White Paper

NEURO ARCHITECTURE
Health, Happiness & Learning

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White Paper for the Association
for Learning Environments

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A Neuroarchitecture Guide
For School Design

"The field of neuroarchitecture is about understanding the fundamental ways that our environment shapes our brain, behavior, and experience, and using that knowledge to design spaces that promote health and happiness."
- Veronica Galvan

INTRODUCTION

Neuroarchitecture is the study of how the built environment impacts the nervous system and its interconnection with other bodily systems, ultimately affecting our overall well-being, including cognitive and emotional health. With the growing awareness about the impact of the built environment on our mental and physical health, there has been a rising need to consider neuroarchitecture while designing schools. Designing learning spaces based on the insights from neuroscience research for architecture can have a significant positive impact on students' academic performance, emotional well-being, and physical health. Neuroarchitecture is about designing schools that are inclusive, stimulating, and supportive of learning in ways that promote a sense of purpose, belonging, and well-being, leading to a more positive and productive educational experience for students.

What is Psychoneuroimmunology and Why is it Important?

Psychoneuroimmunology is an interdisciplinary field of study that explores the relationship between the brain, behavior, and the immune system. It examines the effects of psychological and social factors on immune function and the interactions between the nervous system and the immune system. The goal of psychoneuroimmunology is to better understand the mechanisms by which stress, emotions, and other psychological factors can affect physical health and contribute to the development and progression of diseases.

In the context of school design, considering psycho-neuroimmunology can help create a physical environment that promotes positive emotional health and improves the response to stressors that affect children, ultimately leading to enhanced immunity. This requires an understanding of the impact of environmental factors on the neuroendocrine system and the immune system, as well as the interplay between psychological and physical health *(Fig.1)*. By creating spaces in the school environment that enhance emotional well-being, such as spaces for stress reduction and relaxation, schools can help to improve the neuroendocrine balance in students, which in turn promotes a stronger immune system. A comprehensive approach to school design that considers the psychological, neurological, and immunological aspects of students can ultimately lead to a healthier and more resilient student population.
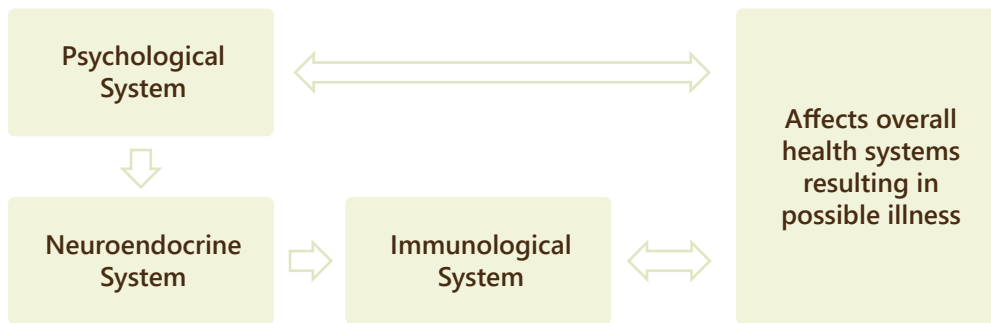
Figure 1. *Understanding the interrelationship.*

Neuro-endocrine Balance And Childhood Stress

Designing schools that promote a healthy neuroendocrine balance and enhance emotional health can help combat the negative effects of stress on children. Stress can impact the physical structure of the brain, decrease immune function and lead to changes in hormone balance. It can also cause neuropeptides to be released, which can reduce the effectiveness of immune cells and damage long-term health. Aaron Antonovsky, a medical sociologist, suggested that good health starts with our ability to cope with stressors, and children need a well-functioning stress response system for healthy development. Childhood stress can lead to negative long-term health consequences, highlighting the need for investing in prevention strategies. Stress in children, when unchecked, can manifest itself in various ways as *(Table 1)*.

Table 1. *Signs of Emotional Distress in Children.*

THE EFFECTS OF STRESS IN CHILDREN	
Physical & Emotional symptoms	**Cognitive Symptoms**
- Irregular bowel movements - Involuntary twitching or shaking - Getting sick more often than normal - Headaches - Nausea - Muscle aches - Trouble sleeping - Heartburn or indigestion - Fatigue - Flushed skin - Clenched teeth - Unusual changes in weight - Less than normal patience - Feelings of sadness and/or depression - Feelings of being overwhelmed - Restlessness - Reduced or eliminated desire for activities once enjoyed or regularly done - Irritability - Sense of isolation - More frequent or extremely pessimistic attitude	- Impaired concentration - Trouble with remembering things, such as homework assignments or deadlines - Chronic worrying - Anxious thoughts or feelings - Reduced or impaired judgment - Impaired speech (mumbling or stuttering) - Repetitive or unwanted thoughts - Behavioral Symptoms - Change in eating habits - Change in sleeping habits - New or increased use of drugs, tobacco, or drugs - Nail biting - Abnormal failure or delay to complete everyday responsibilities - Significant change in school or work performance - Unusual desire for social isolation - Frequent lying - Trouble getting along with peers, such as classmates or teachers

RESTORING NEUROENDOCRINE BALANCE

Providing a school environment that can help restore neuroendocrine balance is essential to reducing stress in students. The right environmental stimuli can trigger desired neural responses and the secretion of necessary neurochemicals. Cortisol is a stress hormone that regulates the body's response to stress, but chronic stress can elevate cortisol levels, leading to negative physical and mental health effects. Unfortunately, over the last few decades, education has become a major source of stress for school-going children, leading to anxiety, learning disabilities, and behavioral issues. Common stressors in school include pressure to excel academically, bullying, peer pressure, social relationships, environmental stress, safety issues, poor self-esteem, and personal life disruptions.

