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Integrating Structural Education and Architectural Projects: A contemporary approach at the University of Brasília, Brazil

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Abstract: This paper discusses the potential realignment of structural design concepts in architecture's teaching and learning process, aiming enhancement and adaptation to a new reality within the construction field. It is recognized that the curricular parameters of a course should focus on developing the ability to acquire, synthesize, and apply knowledge, promoting a resilient education that equips professionals to resolve emerging conflicts and generate new solutions tailored to the reality of each context. In the field of Architecture and Urbanism, it is crucial to suggest the realignment of existing Structures courses, as Architecture and Structure are inseparable, and understanding the behavior of structures under new social demands is part of the architects' legal responsibilities. Such understanding is imperative for professionals to perform their duties with assertiveness and safety, ensuring stability of the conceived form. However, there are indications of potential issues in the teaching of Structures in architecture and urbanism schools, such as purely expository lectures and curricula distant from current professional practice. The methodology applied in this article is bibliographic research, which consists of a systematic analysis of the literature related to the theme of teaching and learning structures in undergraduate architecture programs.

Keywords: Structural Education, Curriculum Innovation, Interdisciplinary Collaboration, Professional Training

1. Introduction

To align universities with the paradigms of the modern world and the scientific and technological training of students, the LDB (1996) established the adequacy of undergraduate courses through National Curriculum Guidelines (DCN). These guidelines transcend the narrow contours of mandatory minimum curricula, allowing for a curricular organization with relative freedom and flexibility. However, the teacher plays an irreplaceable role in mediating, guiding students through increasingly complex processes of internalizing the scientific-cultural and methodological-technical heritage necessary for mastering the reality in which they are social beings and upon which they will act. According to Nóvoa (2007), education is part of human nature. Unlike other living beings, humans need to ensure their subsistence through the transformation of nature and, in doing so, conceive a socially constructed world modified by cultural artifacts.

Throughout the history of Brazilian education, there is a diversity of norms, laws, decrees, and resolutions addressing teaching and education in the country. Thus, quality education is one that promotes learning situations that enable the construction of meaningful knowledge/learning (which goes beyond mere information) and transforms them into skills and competencies for professional performance.

According to Libâneo (1994), the teaching process should stimulate the desire and taste for study, thus showing the importance of knowledge for work and life. It is possible to affirm, based on studies and pedagogical techniques of great educators such as Vygotsky, Piaget, Paulo Freire, Rubem Alves, and Libâneo, that the didactic approach offered to introduce any content can either attract or deter student interest, thereby efficiently promoting learning. It is important that the student's training is adapted to a reality compatible with new paradigms, both in terms of concept construction and the development of a structure that allows the student to experience rational production or "rational thought." Thinking about the educational process within the composition and improvement of praxis aligns with the constant pedagogical re-signification, where educators and students are tied to permanently become subjects.

Given the above, educational reforms have been implemented worldwide to adapt the education system to changes in the economy and society. Alarcão (2003) refers to the current era as the "information society" and the "learning society" (Assmann, 1998, p. 17), an era of relationships and networked knowledge. These markedly multicultural changes demand new roles for universities, professor, and student training, influencing curricular dynamics and adaptation to new concepts or needs evidenced in contemporary times.

It is understood that it is possible to train a professional with the proposed profile, given that transdisciplinarity is the guiding principle of a course, linked to the connection between theory and practice, ensured by the laboratory structure available to the courses.

