception patterns and experiences of the space. The International Olympic Committee recommends that youth athlete development programs focus on athletes' health, ability, and resilience, along with broad, inclusive, sustainable, and enjoyable achievement. The term "dual career" globally represents a solution to the challenge of balancing sport and education for young athletes. The "holistic whole-person" approach was introduced as a solution to the "dual-career" problem[3]. supported by essential features in the youth athlete development environment[4]. To support a "holistic whole-person" program, considerations should address psychosocial, psychological, and academic aspects[5]. This is reinforced by the long-term and short-term impacts experienced by student athletes, including psychological (self-optimization), psychosocial (life skills), and educational (academic) impacts, in addition to physical (fitness and/or injury) impacts[6]. This effort demands the presence of architecture in the creation of the built environment (in this context, a special athlete school), both indoor and outdoor, where athletes are required to deliver optimal performance (during their training process) over a certain period of time while living and undergoing training in that environment. Given this situation, the question arises, "What is the architectural design strategy for creating a spatial experience (holistic brain and body performance through user impressions presented by architectural expression) to optimize athlete performance in a student-athlete school?" based on this, it is felt that there is a need to present a model architecture as a design guideline for a Student-athlete School, which is hoped to generally represent the role of architecture in accommodating the needs of optimizing athlete performance in a Student-athlete school.

Keywords: Neuroarchitecture, Student-athlete School, dual career, holistic brain and body performance.

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1. Introduction

Student-athlete schools (SKO) are indeed beginning to receive attention due to the need to balance the demands of sporting achievement and formal educational standards for young athletes. However, this dual career opens up the potential for conflict, as student-athletes face identity conflict and significant time pressures when trying to meet both academic demands and competitive training schedules.

Therefore, there is real potential for a holistic development model in student-athlete schools that integrates physical, cognitive, emotional, and social aspects to prevent conflicts between athletic and academic balance[5]. Research on the design of sports facilities and learning environments emphasizes that design can improve training effectiveness, recovery quality, and learning focus in student-athletes.

The application of neuroarchitecture principles in spatial planning and design (learning facilities, training facilities, social spaces, and individual spaces) in student-athlete schools has the potential to improve human well-being (intellectual, physical, emotional, and social well-being) and reduce the risk of performance decline through spatial designs that support recovery, concentration, and positive social interactions.

The conflict of balancing learning and training for athletes, centered at student-athlete schools, has received considerable attention recently. Neuroarchitecture is an interdisciplinary field that focuses on the spatial planning and design of buildings and spaces that can enhance brain and body performance through the built environment. The research questions that will be addressed in this study, based on the problem formulation above, are: How can neuroarchitecture-based design strategies optimize brain and body performance for athletes within the context of different spatial functions within athlete schools?

2. Literature Review and Data Collection

Student-Athlete School with Holistic Development

In the field of educational architecture, schools are understood not simply as venues for teaching and learning activities, but as environments that actively shape the learning process, social development, health, and behavior of students. Mark Dudek explains that school architectural design is directly influenced by educational theory, students' psychological needs, and the interaction between space and learning activities. This view aligns with the development of the modern educational paradigm that positions schools as learning environments. The learning environment is understood as a system consisting of physical space and other supporting facilities, within which learning activities and social interactions occur, collectively influencing the quality of the educational process.

According to the Minister of Education, Culture, Research, and Technology Regulation No. 22 of 2023, schools, as educational institutions, particularly in secondary education, aim to develop students' competencies so that they possess academic abilities, character, skills, and readiness for continuing education and community life.1 Based on this understanding, schools function not only as venues for delivering learning materials, but also as a means of developing individual potential.

According to Balyi & Hamilton (2004) and Wylleman et al. (2013), individual development during adolescence encompasses not only academic dimensions but also physical, psychological, and social dimensions, which occur simultaneously. In this endeavor, talent development, in this case, sports talent and interest, requires an environment that supports ongoing training, learning, and experience.[45] A successful development environment is characterized by the integration of education, training, social support, and an organizational culture that fosters individual development. Institutions specializing in Education and Sports Schools are generally called Sport Schools.