Positive experiences in school can enhance the release of happy hormones, including serotonin, oxytocin, dopamine, and endorphins, which can alleviate stress and anxiety, boost mood, and enhance overall well-being. Serotonin and oxytocin can be increased through trust-building, social interaction, and a positive atmosphere, while endorphins are increased through laughter, music, exercise, and mindfulness practices. Dopamine can be increased by promoting learning, motivation, and a positive atmosphere. It is clear that creating a positive and supportive school environment can enhance children's sense of self-worth and belonging, leading to improved neurochemical balance and enhanced health.
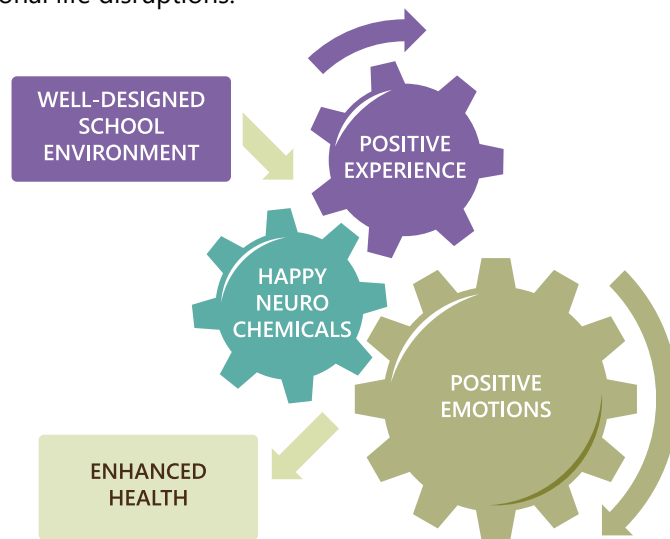

Figure 2: *The Positive Impact of Well-Designed School Environments on Children's Health.*

Figure 2 illustrates the impact of a well-designed school environment that has the power to initiate a cycle of positive experiences. These experiences trigger the release of happy neurochemicals, such as serotonin, oxytocin, dopamine, and endorphins, leading to positive emotions and a state of balance that helps children reach their full potential. A supportive environment that promotes positive experiences contributes to children's emotional well-being and overall health, creating a positive feedback loop where children are more motivated to learn and engage in activities.

Thoughtful design interventions in schools play a pivotal role in enhancing positive experiences for students. By creating spaces that foster a sense of belonging, agency, purpose, and balance, schools actively contribute to students' overall well-being *(Figure 3)*. This initiates a cyclical process where engaging in a supportive learning environment triggers the release of happy neurochemicals, leading to improved mental and physical health.
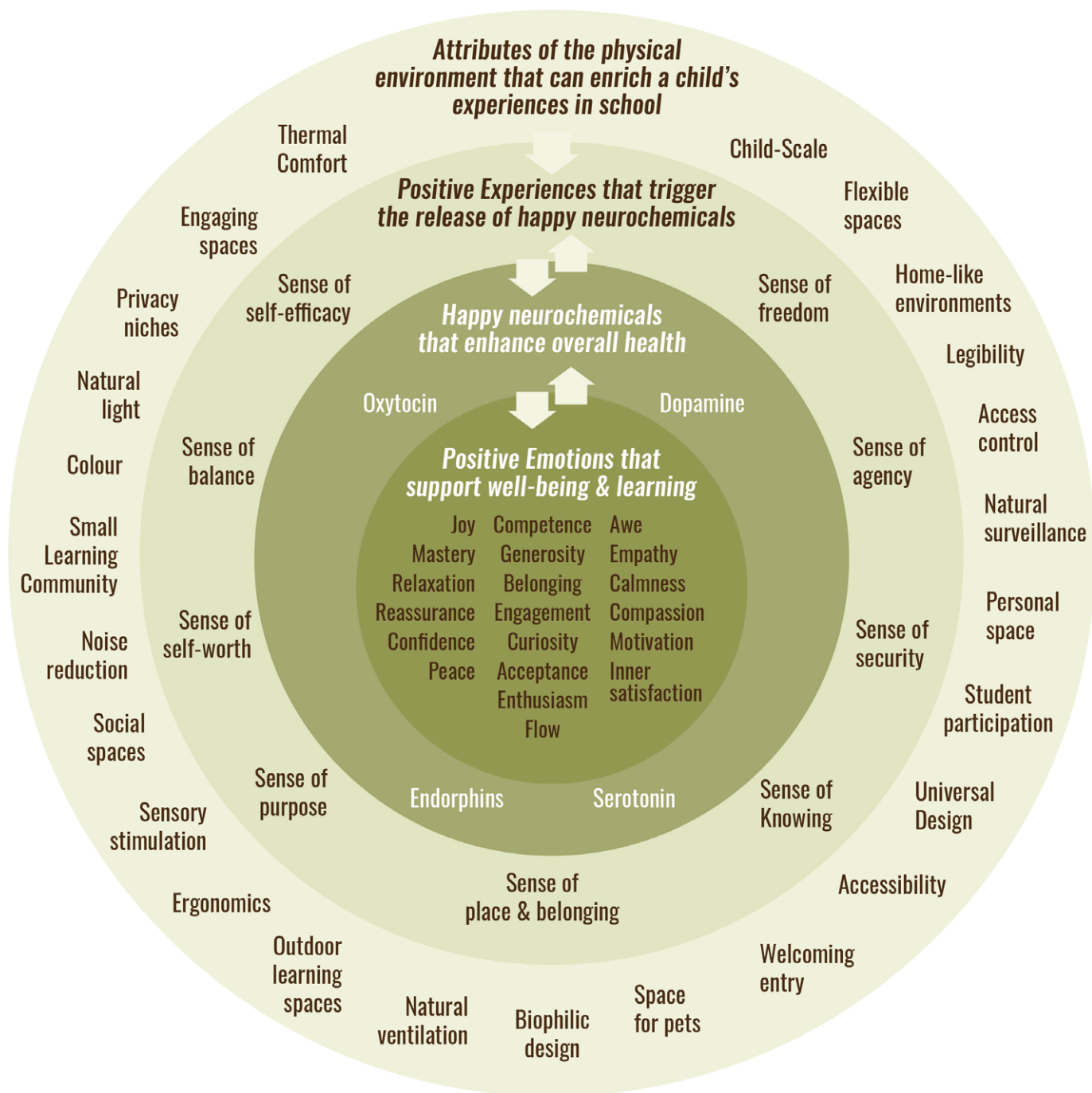
Figure 3: *Physical School Environment's Role in Fostering Self-Actualization in Children.*

NEUROARCHITECTURE INTERVENTIONS:
Enhancing Positive Experiences in School Environments

The subsequent sections will explore design interventions that can effectively increase positive experiences, creating a virtuous cycle of well-being for school children.