2. **Structural Systems and Their Relevance in Architecture**

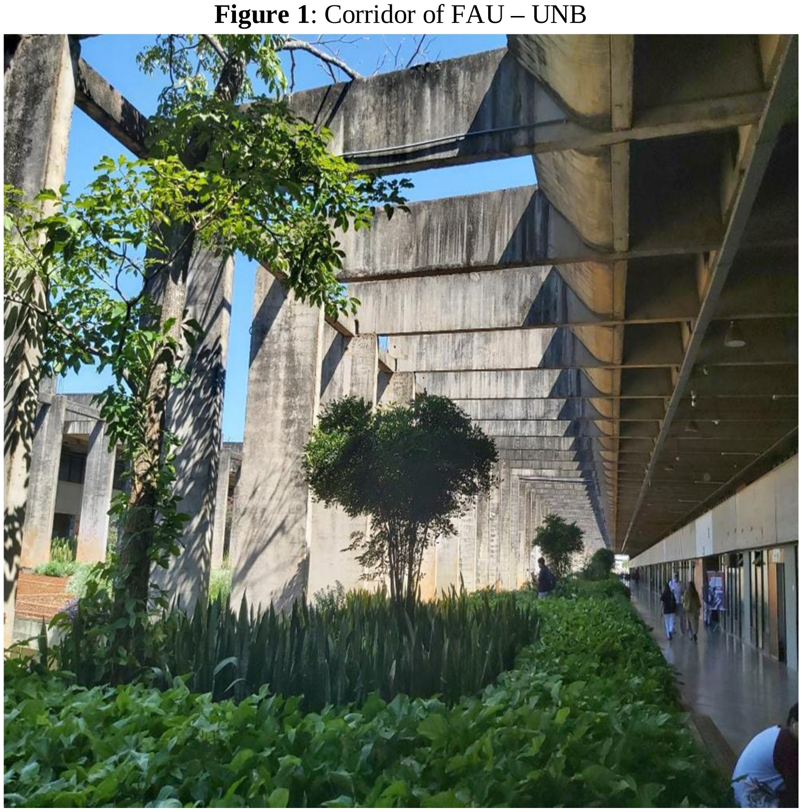
Understanding structural systems, foundations, and construction components is essential for the professional practice of architects and urban planners, as it enhances the technical quality of architectural projects and improves communication with teams during the design process. Similarly, these subjects are fundamental to the education of architecture and urban planning students and should be present in the teaching and learning process during undergraduate studies, raising awareness of the various technological, construction, and structural possibilities.

Teaching practices in architecture and urban planning need to stimulate the experience, guidance, and interpretation of the knowledge that constitutes these areas, countering a rigid and conventional teaching approach that has not fully contributed to student education over the years. Advanced access to information and technology, along with various changes in communication and interaction, has completely transformed the learning process in universities, requiring an urgent update of the methods, concepts, and application of teaching and learning in architecture and urban planning.

The pursuit of quality projects in contemporary cities is driving architecture schools and programs to train professionals with comprehensive, yet predominantly theoretical knowledge. Therefore, it is necessary to provide education that prepares students for the development of new construction technologies and for greater integration among various professional fields related to architecture, including the use of sustainable resources and an understanding of market demands, such as the recovery and rehabilitation of built environments.

The distance learning course “Reabilita” from the University of Brasilia is an excellent example of a rehabilitation program with a broad impact on the performance of its graduates. According to Pazos et al. (2023), the Reabilita course aims to provide continuous education for professionals focused on urban planning, physical space rehabilitation, and the preservation of built heritage with a sustainability perspective.

Figure 1: Corridor of FAU – UNB



Source: Author's image (2023)

Figure 2: Structure of the Chemistry Building – IQ/UNB

Source: Author's image (2023)

The restructuring of the curriculum is essential, as many newly graduated architects feel unprepared to solve practical problems in their professional practice. Many architecture courses offer an academic perspective that is distant from construction reality, which can lead to a lack of structural understanding among architects. This results in many young professionals abandoning the career or seeking other areas of work, which harms architecture and society. It is known that architecture students need to develop skills to understand and design structures and define the materiality of architectural projects. Due to this fact and the need to integrate knowledge from different fields of architectural education, the following research question arose: What resources can be adopted in the teaching-learning process of structures for architecture students? How can the curriculum structure be made more adaptable to the new reality?