Sport Schools, also known as Student-Athlete Schools, are institutions that combine formal education with structured sports development programs. According to the European Commission's EU Guidelines on Dual Careers of Athletes, athlete-specific schools aim to ensure balanced, sustainable, and long-term academic and sports-performance development. This balancing effort is discussed through a dual-career program using a Long-Term Athlete Development (LTAD) approach to avoid potential conflicts between academic and training commitments.

By implementing the Holistic Athlete Development Framework, Athlete Schools can optimize not only physical abilities, but also academic, social, emotional, and self-identity aspects that need to be emphasized for student-athletes. The long-term and short-term impacts experienced by student-athletes include

psychological (self-optimization), psychosocial (life skills), educational (academic) impacts, in addition to physical impacts (fitness and/or injury).

As conceptualized, throughout their sports careers, there is constant interaction between all levels of athlete development (e.g., academic/vocational, athletic/physical, psychosocial, and psychological).[18] To achieve this holistic performance, it is stated that there are five pillars that student-athlete schools need to address: (1) Transition, (2) Integration, (3) Academic/vocational, (4) Athletic/Physical, (5) Psychological/psychosocial.[18]

Area	Practical recommendations
Transition	• Extra support to help them prepare for and cope with the challenges and changes of moving into a sports-friendly school environment
Integration	• Aligned staff in academic, athletic, and psychological/psychosocial support areas, who work together to support and care for the student-athletes holistic development • An integrated/structured timetable for sport and education
Academic/ Vocational	• Support network providing a consistent demonstration of the importance of education • A collaborative academic support system (coaches, teachers and other staff members) • Dual career officer • Extra personal academic support e.g., extra-tutoring • A structured academic curriculum
Athletic/Physical	• High quality, qualified coaches • Sport science support team (i.e., S&C, physio, nutritionists) • High standard of fixtures and matches • High volume/frequency of training • Multi-dimensional training programmes (incorporating technical, tactical, physical and psychological variables) • Injury prevention schemes (e.g., S&C programmes, monitoring of individual workload, recovery strategies, modifying external training variables to achieve a desired internal response, programme malleability and athlete education, extrinsic factors via the use of protective equipment, and implementation of rules and regulations) • Work in tandem with wider sporting organisations in an integrated effort to balance student-athletes training schedules and develop aligned athlete-focused training plans and goals
Psychological/ psychosocially	• Careful management of performance pressures • Holistic approach to coaching • Encourage and advocate for role models/leadership • Encourage community learning • Encourage positive peer support • Additional social and psychological support to help student-athletes deal with the emotional response to injury

Figure 1 5 Pillars of Holistic Athlete Development

Neuroarchitecture Design Elements and Their Impact on Human Well-being

Neuroarchitecture is an approach developed from the understanding that architecture not only provides space for human activity but also shapes thinking capacities, emotional states, and behavioral tendencies through the spatial experiences of its users. Robinson and Pallasmaa (2015) explain that the physical environment can nurture, stimulate, or hinder human development because every architectural experience involves a reciprocal relationship between the body, mind, and the built environment. Robinson and Pallasmaa (2015) explain that architectural experiences are embodied, meaning they involve the whole body through the integration of sensory perception, emotion, memory, consciousness, and individual life experiences. From this perspective, humans do not experience space solely through the sense of sight, but through the involvement of the entire body, simultaneously constructing meaning within the built environment.

The experience of architecture does not occur directly from the physical form of a building, but results from the interaction between environmental stimuli and information-processing mechanisms in the brain (Eberhard, 2009). The physical environment acts as a source of stimuli received through the sensory system, then processed by the brain through various neurological mechanisms, resulting in physiological, cognitive, emotional, and behavioral responses.