1. SENSE OF SELF-WORTH: A healthy sense of self-worth is an individual's perception of their value and importance. It affects their beliefs, emotions, and overall well-being. Creating an environment where students feel valued and supported can foster a positive sense of self-worth. This can trigger the release of happy hormones such as dopamine, serotonin, and endorphins, that can improve mood, reduce stress, and enhance cognitive function. A positive sense of self-worth can also lead to greater resilience and the ability to cope with challenges. School spaces can enhance a child's sense of self-worth in the following ways:

1a) Respect for scale & development needs:
Designing spaces and furnishings that are appropriate for the developmental needs of children can promote their autonomy and confidence. The scale and proportion of buildings and spaces can impact the physical and psychological comfort of occupants. To help children feel valued and engaged, spaces and furnishings should be proportionate to their size, giving them a sense of ownership and belonging. Keeping school or class sizes small can also make children feel that their efforts are significant. Weinstein (1987) recommends scaling spaces and making material storage accessible to children to enhance their self-esteem and ownership of the school environment. Here are a few specific design strategies to promote students' sense of self-worth:

- Vary ceiling heights based on the intended use of the space.
- Design spaces and specify furniture and fixtures that are proportionate to a child's scale.
- Ensure that equipment, such as whiteboards, is located at a height that children can access.
- Make material storage accessible to children.
- Install door handles, switches, and other features at a child's height.
- Offer a variety of space sizes to accommodate different needs and activities.

Image 1: Design spaces and fixtures that are proportionate to a child's scale.

Image 2: *Create spatial layouts that support multiple modalities of learning.*

1b) Flexible learning spaces: Flexible learning spaces are essential to support the diverse needs of students. The physical design of schools should support various learning modalities, such as independent study, peer tutoring, and project-based learning, to name a few. These environments should also accommodate multiple intelligences in children and respect neurodiversity. Here are some ideas for creating flexible learning spaces:

- Create flexible spaces that can be easily resized or reshaped by rearranging furniture.
- Provide sufficient variety in spatial layout to support multiple modalities of learning.
- Incorporate movable partitions that can be easily adjusted.
- Use adjustable furniture that can accommodate both technology use and traditional writing/drawing.
- Install curtains or blinds to enable the use of projectors, smart boards, etc.

1c) Ownership: Encouraging ownership and territoriality in classroom design can foster a sense of responsibility, autonomy, and belonging in students. Personalized spaces have been found to aid in memory and information retention, and classrooms that display students' work promote greater participation in the learning process. Providing each student with a "home base" or workspace can further encourage ownership and autonomy. Students also benefit from having places to display personal items, which can increase their sense of belonging in the school environment. The following ideas will improve student ownership of their learning environment:

- Personalized workspace with lockers for each student
- Spaces designated for personal artefacts.
- Adjustable and appropriately sized desks and chairs for varying ages and sizes.
- Distinctive design elements to differentiate areas from each other.
- Display spaces for student works and projects.

Image 3: *Provide display spaces for student works and projects.*

1d) Stimulating playgrounds: Play allows children to develop self-reliance, self-esteem, creative and social skills, and risk-taking abilities. Risky play is necessary for children to learn how to cope with risky situations and develop risk competence. However, concerns about safety have led to a restriction on risky-play opportunities, which can hinder normal child development and lead to fear, discomfort, and dislike of the environment. Overprotection of children can have negative impacts on their health and ability to cope with unpredictability. Therefore, it is important to provide age-appropriate risky play opportunities to help children develop and thrive. Here are some ideas to create stimulating playgrounds:

- Encourage tree climbing and offer innovative play equipment with movable parts.
- Provide ample space for age-appropriate activities such as running and jumping.
- Ensure the presence of safety nets and other safety measures to prevent injuries.
- Place the school infirmary near the playground area for immediate medical assistance if necessary.
- Create playgrounds featuring a range of levels, heights, and physical challenges to encourage skill-building and risk assessment.
- Integrate natural elements, such as rocks, logs, and uneven terrain, to promote balancing, jumping, and navigating skills.
- Supply loose parts and open-ended materials, like sand, wood, ropes, or tires, to inspire creativity, problem-solving, and exploration.
- Implement a balance of supervision and freedom, allowing children to explore their environment while ensuring their safety.
- Provide age-appropriate challenges that cater to different age groups and skill levels, enabling progressive growth and development.

Image 4: Incorporate natural elements, such as rocks, logs, and uneven terrain that promote balancing, jumping, and navigating skills.

Image 5: *Strategically placed windows provide clear sightlines of the entrance and outside activities.*

2. SENSE OF SECURITY: When children feel safe and protected in school, they experience positive emotions such as happiness, contentment, and well-being. This is due to reduced stress levels and the release of happy hormones such as dopamine and endorphins. A sense of security can also boost children's confidence and encourage them to take manageable risks and explore new opportunities, leading to greater engagement in their learning process. It also helps them develop healthy relationships with peers and teachers, fostering empathy, social skills, and a sense of belonging, which can further reduce stress levels and promote positive emotions. School spaces can enhance a child's sense of security in the following ways:

2a) Access control: Access control measures such as secure entry systems and visitor management systems should be incorporated into school design. Adequate lighting and visibility in and around school buildings can also help deter potential threats. A list of ideas to improve access control follows:

- Designated spaces near the entrance for safe community involvement.
- Strategically placed windows to provide clear sightlines of the entrance and outside activities.
- Effective use of signage, pavement treatments, and landscaping to direct visitors and delineate accessible areas.
- Clearly defined limits to control access and maintain a secure environment.