According to Boccato (2006, p. 266), bibliographic research seeks to solve a problem (hypothesis) through published theoretical references, analyzing and discussing various scientific contributions. This type of research will provide subsidies for knowledge about what has been researched, how, and from what focus and perspectives the subject presented in the scientific literature has been treated.

It is crucial that architects be critical, creative, and capable of continuous learning, teamwork, and understanding their cognitive and emotional potential. They need to have a broad view of the social and ecological problems affecting humanity while having deep knowledge in specific domains. In summary, it is necessary to train professionals who are attentive and sensitive to societal changes, with a transdisciplinary vision and capable of constantly improving their ideas and actions.

The teaching of Architecture, while stimulating the development of skills to design an architectural object, must also provide knowledge from related fields – including Structural Engineering – so that the act of designing can be fully realized. The disciplines in the Structural area are invariably taught by civil engineers, who are considered, due to their technical training, more qualified for this task. Often, this is a misconception, as their excessively mathematical training, distant from design conception, leads them to transmit knowledge without ensuring that students can connect it to architectural design.

Consequently, in the field of Architecture education, it is not difficult to identify didactic lapses in teaching processes. In a typical Strength of Materials class, it is common for the instructor to proceed as follows: represent a beam with a line, supports with basic triangles, and loading with arrows, without considering questions such as: what is the purpose of a beam?; what does a support represent in the structure as a whole?; where does the load that acts on the beam originate from? The less curious student might learn the mechanism to solve the problem, calculating the values of mysterious mathematical entities like "bending moment" and "shear force," and completing the feat with the respective variation diagrams. However, it is common for this knowledge to be forgotten shortly thereafter, as it does not represent any meaningful connection to the goal, which is the creation of spaces for human activities.

Figure 3: Photo of concrete beams.

Source: Author's image (2023)

It is possible to conclude that if the role of the design instructor is to teach the student to feel, think, and act, and consequently to design based on cultural and timeless aspects, with critical, aesthetic, and ethical awareness, then this teaching needs to be adapted to the realities of their time, including all current technologies and prerogatives, so they are prepared to address them.

Regarding the specific learning process of Structural Behavior, Rebello (1999) is one of the authors who has most closely approached this issue. According to the author, the conception of a structural framework results from the synthesis of specific criteria that can be obtained by observing existing examples and natural phenomena. The author proposed a method based on a 'system' of basic structural systems, which helps organize the mental process of Structural Conception.

Thus, from the knowledge of a certain number of elements, it becomes possible, by establishing appropriate associations between them, to create an infinite number of structural possibilities and forms. This same reasoning can be inferred from nature's inexhaustible capacity to produce variations from combinations of a determined range of chemical elements, as pointed out by Pearce (1990). The author proposes the development of a construction strategy based on the use of modular systems inspired by the triangular composition of natural structures, considered efficient in the use of materials and energy resources.

Cassie and Napper (1958) also highlight the relevance of studying natural structures with the idea of economy of means. They analyze that nature achieves optimal results in the use of materials, as the structural form of organic elements has a section such that, with a minimal amount of material, it is possible to achieve high strength.

Vasconcelos (2000) revisits the inspiration from natural elements by presenting a series of comparative examples between existing structures in the biotic environment and human-produced structural systems. His study is relevant for understanding that through careful observation of nature, it is possible to conceive alternative and innovative solutions to structural problems in buildings.

Regarding the difficulties in teaching Structures, a possible explanation could be that most of the subjects taught in Architecture courses are traditionally offered by Engineering courses, whose focus and concerns are quite different.

Thus, by emphasizing quantitative aspects without necessarily addressing the connections to the logic, scales, and concerns specific to Architecture, these subjects become overly abstract, hindering students' understanding of Structural Behavior. In other words, instead of visualizing and understanding a physical, geometric, and concrete event, a strategy of dimensioning through a quantitative and abstract model is interposed (Polillo, 1974; Rebello, 1993; Zanettini, 1974).

