

ANALYSIS OF CONSTRUCTION SYSTEMS COURSE THROUGH A NEUROSCIENCE EDUCATION PERSPECTIVE

MARIA LORENA RODRIGUEZ¹, ENRIQUE VILLACIS TAPIA¹, and CYNTHIA AYARZA²

¹*School of Architecture, Pontificia Universidad Catolica del Ecuador, Quito, Ecuador,*

²*Ensusitio, Quito, Ecuador*

During the Building Systems and Structures I course, within the first years of the Architecture program (PUCE-FHIC), the students are introduced to a constructive logic, where they learn how to coherently relate the architectural intentions of a project with construction decisions. However, a persistent disconnection between disciplines, particularly when learning about construction systems and structural concepts, was identified. Due to this, a new curricular design was implemented to foster an integrative thinking and strengthen the essential connections across disciplines between architecture and engineering. Within the new curriculum, interdisciplinary team teaching is adopted, in which an architect and a civil engineer jointly conduct the sessions, engaging with students together in a shared classroom. Through a perspective of neuroscience education, this paper analyzes the methodology and the exercises developed during Construction Systems and Structures I course. Some of the neuroscience pedagogic principles will evaluate the course: real-life experiences, kinesthetic learning, intrinsic motivation, and emotions. The authors then critically review if the methodology and activities developed are suitable and encouraging for addressing an integrative and more connected learning.

Keywords: Neuro-education, Dissociation within disciplines, Building systems, Co-teaching.

1 INTRODUCTION AND METHODOLOGY

As architecture requires an interdisciplinary education, technical subjects such as construction and structures should be taught by architects and engineers, preferably in collaboration to enable students to integrate their design thinking with appropriate structural solutions. Within the new curriculum of Architecture School (FHIC) of Pontificia Universidad Catolica del Ecuador (PUCE), technical subjects have been integrated. While Structures and Constructions were previously offered as two separate courses, they have now been combined into a single course named Construction Systems and Structures, which is co-taught by an architect and an engineer. The aim of this study is to analyze the curriculum of this subject throughout neuroscience principles—as real-life experiences, kinesthetic learning, intrinsic motivation and emotions—to determine if the joint-class is bringing the expected learning. Additionally, this study seeks to determine how the new curriculum of the class fosters an education aligned with professional architectural practice and encourage students to move beyond the “comfort zone that is not aware nor in contact with reality” (Villacis Tapia and Ayarza 2020).

2 FRAGMENTATION BETWEEN DISCIPLINES

The previous curriculum reflects fragmentation between disciplines and also between the understandings of constructions as a sequential process. According to FHIC (2023), in the former curriculum, technical subjects were introduced as two separated courses—Constructions and Structures—each taught independently by an architect and an engineer. Consequently, the understanding of construction was compartmentalized, separating structures from envelopes and mechanical systems. In the same vein, the preceding curriculum fostered the comprehension of materials rather than systems. Both of the subjects addressed construction and structure's systems from a material perspective rather than as integrated systems composed of structure, envelope, mechanical, and interior components.

According to FHIC (2023), during the second year of architecture, while Structures I is based on an introduction to structural systems which includes a description of their components in various materials such as reinforced concrete, steel, wood, stone, and earth, Constructions II aims to address the construction process of a building, beginning with the coherent sequence of the structural framework of a project. Furthermore, while the content of Structures I covers fundamental concepts such as vectors, statics, material properties, equilibrium of rigid bodies, internal forces, and structural systems in various materials. In contrast, Constructions II focuses on practical building processes, including tectonics, soil studies, foundations, formwork, and frame-based construction systems with concrete and vertical circulation elements. By examining the course contents of both subjects, it becomes evident there is neither integration between them nor a holistic approach. Consequently, students may develop a fragmented understanding, which can lead to a disconnection between academic learning and professional architectural practice.

3 NEUROSCIENCE AND EDUCATION

Based on a theoretical approach, some principles identified within neuroscience education perspective will be discussed below, see Table 1. These same factors will then be used to evaluate the exercises proposed in Construction Systems and Structures I curriculum.

Table 1. Neuroscience principles.

Real-life experiences A	• Relation between environmental stimulation and new connections. • Outside world to create new learning experiences. • Real-life situations and context. • Formulation of projects and reach of objectives. • Connection of academic content to life's situations.	Intrinsic motivation C	• Motivation beyond immediate reward. • Curiosity, novelty and relevant feedback. • Association of pleasure with positive experiences. • Experiences that emphasizes process, rather than the end.
Kinesthetic approach B	• Kinesthetic learning. • Integration of movement and physical activities. • Sensory-motor experiences. • Body experience related to emotions. • Construction of models, hands-on activities.	Emotions and learning D	• Emotions help us recall things better. • Emotions influence how we relate with peers. • Positive experiences direct to motivation, curiosity and engagement. • Negative emotions can provoke stress. • Affective side of learning: interplay between how we feel, act, and think. • Memory related with hands-on experiences, experiments and field trips.