2b) Natural surveillance: Natural surveillance refers to the design of physical spaces in a way that allows people to see and monitor their surroundings. In the context of schools, natural surveillance can promote a sense of security in children by creating an environment that is both physically and psychologically safe. When children feel that they are being watched and protected by adults, they are more likely to feel secure and less vulnerable to threats or violence. Here are some ideas to promote natural surveillance in school:

- Install glass partitions or walls in strategic locations to increase visibility and natural light.
- Avoid creating hiding spaces in the ground, parking areas, or other places around the school through landscaping or fencing.
- Use windows and glazed doors to enhance natural surveillance of entrances, pathways, and other areas.

- Avoid unattractive barriers such as barbed wire on the school grounds. These can give a negative impression and may not be effective in preventing unauthorized access.
- If possible, attach toilets to classrooms or provide auditory connections with adjoining areas. This will prevent isolated and potentially dangerous situations.
- Install a security system with unimposing alarms, lights, and locks to provide elevated levels of security.
- Create physical or symbolic barriers along the property boundary that are attractive and welcoming.
- These can help prevent unauthorized access and create a positive impression for children and visitors.

Image 6: Glass partitions in strategic locations facilitate natural surveillance.

Image 7: Decorative touches with rugs and furniture can enhance a home-like school environment.

3. SENSE OF FREEDOM: Providing children with a sense of freedom has numerous positive impacts on their emotional and social development. Children who have greater freedom feel less stressed and more confident, which enhances their interest and enjoyment in learning. This sense of freedom also allows children to feel respected and treated with kindness, which fosters empathy and reduces the need for disciplinary action. Additionally, a greater sense of freedom leads to positive emotions and the release of happy hormones such as dopamine and endorphins, which help reduce stress levels and promote overall well-being. Ultimately, this can help children develop social skills, a sense of community involvement, and even leadership qualities. School spaces can enhance a child's sense of freedom in the following ways:

3a) Home-like environment: Home-like school environments offer children a sense of freedom in a variety of ways. First, a warm and welcoming environment can encourage children to express themselves and take risks in their learning. Second, flexible learning spaces allow children to work in ways that best suit their individual learning style, promoting independence. Third, children are given choices and decision-making opportunities that foster autonomy.

Finally, a sense of belonging and community helps children feel secure to take manageable risks and be themselves. In summary, home-like school environments promote freedom through a welcoming environment, flexibility, autonomy, and comfort. Here are some ideas to promote home-like environments:

- Choose comfortable furniture like a couch or large armchair that is inviting for children to relax and learn in.
- Incorporate nontoxic plants in the space to bring a sense of calm and freshness.
- Use natural or soft lighting from windows or lamps to create a warm and welcoming atmosphere.
- Add throw pillows and cushions to the seating area for extra comfort and coziness.
- Include decorative touches like area rugs or repurposed furniture to give the space character and personality.
- Display family photos from children and staff to create a sense of belonging and community.
- Use inexpensive frames to showcase children's artwork on the walls and encourage creativity.
- Paint the walls in neutral or pastel colors to create a calm and soothing environment that is not visually overwhelming.

3b) Density & Personal space: Considerations like density and personal space in learning environments can promote a sense of freedom in school children. When children have their own personal space and low density, they can feel a sense of autonomy, safety, and respect for others' personal boundaries. They can also feel more relaxed and focused, leading to a greater willingness to engage in their learning process. Ultimately, promoting a culture of empathy and kindness can foster a sense of freedom and belonging for all students, contributing to a positive and inclusive learning environment. Ensure that children have ample space to move around, so that they feel less confined and more comfortable. Make sure that there is at least 7-10 sq.m. gross area provision per child to avoid overcrowding.

- Divide children into smaller groups or cohorts, which allows for more individual attention and a sense of belonging within the group.
- Keep classrooms and walls uncluttered to provide a clear and calm environment. Do not make the walls too busy or visually overwhelming.
- Limit the number of students per class to between 17-25, allowing for a more manageable and personalized learning experience.
- Consider splitting the school into smaller learning communities, which promotes a sense of identity and belonging for students within their specific community.
- Increase the area available for children by getting rid of hallways and incorporating that space into the learning community.

Image 8: Ample space to move around makes children feel less confined and more comfortable.

Image 9: Use visual cues to distinguish between different areas within the school, such as colors, textures, forms, and ceiling heights.

4. SENSE OF KNOWING: A sense of knowing refers to the ability to comprehend something instinctively, without conscious reasoning. This can instil confidence in children, empowering them to navigate their surroundings independently and reduce stress levels by enabling them to anticipate their environment. Cultivating this sense can also lead to greater emotional intelligence, self-reliance, and resilience. Moreover, a strong sense of knowing can reduce stress and promote positive emotions and happy hormones, such as dopamine and endorphins, which contribute to a sense of well-being. School spaces can enhance a child's sense of knowing in the following ways:

4a) Enhancing Legibility: Improving legibility in school environments through effective wayfinding strategies can enhance children's sense of knowing by creating a clear and organized learning environment. It can increase their confidence, motivation, engagement, and positive attitude towards learning while reducing distractions and improving their focus. Legibility plays a crucial role in shaping children's perception of their school environment and can impact their learning experiences and outcomes. Some ideas to enhance

legibility in schools are as follows:

- Create a unique identity for each location within the school.
- Use landmarks as visual cues to help students identify different areas within the school.
- Ensure that paths within the school are well-structured and have clear goals to help students understand where they are going.
- Limit the number of navigational choices available to students to reduce confusion and increase clarity.
- Use sightlines to show students what's ahead and help them anticipate their next steps.
- Implement color-coded indoor pathways to assist students in keeping their orientation towards important locations within the learning environment.
- Ensure that the main building is an obvious point of reference among the school's buildings and that paths and buildings connect effectively and intuitively.
- Use various forms of visual cues to distinguish between different areas within the school by varying colors, textures, forms, and ceiling heights.