Torroja (1960) is one of the origins of this stance: he was one of the first to advocate that structural conception, because of a creative process, must necessarily establish a connection between technical and artistic processes. The author argues that the conceptual discussion of form and structure should be prioritized so that the mathematical model is the result, not the cause, of the design. For him, the conception of a structural system precedes the calculation, which exists to confirm or test what has been conceived by the human mind.

In this context, this work proposes a bibliographic research methodology, reviewing the literature related to this theme, with the aim of contributing to the advancement of professional training in architecture and urban planning.

Figure 4: Structure of the Biology Building - UNB.

Source: Author's image (2023)

3. Integration of structural design and architectural projects

The lack of coordination and communication between the disciplines of structural engineering and design in architecture education is a challenge that can undermine the comprehensive training of future professionals in the field. Architecture is a multifaceted discipline that requires a broad and integrated understanding of various aspects of design and engineering, with structure being a fundamental part of this whole. However, it is common to observe gaps in collaboration between architecture and structural engineering students during the learning process.

One of the reasons for this lack of coordination could be curricular segregation, where disciplines are often taught in isolation without an integrated approach. This can result in architects having a limited understanding of structural demands and engineers not being fully aware of the aesthetic and functional considerations of architectural design. This division in education can lead to architectural projects that, although visually appealing, face substantial structural challenges.

The development of Engineering has culminated in a teaching approach for Structures based on calculation and detached from the practical-reflective learning characteristic of Project teaching, resulting in student disinterest in this subject and the perception that such disciplines are merely obstacles to their graduation.

According to Phillipe Boudon (Boudon et al., 2000), the pinnacle of Architecture education is the empirical experience of design, which relates to all other disciplines of the course and, therefore, should be at its core, with a specific organization, time, and place (Lebahar, 2007). Thus, the role of the design instructor is to teach the student to feel, think, and consequently, to design based on cultural and timeless aspects, with their critical, aesthetic, and ethical awareness.

The lack of effective communication between disciplines can also manifest in the reluctance to acknowledge the interdependence between form and function. Architects and structural engineers often operate in separate silos, without sharing insights or challenges during the design phases. This can result in structural solutions that are not optimized for architectural design, or vice-versa, compromising the overall quality of the project.

Architecture students need to explore the function of structure in their projects, seeking ways to integrate the knowledge acquired in technology subjects and develop an intuitive/reflective ability to conceive it. Like the teaching of architectural design, such competence can be obtained throughout the course through practical and active teaching. At a fundamental level, the architecture and structure of a building are intrinsically intertwined.

The way a building is architecturally conceived directly impacts the structural demands, and vice-versa. Therefore, it is imperative that professionals from these two disciplines work closely together from the early stages of the project. Effective integration between structural design and architectural projects can result in innovative and efficient solutions. For instance, the intelligent choice of materials and the optimization of load distribution can not only strengthen the structure but also positively influence the architectural design, providing more open, illuminated, and versatile spaces.

On a national level, the situation is no different, as there is a noticeable deficit in the training of architects in the field of structures within Architecture Schools. This is due to the historical division between two models of education: the School of Fine Arts and the Polytechnic School (Saramago, 2011). This polarization persists because didactic conflicts remain, causing evident consequences in the learning of structural design (Rebello; Leite, 2015).

Based on recent literature, it is observed that this problem may have three probable causes: the type of training of the teachers, the habit of teaching focused on calculation and adapted from Engineering Schools, and different points of view and languages within the course. According to Rebello and Leite (2015), it is not only departmentalization that causes this distancing but also the overly technical training of structural teachers, which gives architecture students the impression that what is being taught is devoid of meaning and creates a disconnection between the two branches of constructive knowledge (Rebello; Leite, 1998). There is a fascination that numbers can generate in the teachers of these subjects (Swartz, 2006), and many works around the world comment on the same issue of their persistence in maintaining a teaching standard focused on structural calculation (Gulling, 2006).