Based on a systematic review of various neuroscience and architecture studies, Assem et al. (2023) explain that the influence of the built environment ultimately leads to improved human well-being, encompassing four dimensions: physical well-being, cognitive (intellectual) well-being, emotional well-being, and social well-being.

a. Cognitive (Intellectual) Well-being
   Cognitive (Intellectual) Well-being is a condition in which the built environment supports the user's cognitive functions, thereby improving the ability to think, concentrate, learn, remember information, solve problems, and make decisions effectively.
b. Physical Well-being
   Physical Well-being is a condition in which the built environment supports the user's physical health and physiological balance by creating environmental comfort, reducing physiological stress, and enhancing the body's recovery process.
c. Emotional Well-being
   Emotional Well-being is a condition in which the built environment creates positive emotional experiences by fostering a sense of comfort, safety, calm, and enjoyment.
d. Social Well-being
   Social well-being is a condition where the built environment facilitates positive social interactions, a sense of belonging, collaboration, and bonds between individuals within a community.

In design practice, improving user well-being depends on the characteristics of the built environment, which stimulate the human nervous system. Therefore, understanding the relationship between architectural elements and each dimension of human well-being is necessary to formulate neuroarchitecture-based design strategies. Assem et al. (2023) synthesized this relationship through a systematic review of various studies that identified the contribution of each architectural element to users' physical, cognitive, emotional, and social well-being.

Architectural Elements	Neuro-architecture Pillar	Impact on Cognitive, Body Psychology, Emotion, Behavior
Massing		
3D Symmetrical	Emotion	Generate Emotional Response
		Reduce Satisfaction & Interest
	Cognitive	Stimulate Brain Activity
3D Asymmetrical	Emotion	Generate Emotional Response
	Cognitive	Activate Higher-order Thinking
3D Curvilinear	Emotion	Increase Fear
		Attractive and Acceptable
	Cognitive	Evoke Memory
		Activating Visual & Spacial Perception
3D Sharp-angled	Emotion	Attractive and Understandable
Color		
Cool Color Tempetarure		
Yellowish Green, Purple	Cognitive	Enhance Memory and Attention
	Body Psychology	Increased Heart Rate and Alertness
Warm Color Temperature	Cognitive	Higher Level of Memory and Attention
	Body Psychology	Lower Heart Rate, Increase Relaxation
Bright Color	Emotion	Positive Emotion
Green	Emotion	Pleasure and Comfort
Natural Light	Emotion	Positive Emotion
Purple, Blue, Green, Yellow,	Cognitive	Stimulate Perception
White	Cognitive	Increased Learning Performance
Dark Color		
Dark Wood Brown	Body Psychology	Decrease Perspiration
Form		
2D Linear	Emotion	Low Arousal and Low Pleasure
	Cognitive	Focus on Learning Process
2D Curvilinear	Behavior	Specific Character
	Body Psychology	Lower Heart Rate
Ceilling Height		
Low Ceilling Height	Emotion	Calmness
	Cognitive	Lower Aesthetic Appreciation
	Behavior	Desire to Leave
Higher Ceilling Height	Emotion	Freedom
	Cognitive	High Activity Intensity
	Behavior	Searching for Direction, Attractive

Architectural Elements	Neuro-architecture Pillar	Impact on Cognitive, Body Psychology, Emotion, Behavior
Lighting		
Contrast	Cognitive	Evoke Memories
Natural Light	Body Psychology	Reduce Stress
	Cognitive	Improve Brain Performance for Writing Activities
Artificial Lighting		
> 7500k	Body Psychology	Increase Blood Pressure
White	Body Psychology	Regulate Sleep Rhythm
5000-3000k		
White	Emotion	Influence Mood
Blue	Emotion	Promote Faster Relaxation
Undirect Light	Emotion	Comfortable
Atmosphere Lighting	Emotion	Reduce Pain
Proportion		
Wide	Cognitive	Less Brain Performance
	Body Psychology	Less Emotional
Narrow	Emotion	Increase Emotion
	Behavior	Increase Attention
Material		
Natural Material	Emotion	Relaxation and Comfort
	Body Psychology	Lower Heart Rate, Decrease Perspiration
Squared Wood	Cognitive	Focus and Form Memories
Artificial		
Steel, Concrete, Glass	Cognitive	Increase Attention on Interior
Sound		
Noise	Emotion	Increase Emotion
Quiet	Cognitive	Increase Attention
Noise	Emotion	Stress
Natural Noise	Emotion	Reduce Stress
Music	Body Psychology	Reduce Blood Pressure
Vegetation		
Scent	Emotion	Relaxation & Pleasure
Less Vegetation	Emotion	Stress
	Behavior	Negative Impact
Natural Environment	Emotion	Less Stress Less Anxiety, Pleasure
	Cognitive	More Logical and Consistent
	Body Psychology	Reduce Pain