4b) Welcoming Entry & Signature Elements:
The school entrance should be inviting, secure and visible, with a covered space for drop-offs and pick-ups. A signature element reflecting local culture/history/ architecture can enhance the welcoming feeling and promote a sense of place among children, helping them take pride in their school's unique identity. These elements should be visible not only at the entrance but also in the layout of spaces and activities. Here are some ideas to design a welcoming entry:

- Design the entrance to be inviting, highly visible, and well-defined with architectural features, signs, lighting, artwork, landscaping, and other local landmarks.
- Ensure that the entrance is not intimidating for children and is scaled appropriately for their size.
- Use motivational signs that send positive messages and make the school more inviting.

- Include landscaping features or small play areas that are visible from the entrance to make the space more inviting.
- Provide a covered entrance that provides shelter from bad weather and facilitates transition between the indoors and outdoors.
- Ensure a safe drop-off/pick-up area where children don't have to cross traffic and separate access for students and visitors.
- Incorporate signature elements relating to local culture and architecture into the built environment, preferably visible from the entrance to make it unique and special to the school.

Image 10: A welcoming entry space that sends positive messages and invites children to school.

Image 11: *Encouraging teamwork and fostering agency through student participation.*

5. SENSE OF AGENCY: When individuals feel like they have control over their lives and can make meaningful decisions, they experience a sense of empowerment and accomplishment. This feeling of agency triggers the release of happy hormones, such as serotonin and dopamine, that can enhance mood and reduce stress levels. Furthermore, having agency allows individuals to better cope with difficult situations, as they are better equipped to make choices and take actions that can help them navigate challenges. This sense of control that children have can lead to increased resilience and greater satisfaction with life. School spaces can enhance a child's sense of agency in the following ways:

5a) Student Participation: Student participation in the school design and renovation process enhances their sense of agency by giving them ownership, fostering trust and collaboration, reducing vandalism and anti-social behavior, building competence, and raising learners' self-esteem. By working alongside industry practitioners, students can learn about risk assessment, waste management, materials performance, design techniques, and develop soft skills such as collaboration and problem-solving. Decorating their own spaces with their art and ideas can further enhance their sense of ownership and pride in their school environment. Here are some ways to increase student participation:

- Foster a sense of community and teamwork and encourage effective communication by involving students during the design of school renovation, refurbishment, and rebuilding projects.
- Consider and implement relevant student feedback and ideas by using surveys, focus groups, or other methods to gather input during the planning, design, and execution of capital projects.
- Keep students informed and engaged by providing regular updates and communications through newsletters, emails, and announcements.
- Utilize social media and other technology platforms to engage with students and encourage them to share their ideas and feedback.
- Provide opportunities for student leadership and mentorship by assigning leadership roles to them and pairing students with industry professionals.

5b) Sustainable architecture: Sustainable (green) architecture of schools can promote a sense of agency in children by involving them in the design and implementation of environmentally sound building projects. This empowers students to take ownership of their environment, fosters responsibility for their actions, and inspires them to make more conscious choices. By learning about sustainable practices and technologies, students can develop the knowledge and skills needed to become leaders in sustainability efforts in their community. Working together towards a common goal also promotes teamwork and leadership skills, leading to a more engaged and empowered student body and a more sustainable future for society. To promote a greater sense of agency in children, school spaces can be designed sustainably, and here are a few ideas to achieve this:

- Design spaces that allow students to learn from natural processes, such as sun orientation and wind flow patterns.
- Make energy conservation and sustainable measures visible, such as rainwater harvesting and solar panels.
- Use sustainable design features as teaching tools for project-based, experiential learning and to connect students with curricula in environmental and STEM education.
- Involve students in the design and implementation of sustainable building projects, empowering them to take ownership of their environment and fostering a sense of responsibility for their actions.

6. SENSE OF SELF-EFFICACY: Sense of self-efficacy refers to an individual's belief in their ability to achieve goals and perform tasks successfully. A strong sense of self-efficacy can help reduce stress in school children and trigger the release of happy hormones such as dopamine, serotonin, and endorphins. This leads to positive and productive learning experiences. Building a sense of self-efficacy in children involves providing them with opportunities to take ownership of their learning, setting and achieving goals, and providing positive feedback and reinforcement. When children feel empowered and confident in their abilities, they are more likely to engage in learning, take on new challenges, and experience a sense of accomplishment, leading to increased well-being. School spaces can enhance a child's sense of self-efficacy in the following ways:

6a) Universal Design Principles: Universal design principles can improve the sense of self-efficacy in school buildings by creating inclusive and accessible learning environments that support the diverse needs of all students. When students feel that their environment is accommodating and accessible to their needs, they are more likely to feel empowered and confident in their abilities, leading to a stronger sense of self-efficacy. Some ways that universal design principles can be applied in school buildings to improve self-efficacy include:

- Design clear and easy-to-follow circulation paths with tactile cues.
- Improve accessibility and hygiene of washrooms.
- Ensure appropriate width and clearance of circulation routes, and utilize easy-to-use hardware and controls.
- Consider acoustics and lighting for people with visual impairments.
- Use contrasting textures and borders to indicate changes in grade or landscape.

6b) Ergonomics: Ergonomic considerations in school environments foster self-efficacy by improving students' physical comfort and well-being. When children are free from discomfort caused by poor posture or ill-fitting furniture, they can better focus on learning, develop confidence in their abilities, and feel more empowered to take on challenges, leading to an enhanced sense of self-efficacy. Some ideas to create ergonomic learning spaces are noted below:

- Provide diverse, adaptable furniture that's user-friendly.
- Ensure age-appropriate, well-maintained furniture.
- Design IT-compatible workstations.
- Offer floor seating and reclining options in classrooms and other learning spaces.

Image 12: *Diverse, adaptable, and user-friendly furniture.*

- Provide varying sized furniture to account for diversity of student sizes within the same classroom.
- Ensure that children's feet touch the floor while seated; provide footrests for shorter students.
- Incorporate rounded edges on tables and built-in shelves.