To overcome these challenges, it is crucial to promote a more integrated approach in architecture education, encouraging collaboration among students from different disciplines from the beginning of the course. Joint workshops, collaborative projects, and the integration of structural concepts into design studies can help bridge the gap between the disciplines. Moreover, teachers and professionals in these fields can play a vital role by emphasizing the importance of effective communication and mutual understanding for the success of integrated and successful architectural projects. This more holistic approach to teaching will help train architecture professionals who possess a comprehensive and integrated view of the design process, combining creativity, functionality, and structural stability.

4. Methodology

This paper is classified as a bibliographic study with a qualitative-quantitative nature, in which a systematic literature review is conducted on the topic of teaching and learning structures in undergraduate architecture courses. The systematic search in the literature is a scientific investigation method that aims to eliminate biases by systematizing searches in scientific databases and organizing a bibliographic portfolio. The method adopted in this work is known as the "SSF Method" (Systematic Search Flow), represented by four phases. See:

Figure 5: "SSF Method" (Systematic Search Flow)

Phase 1 - "Research Protocol":	This phase includes search strategy activities, database consultation, document management, standardization and selection of documents, and the composition of a document portfolio.
Phase 2 - "Analysis":	This phase involves data consolidation.
Phase 3 - "Synthesis":	This phase covers the preparation of reports.
Phase 4 - "Writing":	The research will be conducted using a qualitative approach, employing various methods to collect and analyze data.

Source: Author's image (2023)

According to Bastos and Keller (1995, p. 53), scientific research is a methodical investigation into a particular topic with the objective of clarifying aspects under study. Searches were conducted in four scientific databases during November 2023. The databases used were: Google Scholar, Scielo, Portal Capes, and Arquitexos.

As inclusion criteria, scientific articles related to the topic, all in Portuguese, were listed. Texts similar to the topic were added to the literature review. According to Gil (2002, p. 17), research is necessary when there is insufficient information to address a problem or when the available information is so disorganized that it cannot be adequately related to the problem. Bibliographic research is primarily found in the academic field and aims to enhance and update knowledge through the investigation of already published works.

From this perspective, bibliographic research is based on the study of previously published theory, and it is essential for the researcher to master the reading and systematize all the analyzed material. During the bibliographic research, the researcher should read, reflect, and write about what was studied, dedicating themselves to reconstructing the theory and improving the theoretical foundations. Furthermore, it is essential for the researcher to organize the selected works into notes that contribute to the construction of the research.

According to Macedo (1994, p. 13), bibliographic research is the first step in any type of scientific research, aiming to review the existing literature and avoid redundancy in the study or experimentation topic. Lakatos and Marconi (2003, p. 183) add that bibliographic research is not limited to repeating what has already been said or written about a particular subject but to provide analysis of a topic from a new perspective, leading to innovative conclusions.

5. **Results**

The successful integration of teaching structures in architectural projects brings a range of benefits that promote not only the technical quality of the projects but also the comprehensive and innovative training of future architecture professionals. Without a doubt, there will be benefits such as the emergence of more sustainable projects. Integrated understanding of structures from the early stages of the project enables architects to consider sustainable aspects more effectively. This includes the selection of eco-efficient materials, energy efficiency strategies, and the incorporation of construction practices that minimize environmental impact.

Figure 6: Partage Shopping Brasília.

Source: Author's image (2023)

Structural and Economic Efficiency is also one of the benefits. Architects with solid knowledge in structures can optimize the design to ensure maximum structural efficiency. This not only enhances the safety of the construction but can also result in significant material and construction cost savings, contributing to more affordable and economically viable projects.

The integration of disciplines allows for the creation of innovative projects that unite architectural aesthetics with structural functionality. Architects who understand the possibilities and limitations of structures can explore new forms, materials, and construction techniques, leading to more creative and avant-garde solutions.