Figure 2: Architectural Design Elements and Their Impact on User Impressions

3. Method

This research employs a qualitative descriptive approach, combining theoretical research methods with a research-for-design approach. The descriptive approach was chosen because the research aims to understand and explain the relationship between the concepts of Holistic Athlete Development and

Neuroarchitecture without statistical hypothesis testing. Analysis is conducted through interpretation of various theories, research findings, and precedent studies to understand relevant design principles.

The research-for-design approach was used because the research output goes beyond conceptual understanding and is developed into design guidelines that can be applied in the design process of the Student-Athlete School. Thus, theory serves as a conceptual foundation that is then synthesized into a design strategy contextualized to user needs and site characteristics.

Through this approach, this research positions the design process as the result of a synthesis of theory, precedent, and empirical site conditions, ensuring that the resulting concepts are both scientifically grounded and relevant for application in architectural design practice.

4. Results And Discussion

Student-athlete School with Holistic Athlete Development

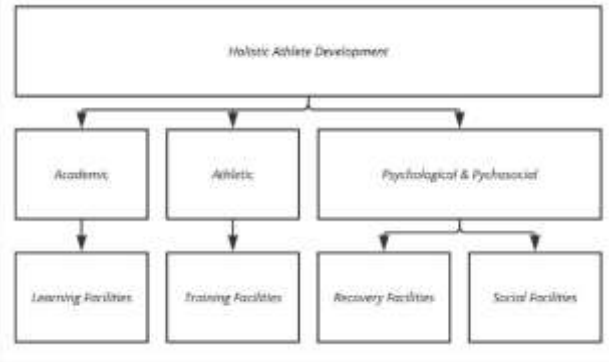


Figure 2 Transformation Holistic Athlete Development Pillar on Student-athlete School Facilities

The concept of Holistic Athlete Development explains that student-athlete development occurs through the integration of academic, athletic, psychological, and psychosocial aspects. Each aspect of development requires different activities, thus requiring different built environment characteristics. Therefore, the first step in developing design guidelines is to identify the relationship between the dimensions of student-athlete development and the activities and facilities that must be provided at the Student-Athlete School.

PERMENDIKBUDRISTEK		Holistic Whole Person for Holistic Athlete Development Integration Between Academic, Athletic, Social & Individual Physical, Biological and Psychological (Social & Emotional) Value Precedents Study-based Facilities		
Academic Facilities	add	Physical/Athletic Facilities	Health & Recovery Facilities	Living Facilities
1 Learning Facilities		1 Training Facilities	1 Recovery Facilities	1 Living Facilities
a Classroom		a Weight Training	a Physical Therapy	a Dormitory
b Laboratorium		b Athletic Court	b Hydrotherapy	2 Entertainment Facilities
c Library		c Sport Science Center	c Clinic	a Entertainment Court
2 Administration				
a Head				
b Staff				
c Guest				
3 Supporting Facilities				
a Health Unit				
b Prayer Room				
4 on Site Facilities				
a Plaza				
b Parking				
c Greeneries				

Figure 3 Kind of Facilities Based on Holistic Athlete Development and PERMENDIKBUDRISTEK

Based on the interpretation of Holistic Athlete Development and the synthesis of precedent studies, four main facility groups were identified as the basis for developing the Student-Athlete School design guidelines: Learning Facilities, Training Facilities, Recovery Facilities, and Social Facilities and Living

Facilities, which can be translated into recovery objectives. These five facility groups were then used as units of analysis in linking spatial functions with neuroarchitecture principles.