6c) Natural ventilation and thermal comfort:

Natural ventilation and thermal comfort contribute to a healthier, more comfortable learning environment for school children. To create an environment that supports students' focus and sense of control in their learning experiences, school spaces should be designed to minimize factors such as fatigue, distraction, and toxins. This enhanced concentration and well-being can lead to a stronger sense of self-efficacy as students feel empowered to achieve their academic and personal goals. Some ideas:

- Apply passive thermal insulation techniques for extreme climates.
- Install windows at various levels for diverse weather conditions.
- Utilize quieter mechanical systems that don't disturb learning activities.
- Employ mechanical systems that draw a significant amount of outdoor air into the building.
- Use natural airflow patterns for increased fresh air circulation.
- Utilize higher ceiling heights wherever appropriate.

6d) Engaging Spaces: Engaging spaces, such as libraries, performing arts areas and maker spaces, foster self-efficacy by creating inviting environments that encourage children to explore and immerse themselves in various activities. These well-designed spaces support a sense of autonomy, allowing students to confidently engage in learning, collaboration, and creativity. As a result, students develop a stronger belief in their abilities, enhancing their overall self-efficacy. Some ideas to create engaging spaces follow:

- Create maker spaces that provides a variety of tools and materials, allowing students to explore and create in their own unique way.
- Create well-lit reading areas with designated spaces for group work.
- Ensure acoustically well-designed and well-lit music and dance areas.
- Incorporate vibrant furniture, furnishings, and colors to stimulate activity.

Image 13: *Maker spaces to encourage exploration.*

Image 14: *Designated spaces for self-reflection can be designed while allowing natural surveillance.*

7. SENSE OF BALANCE/STABILITY: Emotional stability involves the ability to remain calm, manage emotions in a healthy manner, and cope properly with stress and challenges. Emotionally stable individuals possess self-awareness, self-regulation, and self-compassion, enabling them to handle frustrations and delays, and adapt to situational demands. This stability can trigger the release of happy hormones, further enhancing well-being. Emotionally stable children effectively adjust to their surroundings, peers, and family, while understanding and expressing emotions constructively. School spaces can enhance a child's sense of balance in the following ways:

7a) Spaces for self-reflection: Self-reflection and privacy play crucial roles in promoting balance and stability in school children. Providing various spaces, including those for solitude, allows children to recharge mentally, process experiences, and achieve a sense of belonging. Opportunities for self-reflection enhance understanding and personal growth, helping students transform learning into knowledge and wisdom. Spaces for privacy and self-reflection are essential in learning space design, especially for neurodiversity, as some children may require such areas more frequently to maintain their emotional balance. Some ideas for spaces that encourage self-reflection are listed below:

- Create designated spaces for solitude, such as reading, quiet, reflection, and listening areas.
- Design classrooms and learning areas with 2-3 private spaces for controlled interactions.
- Provide inviting, supervised "cave" spaces for students to momentarily escape from busy schedules.
- Incorporate distinct breakout zones within or attached to classrooms, avoiding placement in areas with high pedestrian traffic or noise.

7b) Color for Comfort: Color influences children's interactions with their environment, impacting their sense of balance and stability. Balancing stimulation is crucial for learning environments. Brightness and warm colors can stimulate creativity, but overstimulation may result in adverse physiological and psychological reactions. Under-stimulation may cause anxiety and concentration difficulties. Children respond well to nuanced colors, especially those found in nature and human skin tones. Avoiding a neutral approach, carefully chosen colors in educational architecture, including calming colors for neurodivergent children, can enhance students' emotional stability. Some ideas for proper use of colors are listed below:

- Incorporate a variety of colors, ensuring overstimulation is avoided.
- Consider color and lighting together in the design of learning spaces.
- Add colorful displays to walls and doors.
- Apply cooler colors in physical activity areas, such as gyms and yoga halls.
- Paint privacy niches and withdrawal areas in cooler colors.
- Utilize a nature-inspired color palette.

Image 15: *A variety of nature-inspired colors avoids overstimulation.*

Image 16: *Ample daylight and views reduce eye strain and connect indoor and outdoor environments.*

7c) Natural Light: Natural light plays a crucial role in fostering a sense of balance and stability in school children by triggering the release of happy hormones. It offers numerous health benefits such as reducing mental fatigue, alleviating seasonal depression, and promoting relaxation. Daylight provides a dynamic light source that reduces monotony and maintains focus. Moreover, natural light contributes to the production of vitamin D, regulates internal body clocks, reduces stress and headaches, and positively impacts mood, promoting overall emotional well-being. Some ideas to improve students' exposure to natural light are as follows:

- Ensure glare-free, diffused daylight in spaces where children spend extended periods of their time.
- Install eye-level windows for views and incorporate skylights or clerestory windows to provide glare-free light throughout the space.
- Offer unrestricted views to reduce eye strain and connect indoor and outdoor environments.
- Supplement daylight with electric lighting, combining natural and artificial light sources, ideally from two sides of each room.
- Avoid direct exposure to bright light sources that can cause glare and discomfort.
- Avoid windows on East and West facades which increase glare and force teachers to close blinds.
- Allow diffused daylight from multiple directions to minimize shadows and evenly distribute light.

7d) Noise reduction: Everyday environmental noise can increase stress, resulting in increased blood pressure, and heart rate, potentially leading to lasting health issues. Younger children are particularly sensitive to noise and require quieter spaces for optimal learning. Spending time in quieter areas not only minimizes stress but also triggers the release of happy hormones, fostering a sense of balance and stability. Implementing noise reduction strategies such as those listed below can lead to improved cognitive functioning and balance restoration:

- Select a site located in a peaceful area with low noise and air pollution.
- Incorporate barriers and buffers to counter traffic noise.
- Utilize landscaping as a noise dampener.
- Avoid using hard materials that cause echoes in interior spaces.
- Use appropriate sound-absorbing materials in classrooms and common areas to minimize noise levels.

Image 17: Sound-absorbing ceiling, wall and free-standing panels can greatly minimize noise levels.