Education is a complex system that works in an interdisciplinary mode, which according to Caballero *et al.* (2021), in an effort to improve teaching and learning processes, neuro-education emerges from the integration of knowledge from different fields—neuroscience, pedagogy, psychology, etc. To understand better how to improve the learning experience, it is important to consider that “the brain works by simultaneously taking into account all the aspects that influence learning: the instinctive aspects, the emotional processes, and the cognitive processes related to executive functions” (Caballero *et al.* 2021). In this sense, the learning process can be fostered through exercises and strategies that stimulate emotions, comprehension, and motivation, rather than relying in learning by mere memorization.

Real-life experiences and application: Jensen (1998) argues that “the outside world is the growing brain’s real food”. The author manifests that human’s brain is malleable and new connections can grow with environmental stimulation. “As the brain begins to make sense of the world, it creates a neural farmland” (Jensen 1998). In other words, as we are exposed to diverse realities, “new learning experiences and challenges become critical to brain growth” (Jensen 1998). One of the challenges of education is to promote activities where students develop skills to reach understanding, rather than activities that merely require memorization. According to Villacis Tapia and Ayarza (2020), information acquired in class becomes knowledge when its application to real-world situations is appropriate and oriented toward the common good. To complement this idea, Jonhson (2001) states that “when students formulate projects or identify interesting problems, when they make choices and accept responsibility, search out information and reach conclusions, when they actively choose, order, organize, touch, plan, investigate, question, and make decisions to reach objectives, they connect academic content to the context of life's situations”. Experiences that enable students to connect novel learnings with real contexts can potentially promote long-term understanding.

The body, a kinesthetic approach: Body, mind and learning are directly interconnected. Jensen (1998) “observes that learners retain much more when the learning is connected to a field trip, music, a guest speaker, or a novel learning location”. Integrating physical activities into the classroom can significantly enhance cognition. This is explained by the “strong connection between the cerebellum and functions such as memory, spatial perception, language, attention, emotion, nonverbal communication, and even decision-making” (Jensen 1998). One of the key benefits of incorporating movement into education is that “sensory-motor experiences feed directly into their brains’ pleasure centers,” (Jensen 1998) and when students are motivated, they are also engaged with their learning process. Likewise, if “emotions are directly related to the body experience, then the more we create that experience with a multidisciplinary body engagement during the process, then the cognitive process will be more effective” (Villacis Tapia and Ayarza 2020). Thus, physical activity, construction of models, hands-on experiences and experiments are practices that can be incorporated in class to promote a kinesthetic learning.

Intrinsic motivation: “Motivation should be understood not only as a short (visceral desire) but as a long term (university or professional goals) approach” (Villacis Tapia and Ayarza 2020). As Jensen (1998) mentions, the brain works in a more complex way than just pursuing an immediate reward. The brain is satisfied when there is curiosity, novelty and relevant feedback. By understanding the brain’s chemistry, it “makes its own rewards. They are called opiates, which are used to regulate stress and pain. These opiates can produce a natural high, similar to morphine, alcohol, nicotine, heroin, and cocaine” (Jensen 1998). When students associate pleasure with a positive experience, they are more likely to transfer that knowledge into their daily lives. Education should promote motivation and transcendental rewards through experiences that emphasizes the learning process itself, rather than focusing on the rewards after obtaining the answer.

Emotions and learning: Emotions give us a more activated and chemically stimulated brain, which helps us recall things better (Jensen 1998). As mentioned in a previous study, while positive experiences could direct to motivation, curiosity and engagement, negative emotions can provoke stress and emotions that wanted to be avoided (Rodriguez *et al.* 2024). Learning is closely linked with emotions, which, according to Jensen (1998), there is an affective side of learning that is the critical interplay between how we feel, act, and think. Emotions influence how we relate with peers, what memories we recall or how we learn. It’s common for students to remember a field trip, or a hands-on science experiment far longer than most lectures (Jensen 1998). Ultimately, it is about how professors guide a class and design experiences that transform information into knowledge.

4 CONSTRUCTION SYSTEMS AND STRUCTURES I WORKSHOP

Construction Systems and Structures I is a second-year architecture course part of the new curriculum of FHIC-PUCE in Quito, Ecuador. As it is described in the syllabus (FHIC 2025), the goal of this subject is to develop students' understanding of construction logic, from the conception of an architectural project through its materialization. In this context, students are introduced to constructions, structures and building services as integral systems which respond to a range of criteria, including architectural intentions, structural configuration and materiality. The subject is delivered in a co-teaching approach involving an architect and an engineer who conduct the class as a team. The idea is to foster an integrative thinking and a comprehensive understanding of construction systems, as it is tackled in the professional practice.