4 Pillars of Human Well-being as Design Goals

By integrating the functional needs of the Student-Athlete School space with the principles of neuroarchitecture, this study matches the activity characteristics of each facility group with architectural elements that support Human Well-being. The results of this synthesis produce design guidelines that serve as the conceptual basis for developing the design concept in the following chapter.

a. Learning Facilities are developed based on the needs of student-athletes' academic activities, which require a learning environment with visual, acoustic, and thermal comfort levels and spatial quality that support Cognitive Well-being while maintaining the emotional balance of users. Therefore, the guidelines focus on architectural elements that enhance concentration, reduce distractions, and create a conducive learning environment.
b. Training Facilities are designed to support training performance through a built environment that enhances Physical Well-being, maintains emotional well-being during training, and supports user orientation and safety. The guidelines are developed based on the characteristics of sports activities and the influence of architectural elements on athletes' physical performance.
c. Recovery Facilities serve as a restorative environment that supports physiological and psychological recovery processes after training and learning activities. The guidelines focus on applying architectural elements that reduce stress, promote relaxation, and accelerate recovery through the quality of the built environment.
d. Social Facilities are developed as spaces that support social interaction, collaboration, and a sense of belonging to the school environment. The guidelines focus on space configuration, activity flexibility, and environmental quality that can enhance Social Well-being through the creation of positive interactions between users.

i Learning	i Cognitive
ii Training	i Physical
iii Recovery	i Physical
	ii Emotional
iv Social	i Social
	ii Emotional

Figure 4 Student-athlete School Facilities and Their Goals on Human Well-being

The synthesis results indicate that each facility group has different Human Well-being priorities. Learning Facilities are oriented toward improving cognitive function, while Training Facilities emphasize users' physiological condition. Recovery Facilities are more directed towards supporting physical and emotional recovery, while Social Facilities serve to strengthen social interaction and emotional well-being of users. Nevertheless, all dimensions of Human Well-being remain interconnected and cannot be completely separated.

Facilities		Impression Goals
1	Learning Facilities	i Stimulate Brain Activity
		ii Enchance Memory and Attention
		iii Higher Level of Memory and Attention
		iv Positive Emotion
		v Increase Learning Performance
		vi Focus on Learning Process
		vii Improve Brain Performance for Writing Act.
		viii Increase Attention
		ix Focus and Form Memories
		x More Logical and Consistent
2	Training Facilities	i Positive Emotion
		ii High Activitiy Intensity
		iii Increase Blood Pressure
3	Recovery Facilities	i Lower Heart Rate, Increase Relaxation
		ii Decrease Perspiration
		iii Lower Heart Rate
		iv Calmness
		v Reduce Stress
		vi Promote Faster Relaxation
		vii Comfortable
		viii Reduce Pain
		ix Relaxation and Comfort
		x Reduce Stress
		xi Reduce Blood Pressure
		xii Relaxation and Pleasure
		xiii Less Stress Less Anxiety, Pleasure
4	Entertainment Facilities	i Attractive & Acceptable
		ii Positive Emotion
		iii Freedom
		iv High Activitiy Intensity
		v Reduce Stress
		vi Relaxation and Comfort
		vii Reduce Stress
		viii Reduce Blood Pressure
		ix Relaxation and Pleasure
5	Living Facilitiies	i Lower Heart Rate, Increase Relaxation
		ii Decrease Perspiration
		iii Lower Heart Rate
		iv Calmness
		v Pleasure and Comfort
		vi Comfortable
		vii Reduce Pain
		viii Relaxation and Comfort
		ix Reduce Stress
		x Reduce Blood Pressure
		xi Relaxation and Pleasure
		xii Less Stress Less Anxiety, Pleasure

Figure 5 Student-athlete School with Their User Impression Goals

Neuroarchitectural Design Elements Implementation on Student-athlete School

Based on this interpretation, a neuroarchitectural design guideline matrix was developed that systematically connects facility categories, user experience objectives, and architectural design elements. This matrix synthesizes the entire literature review analyzed in Chapter 2 and serves as a conceptual guideline for the design of the Athletes' Special School in the following chapter. Thus, the resulting guideline is not merely theoretical but also clearly connects user needs, neuroarchitectural objectives, and architectural design decisions.