8. SENSE OF BELONGING: A sense of belonging in schools is crucial for students' well-being and academic success. It fosters feelings of acceptance, connectedness, and being valued within the school community. A sense of belonging positively impacts academic achievement, mental health, and self-esteem. When children feel they belong, they are more engaged, motivated, and resilient. The release of happy hormones, such as oxytocin, serotonin, and endorphins, is triggered by a sense of belonging, which further contributes to their overall happiness and well-being. Ensuring a supportive and inclusive environment helps children develop into healthy, well-adjusted adults. Sense of belonging can be enhanced in school spaces through interventions like:

8a) Spaces for peer/teacher interaction: School spaces that promote peer and teacher interaction, such as auditoriums, amphitheatres, media centres, and dining areas, can significantly enhance children's sense of belonging. These inviting and comfortable settings encourage social interaction, foster a sense of community, and facilitate collateral learning. By supporting the development of social skills and fostering enduring attitudes, these spaces help students feel connected and valued, contributing to their overall well-being and desire for lifelong learning. Some design ideas for spaces that foster peer and teacher interaction in school are noted below:

- Provide multiple safe and visible locations where groups of four or more children can interact and engage in various activities.
- Create designated areas where students can share meals with their peers and teachers, fostering a sense of community.
- Include facilities such as auditoriums or large gathering areas indoors as well gathering stairs and outdoor amphitheaters in the school design to encourage gatherings, events, and performances.

Image 18: *Informal spaces for peer/teacher interaction tend to foster a sense of belonging in students.*

8b) Materials & Textures: Materials and textures play a crucial role in enhancing students' sense of belonging in school. By incorporating natural materials, warm colors, and diverse textures, the environment becomes more inviting and nurturing. Introducing soft, cozy elements like pillows, plants, and upholstered furniture provides a home-like atmosphere, fostering a sense of comfort and connection. The use of curvilinear forms, color gradations, and blended textures further enriches the space, making it more appealing to children. Overall, thoughtful material and texture choices contribute to supportive learning environments that promote a strong sense of belonging among students. Some ideas in this regard are noted below:

- Incorporate natural materials and showcase visible details.
- Employ multi-sensory materials to create surfaces with varying qualities such as smoothness, roughness, brightness, opacity, and transparency.
- Choose materials that evoke warmth and comfort.
- Utilize glass to establish a connection between indoor and outdoor spaces while ensuring a sense of security for students.
- Introduce soft, comforting elements like pillows, plants, and soft furnishings to create a warm, home-like atmosphere.
- Incorporate curvilinear shapes and forms whenever possible to enhance the appeal of the environment.

Image 19: Curvilinear shapes and multi-sensory materials to enhance the appeal of the environment.

8c) Small Learning Community: The Small Learning Community Model enhances children's sense of belonging in school by creating an environment that promotes close peer interactions and strong bonds with teachers. These smaller communities, accommodating 80 to 150 students, prevent feelings of isolation and anonymity. The model incorporates learning studios, small group rooms, multi-purpose labs, commons spaces, and outdoor connections to support diverse learning modalities. By fostering more intimate and supportive educational settings such as those listed below, small learning communities significantly improve student engagement, performance, and overall well-being:

- Divide the school into smaller learning communities using separate blocks or levels.
- Provide each learning community with designated open spaces and indoor areas for socialization.
- Ensure transparency within each community to always facilitate passive supervision.

Image 20: Small Learning Communities facilitate collaborative learning and socialization.

9. SENSE OF PLACE: "Sense of place" refers to the emotional and psychological connection that an individual has to a specific location, and it can be an important aspect of personal identity and well-being. In the context of a school, sense of place refers to the connection that students, teachers, and staff have to the physical and social environment of the school. A strong sense of place can reduce stress and anxiety in school children, as it triggers the release of happy hormones such as serotonin, dopamine, and oxytocin, leading to increased well-being and positive emotions. It can also improve academic performance and social connections, promoting a sense of belonging and enhancing personal identity. A sense of place in a school can be fostered through various means, such as:

9a) Outdoor Learning Spaces: Outdoor learning spaces in schools can help foster a sense of place by allowing students to connect with their local environment and appreciate their surroundings.

These spaces provide opportunities for collateral learning, social interaction and personalization, individual mastery, and student ownership and agency. Outdoor learning can be facilitated by using a variety of structures such as trees, awnings, tents, and greenhouses. Overall, outdoor learning spaces offer a rich palette of learning modalities that inspire students to customize their learning and achieve a deeper understanding of the world around them. Some ideas for enhancing outdoor learning experiences follow:

- Provide an accessible green/open space outside each classroom.
- Include an amphitheater for outdoor plays, performances, and presentations.
- Use temporary structures and benches to facilitate outdoor classrooms.
- Organize field trips, community service, and other activities that involve new places and experiences.
- Create a variety of open spaces to allow for different types of outdoor learning.

Image 21: Shaded outdoor spaces provide opportunities for multi-sensory learning.

Image 22: *Display spaces for children's artwork can help enhance a sense of place.*

9b) Design the school to reflect local culture and history: As examples, incorporate elements of the local architecture or landscape into the design of the school, or highlight the achievements and contributions of local figures in the school's history (refer also to section 4b).

9c) Creating opportunities for students to personalize their environment: As an example, allowing students to decorate their classroom with their own artwork, or encouraging teachers to add personal touches to their classrooms (refer also to section 3a).