Students acquire new knowledge through a progressive process in which, as outlined by the learning outcomes (FHIC 2025), they advance through the stages of recognition, critical analysis, and practical application. Each of the learning outcomes is evaluated throughout the different phases of the course: Paper Structure Challenge, Architectural Case Studies and Systems Integration Projects. Complementary activities are part of the methodology and are implemented along the semester to foster an integrative understanding of the subject. See Fig. 1.



Fig. 1. Hands-on experiences, workshop-based learning and construction site visits.

Paper Structure Challenge: The course starts with an exercise where students use their body to measure the class. The idea of this first task is to introduce students to space and modulation through their own bodies. The next activity, developed by an empirical approach, students build the tallest feasible structure made with paper able to sustain the load of a bottle filled with water. The aim of this project is to encourage reflection on the relationship between modulation and structure configuration. Through an experiential application, students are introduced to the principles of statics and structural logics before learning calculation methods.

Architectural Case Studies: The second phase follows an analytical and practical approach. Students engage with structural families through theoretical study, case analyses, the construction of physical models, basic structural calculations and the observation of real examples found in their own context. The case studies are iconic buildings of diverse contexts, showcasing relevant construction systems and clear architectural conceptual approach. Through them, students can understand how conceptual framework and architectural strategies are translated into a coherent construction logic that functions as an integrated whole. After analyzing, students identify a distinctive condition within the project and subsequently propose a new construction system that reinforces that specific aspect. For this phase, students develop conceptual and construction models as well as detailing. Since the materials used are the same as those in the real project, students utilize the wood and metal workshops to build physical models, which are then tested.

Systems Integration Projects: In the third phase, students implement construction and structural concepts in the Design Studio I project. The objective is to demonstrate how construction systems work in accordance with conceptual and spatial intentions of a project developed by the students themselves. Once the main condition of their project is identified, students are expected to demonstrate the integrated functioning of structural systems through a model of one module, as well as a section drawing and representative detailing.

Complementary Activities: Complementary strategies are implemented. One of them is to use the body to build personal and collaborative structures with peers, through it, students analyze the influence of structural configuration and its responses. Another one is to incorporate hands-on activities like a 20 minute's challenge to build a paper structure capable of supporting the maximum number of phones, or the two-hour challenge to build models using the available materials. Both challenges are implemented to introduce new theories like the Active Surface of the Active Form. A third strategy is to promote activities that need to be carried out in both, in the class and in the wood and metal workshops. A final strategy is to complement theoretical and practical classes with the field trips and visits to construction sites or materials manufacturing plants.

5 CONSTRUCTION SYSTEMS AND STRUCTURES I AND NEUROSCIENCE

The following section analyzes the Construction Systems and Structures I curriculum through a neuroscience education perspective. See Table 2.

Table 2. Analysis of Construction Systems I curriculum through a neuroscience education perspective.

CONSTRUCTION SYSTEMS I . CURRICULUM			NEUROSCIENCE . PRINCIPLES							
I	Paper Structure Challenge	• Use of the body to measure the class. - Introduction of space and modulation. • Build of the tallest feasible structure made with paper. - Learn about modulation and structure configuration. - Introduction of statics principles and structural logics.	B	B Kinesthetic learning	- Sensory-motor experiences. Hands-on activities. - C Curiosity and novelty - Association of pleasure with positive experiences. - D Positive experiences direct to motivation, curiosity and engagement.					
		C	C							
		D	D							
II	Architectural Case Studies	• Learning from structural families: case study analysis and proposal - Observation, analysis, and development of conceptual /structural models. - Rethink a particular condition and propose a new construction system. - Wood and metal workshop for the construction of scale models. - Theoretical approach of new concepts. Basic structural calculations.	A	A Outside world to create new learning experiences	- Real-life situations and context - Formulation of projects and reach of objectives. - D Memory related with hands-on experiences and field trips.					
		D	D							
III	Systems Integration Projects	• Construction concepts in the Design Studio I project. - Construction systems aligned with conceptual and spatial intentions. - Build a scale model of one of the project modules. - Develop a detailing proposal.	A	A Formulation of projects and reach of objectives	- Connection of academic content to life's situations. - C Experiences that emphasizes process, rather than the end. - D Memory related with hands-on experiences.					
		C	C							
		D	D							
IV	Complementary Activities	• Experiential body-based exercises: - Use of hands and body to build structures. - Collaborative structures with peers. • Hands-on challenges: - 20 minute challenge to build a paper structure. - Two-hour's challenge to build models using the available materials. • Field trips: - Construction site visits. Visits to material manufacturing plants.	A	A Outside world to create new learning experiences	- Real-life situations and context - Connection of academic content to life's situations. B Kinesthetic learning / Sensory-motor experiences / Body experience related to emotions / Construction of models, hands-on activities. - C Curiosity and novelty / Association of pleasure with positive experiences. - D Positive experiences direct to motivation, curiosity and engagement.					
		B	B							
		C	C							
		D	D							
			A	A Real-life experiences	B	B Kinesthetic approach	C	C Intrinsic motivation	D	D Emotions and learning