Interdisciplinary collaboration between architects and structural engineers during academic training fosters a culture of teamwork. This is crucial in professional practice, where successful projects often depend on effective communication and collaboration between different specialties.

An integrated understanding of structures contributes to the creation of buildings that are more resilient to natural disasters and adverse conditions. Architects who incorporate structural considerations from the beginning can design constructions that better withstand earthquakes, strong winds, and other threats, improving long-term safety.

By integrating structural considerations into architectural design, professionals can offer solutions that meet not only aesthetic criteria but also the practical expectations and needs of clients. This results in projects that are visually appealing, functionally efficient, and structurally sound.

In summary, the integration of teaching structures into architectural projects is essential for the training of well-rounded architects capable of tackling the complex challenges of contemporary design. By combining creativity and technical knowledge from the beginning, professionals trained in this manner are well-equipped to significantly contribute to the advancement of architecture and engineering, creating innovative and sustainable spaces. Structural systems are a fundamental part of architectural projects, providing the solidity necessary for the project's technical viability and affecting the triad of spatial quality, functionality, and aesthetics of the building.

From the analyzed reports, publications studying the teaching-learning process of structures for architecture have been increasing since the year 2000. The growth in publications from 2000 to the present may be related to the transformation that new technologies have brought to the construction sector, reflecting on the university environment.

6. Conclusion

In curricular units that consider the relationship between structure and architecture and adopt emerging resources and active methodologies in teaching, there is a tendency to improve architectural project performance by providing greater clarity regarding the inconsistencies of initial ideas. Internationally, many schools have introduced integrated studios where students from different areas participate in solving practical problems, such as multidisciplinary projects. There is a need to review the curriculum to include these educational technologies in undergraduate courses, aiming to incorporate these integrated work processes that allow for greater reflection on projects and closer alignment with practice.

For work processes involving active methodologies in the teaching-learning of structures, it was found that the use of some technological resource to support integrative activities is common. Finally, actions aimed at the curricular structure of undergraduate courses were identified, which foresee ways to facilitate collaborative and interdisciplinary processes, as well as the inclusion of digital technologies.

Possible Suggestions for Curriculum Adaptation: improving the architecture curriculum to effectively integrate structural design with projects is crucial for preparing future architects for the multidisciplinary challenges of professional practice. Here are some strategies to enhance this integration in the curriculum:

Curricular Integration: develop courses that simultaneously address architectural and structural concepts from the early stages of the program. These courses should encourage collaboration between architecture and structural engineering faculty to create a holistic approach to teaching.

Collaborative Projects: incorporate practical projects that require collaboration between architecture and structural engineering students. Working together from the early stages fosters a deeper understanding of the interdependence between form and function. **Practical Focus:** include case studies that highlight real-world examples where efficient integration between structural design and architecture was key to success. This provides students with practical insights into the application of the principles learned.

Modeling Simulation: Integrate structural modeling and simulation tools into the courses. This allows students to visualize and understand the structural implications of their design decisions in real-time.

Interdisciplinary Communication Training: include specific modules that teach effective communication skills between architects and structural engineers. This is essential for ensuring successful collaboration in a professional environment.

Workshops and Seminars: organize regular workshops where industry professionals share experiences on how effective communication contributed to the success of architectural projects.

Joint Research Projects: promote research projects that require collaboration between architecture and structural engineering students. These projects can explore innovations at the intersection of architectural design and structural engineering.

Faculty Participation in Applied Research: encourage faculty to engage in applied research that explores the synergy between architecture and structure. This experience can be passed on to students through specific courses or seminars.

By implementing these strategies, educational institutions can create a learning environment that prepares students not only to design visually appealing spaces but also to understand and effectively integrate structural aspects into their projects, resulting in more qualified professionals prepared for the challenges of architectural practice.

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