Facilities	Impression Goals	Architectural Element
1 Learning Facilities	i Stimulate Brain Activity	i 3D Symmetrical
	ii Enchance Memory and Attention	ii Yellowish Green, Purple
	iii Higher Level of Memory and Attention	iii Warm Color Temperature
	iv Positive Emotion	iv Bright Color
	v Increase Learning Performance	v White Bright Color
	vi Focus on Learning Process	vi 2D Linear
	vii Improve Brain Performance for Writing Act.	vii Natural Light
	viii Increase Attention	viii Narrow Proportion, Quiet
	ix Focus and Form Memories	ix Squared Wood
	x More Logical and Consistent	x Natural Environment
2 Training Facilities	i Positive Emotion	i Bright Color
	ii High Activitiy Intensity	ii Higher Ceilling Height
	iii Increase Blood Pressure	iii Artificial Light >7500k
3 Recovery Facilities	i Lower Heart Rate, Increase Relaxation	i Warm Color Temperature
	ii Decrease Perspiration	ii Dark Wood Brown
	iii Lower Heart Rate	iii 2D Curvilinear
	iv Calmness	iv Low Ceilling Height
	v Reduce Stress	v Natural Light
	vi Promote Faster Relaxation	vi Artificial Light Blue
	vii Comfortable	vii Undirect Light
	viii Reduce Pain	viii Atmosphere Lighting, Natural Environment
	ix Relaxation and Comfort	ix Natural Material
	x Reduce Stress	x Natural Noise
	xi Reduce Blood Pressure	xi Music
	xii Relaxation and Pleasure	xii Vegetation Scent
	xiii Less Stress Less Anxiety, Pleasure	xiii Natural Environment
4 Entertainment Facilities	i Attractive & Acceptable	i 3D Curvilinear
	ii Positive Emotion	ii Bright Color
	iii Freedom	iii Higher Ceilling Height
	iv High Activitiy Intensity	iv Higher Ceilling Height
	v Reduce Stress	v Natural Light
	vi Relaxation and Comfort	vi Natural Material
	vii Reduce Stress	vii Natural Noise
	viii Reduce Blood Pressure	viii Music
	ix Relaxation and Pleasure	ix Vegetation Scent
5 Living Facilitiies	i Lower Heart Rate, Increase Relaxation	i Warm Color Temperature
	ii Decrease Perspiration	ii Dark Wood Brown
	iii Lower Heart Rate	iii 2D Curvilinear
	iv Calmness	iv Low Ceilling Height
	v Pleasure and Comfort	v Bright Color Green
	vi Comfortable	vi Undirect Light
	vii Reduce Pain	vii Atmosphere Lighting, Natural Environment
	viii Relaxation and Comfort	viii Natural Material
	ix Reduce Stress	ix Natural Noise
	x Reduce Blood Pressure	x Music
	xi Relaxation and Pleasure	xi Vegetation Scent
	xii Less Stress Less Anxiety, Pleasure	xii Natural Environment

Figure 6 Facilities, Impression Goals, and Architectural Elements for Each Facility

5. Conclusion

This research demonstrates that Student-Athlete Schools are educational institutions that function not only as academic organizers but also as a platform for developing student potential based on interests and talents in an integrated manner. Through the concept of a sports school, athlete achievement development is not positioned separately from formal education. Still, it is integrated into a learning system that supports the sustainability of academic and sporting careers. A study of the Dual Career and Holistic Athlete Development programs confirms that successful athlete development is determined by a balance among academic, athletic, psychological, and social development as mutually influencing entities.

Based on a synthesis of all studies, this research develops design guidelines for Student-Athlete Schools that integrate the principles of Holistic Athlete Development with the goal of human well-being in neuroarchitecture. This integration translates into guidelines for function, spatial quality, and the application of architectural design elements that support athletes' learning performance, training, recovery, social interaction, and overall mental health.

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