Phase one emphasizes engagement through curiosity and the association with positive experiences from the beginning of the subject. Exploration of new structural concepts, using both body and daily-life materials, fosters attention and a sense of novelty in learning. Thinking about preparing future professionals, "emotional processes are required for the skills and knowledge acquired in school to transfer to novel situations and to real life" (Immordino-Yang and Damasio 2007). The second phase focuses on learning new concepts, including basic structural calculations. Although this phase is theoretically complex, the proposed exercises are designed to relate real-life situations with learnings and to encourage the formulation of projects to reach objectives. As Johnson (2001) notes, "the broader the context within which students are able to make connections, the more meaning content will hold for them". Thus, the practices and exercises applied in this

stage are intended to evoke understanding rather than mere memorization. The third phase promotes the application of learnings through a self-proposed project. Reflecting professional practice, where architects develop a project through a design process that culminates in the formulation of construction, this final exercise aims to help students connect academic content with real-life situations. Both professors the architect and the engineer provide guidance during the construction development of the project. This stage prioritizes the learning process over the final result and is strengthened by the feedback they provide, supported by “the time provided of quantity, variety, and quality of feedback that encourage better nutrition” (Jensen 1998).

6 SUMMARY

The new curriculum places special emphasis on the interdisciplinarity required by a technical subject such as Construction Systems and Structures I. It reinforces the importance of collaborative work in the classroom, exemplified through co-teaching by an engineer and an architect. The course aims for learning to happen through understanding rather than just memorization. Thus, learning outcomes are fostered through experiences that connect academia with real-life contexts, as well as through activities that involve experimentation, site visits and hands-on work.

7 CONCLUSIONS

Students are able to understand construction as a sequential process while recognizing buildings as the result of these processes and the complex integration of multiple systems. From a neuroscience education perspective, this also means that students are able to organize information, plan, question, and achieve genuine understanding, thus connecting their learning with real-life situations.

One of the results is that students improve their reasoning by recognizing that the body, space, and everyday objects around us can be used to create models, explore processes, or test concepts learned theoretically, thus incorporating principles of neuroscience such as kinesthesia, memory, and curiosity into learning processes. By implementing neuroscience principles, students developed integrative construction reasoning aligned with professional practice.

References

- Caballero, M., Cabrera, M. D. M. G., and Llorent, V. J., *Hacer de la Neuroeducación el Arte de Enseñar: Pensar y Sentir para Desarrollar las Competencias Clave*, Ediciones Pirámide, Madrid, 2021 [in Spanish].
- FHIC, *Syllabus: Estructuras I*, School of Architecture, Pontificia Universidad Católica del Ecuador (PUCE), Quito, Ecuador, 2023 [in Spanish].
- FHIC, *Syllabus: Sistemas Constructivos y Estructuras I*, School of Architecture, Pontificia Universidad Católica del Ecuador (PUCE), Quito, Ecuador, 2025 [in Spanish].
- Immordino-Yang, M. H., and Damasio, A., *We Feel, Therefore We Learn: The Relevance of Affective and Social Neuroscience to Education*, Mind, Brain, and Education, Wiley, 1(1), 3–10, March 2007.
- Jensen, E., *Teaching with the Brain in Mind*, Association for Supervision and Curriculum Development, Alexandria, VA, 1998.
- Johnson, E. B., *Contextual Teaching and Learning: What It Is and Why It's Here to Stay*, Corwin Press, Thousand Oaks, CA, 2001.
- Rodriguez, M., Villacis, E., and Benavides, J., *Architecture Practical Learning: Analysis of Architectural Design Studio Through a Neuroscience Education Perspective*, Proceedings of LATAM SEC 2024, ISEC, 11(1), AAE-13, Quito, Ecuador, March 4-7, 2024.
- Villacis Tapia, E., and Ayarza, C., *Pertinence of a Neuroscience Construction Industry Class in Order to Raise Global Crisis Awareness*, Proceedings of EURO MED SEC 3, ISEC, 7(1), EPE-08, Limassol, Cyprus, August 3-8, 2020.