10. SENSE OF PURPOSE: A sense of purpose in school can trigger the release of happy hormones in children, promoting a sense of balance and stability. When students feel that their actions and efforts in school are meaningful and aligned with their values

and goals, it leads to increased motivation, engagement, and academic achievement. This sense of purpose also creates a positive mindset, promoting mental health and well-being. When children have a sense of purpose, they feel more confident in their abilities and have a greater sense of control over their future. This can lead to the release of hormones such as dopamine and oxytocin, which contribute to feelings of happiness, fulfilment, and overall well-being. School design can augment a student's sense of purpose in following ways:

10a) Biophilic design: Biophilic design can enhance children's sense of purpose in school by providing opportunities for them to connect with nature. Exposure to natural elements can have a positive impact on children's cognitive development, emotional well-being, and physical health. By incorporating natural elements into the design of a school, children can develop a sense of wonder, curiosity, and connection to the natural world. This can help to develop a sense of purpose and stewardship in children as they learn to appreciate and care for the natural environment, leading to enhanced well-being and cognitive focus. Ideas for biophilic design in schools include:

- Incorporate natural materials such as wood, stone, and water into the design.
- Use natural colors and patterns in the interior design.
- Create spaces where natural light and fresh air flow in.
- Provide access to natural views and landscapes through windows and skylights.
- Incorporate elements such as rain gardens, green walls, and green roofs to promote biodiversity and improve air quality.

- Use furniture and other interior elements that mimic natural forms and patterns.
- Design spaces that allow for different sensory experiences, such as the sound of running water or the scent of flowers.
- Create spaces that allow for exploration and discovery, such as a nature trail and outdoor lab.
- Provide ample green and natural spaces throughout the school campus.
- Ensure that restorative spaces with soft furnishings, plants, animals, window seats, or aquariums are generously available.
- Provide opportunities for students to engage in gardening and other outdoor activities.

10b) Sensory Aesthetics: Sensory aesthetics can positively influence a student's sense of purpose in school by creating a visually pleasing and well-organized environment. The use of curvilinear forms and edges, natural elements, and a balance of visual complexity can enhance creativity and promote physical activity. Designers should also consider the different sensory needs of students and provide ample opportunities for sensory stimulation in outdoor play areas and common spaces. Adequate space for

Image 23: Use natural colors and biomorphic patterns in the interior environment.

Image 24: *Sensory space promote exploration and engagement.*

physical activities and physical education should also be included to promote physical fitness. Some ideas regarding sensory aesthetics follow:

- Create a layout that is easy to navigate and promotes a sense of flow.
- Use colors, textures, and materials that are pleasing to the eye and promote a sense of calm and order.
- Provide attractive and well-maintained landscape areas.
- Utilize highly articulated fenestrations for framing of views.
- Incorporate visually pleasing staircases and other movement pathways to encourage walking, with age-appropriate design of walking routes.
- Avoid long narrow corridors and instead use nature-connected pathways.
- Provide dedicated indoor spaces for physical activities like yoga, dance, and fitness training.
- Create sensory gardens with various activity spaces to suit the needs of children with varied temperaments.
- Provision of a sensory room or area with appropriate equipment and materials to allow students to engage in activities that promote sensory exploration and regulation.

10c) Pets in School: Pets in school can enhance children's sense of purpose by providing emotional support, empathy, and responsibility. Interacting with animals can reduce stress and anxiety while also promoting engagement and motivation for learning. Opportunities to learn about animal behavior, biology and welfare can provide a real-life context for learning, making it more meaningful for students. Pets can motivate children to take an active role in their learning and development by teaching them about animal behavior, biology, and animal welfare in a real-life context. Research has shown that pets can increase academic achievement, decrease isolation, depression, anxiety, and agitation, and teach children how to nurture, care for, and respect all life. Use these strategies to increase student exposure to animals:

- Design outdoor spaces that are safe and conducive for pets to be present, while ensuring that the safety of the children is not compromised.
- Allocate a farm area that is accessible to children and provide them with opportunities to care for and tend to the animals.
- Create a dedicated space within the school that is suitable for keeping pets, such as a pet room or an outdoor enclosure.
- Ensure that the space for pets is designed to be clean and hygienic, with appropriate ventilation and drainage.

CONCLUSION

In conclusion, the integration of neuroscience research in school design is an essential step towards cultivating healthy, happy, and successful learners. By understanding the interplay between the built environment and neurological processes, schools can actively contribute to the emotional, cognitive, and physical well-being of students. Incorporating biophilic design principles and fostering small learning communities can be the key strategies in implementing neuroarchitecture in school environments.

Biophilic design, which emphasizes the innate human connection to nature, can have a profound impact on students' well-being and cognitive function. By incorporating natural elements such as sunlight, fresh air, green spaces, and natural materials into school design, we can create environments that reduce stress, improve air quality, and enhance overall mood and cognitive performance. This approach not only creates visually appealing spaces but also supports the neurological and emotional well-being of students, enabling them to thrive academically and emotionally.

Small learning communities, characterized by close-knit groups of students and teachers, provide a supportive environment that promotes positive social interactions and a sense of belonging. These communities foster strong relationships, personalized learning, and a collaborative atmosphere, which can lead to improved academic outcomes and emotional well-being. By integrating small learning communities into the school design, we can create spaces that facilitate interpersonal connections, trust-building, and collaborative learning, ultimately enhancing the neuroendocrine balance and promoting students' overall health.

By fostering a sense of belonging, agency, purpose, and balance through thoughtful design interventions, schools can effectively promote a neuroendocrine balance, enhancing students' resilience to stress and improving overall health. A well-designed school environment with the above-mentioned considerations not only elevates academic experience but also positively impacts students' long-term health, empowering them to reach their full potential. It is crucial that architects, educators, and policymakers recognize the value of neuroarchitecture in designing schools that nurture the minds and bodies of our future generations.

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Architecture, Landscape Architecture, Education, School Reform

Neuroarchitecture is the study of the impact of the built environment on the brain and how it affects our cognitive, emotional and physical well-being. There is a rising need to consider neuroarchitecture while designing schools. Learning spaces that properly apply the principles of neuroarchitecture will positively impact students' academic performance, emotional well-being, and physical health. Neuroarchitecture is about designing schools that are inclusive, stimulating, and supportive of learning in ways that promote a sense of purpose, belonging, and well-being, leading to a more positive and productive educational experience for students.

This white paper provides compelling research-backed evidence regarding the many health and learning benefits of Neuroarchitecture and includes specific strategies for incorporating it into the design of schools.
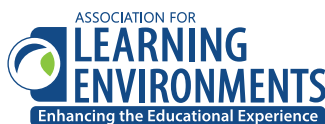
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