Fecha de recepción: noviembre 2025
Fecha de aprobación: enero 2026

Design processes under systems thinking: A look at architecture students' projects in Ecuador in complex contexts.

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Abstract: This article contextualizes, critiques, and analyzes the relevance and pertinence of systems thinking in architectural design processes within complex urban contexts, particularly in academic experiences developed by architecture students at the Pontifical Catholic University of Ecuador, Ibarra Campus. In an environment characterized by heritage and public spaces, such as the historic center of Ibarra, understanding urban systems as interdependent structures is important for designing coherent and sustainable interventions. From a theoretical and methodological perspective, the paper proposes how architectural education should transition toward problem-based learning models, promoting analysis, synthesis, and integrative representation. In addition to the insights of several authors, a bridge is established between complex thinking, systems theory, and design practice in workshop exercises. Based on the study of Ibarra's historic center and its urban parks as nodes of the system, a design methodology is proposed that configures each identified problem into a systemic element and proposes simultaneous solutions using three-dimensional models. Finally, the need to transform systems thinking into a conceptual tool for understanding and acting on the city is discussed, concluding with the pedagogical, social, and urban benefits of this approach for contemporary architectural education.

Keywords: systemic thinking - architectural design - architectural education - heritage urban planning

[Resúmenes en español y portugués en la página 171]

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Introduction

The design process in architecture has been considered an exercise in formal, functional, and technical synthesis to solve problems posed in different settings, both in academia and in the real world. However, contemporary phenomena such as climate change, social fragmentation, heritage degradation, and unprecedented urban expansion require new visions, perspectives, and ways of thinking, teaching, and designing.

Under this principle, systems thinking emerges as an epistemological and methodological tool that allows us to rethink the complexity of urban and architectural phenomena through a lens of relationships that form a conceptual construct to address ways of living. In general, everything that happens in cities, and even the city itself, can be viewed as a complex adaptive system, as it is made up of physical, social, ecological, environmental, cultural, and economic dimensions, among others, that constantly interrelate and interact. This perspective demands that solutions or design work should not be linear and fragmented, but rather should maintain a notion of dynamics or cyclicality to understand the different relationships that shape what happens in the city. This way of thinking must be presented in architectural training so that students not only represent or design objects, but also structure processes that transform them into realities.

This way of thinking that has been built at the Universidad Veracruzana in Mexico, has yielded adequate results in design students, who moved to share experiences at the Pontificia Universidad Católica del Ecuador Ibarra where this type of exercises have been detonated in studies of the historic center of Ibarra, which has allowed to show a paradigmatic scenario where an intermediate city, with great heritage value in public spaces, especially in parks, which become nodes of social interaction and coexistence of people, in addition to converting urban, cultural and environmental problems to promote the designs of integrative projects.

In this sense, the objective is to demonstrate that systemic thinking, applied to architectural and urban design, is one of the most efficient ways to develop academic projects that impact the social sector by transforming interactions between individuals, based on the

concept of systemic design as a methodology that argues that design is a way to visualize, structure, and solve urban problems synergistically.

Teaching architectural design and the need for problem-based approaches

From teaching the object to learning the process

Eventually, the teaching of architectural design has been based on the logic of the *atelier*, a workshop concept inherited from the École des Beaux-Arts, in which students generate strategies and develop projects through individual corrections and formal evaluations by a professor. In this sense, the classroom becomes a space for praxis, the materialization of theory, and decision-making to discuss, reflect, and critique proposals within architectural challenges (Sánchez García & Rios Aburto, 2023).

Although this model has been replicated in architecture academia as a way for students to learn, it has, to a certain extent, limited contemporary ways of generating architectural projects in the classroom. As Schön (1983) mentions, architects must not only solve the technical aspects of problems but also face scenarios of uncertainty, ambiguity, and questioning of values that require a reflective individual capable of learning while designing.

In this context, the use of architectural design models in workshops or classrooms demonstrates the potential for combining innovative and collaborative approaches. However, they face challenges that limit creativity, recognizing the rigidity of studied and conventional paradigms. Pedagogical structures have displayed a structuralism by privileging the memorization and acquisition of theoretical knowledge, neglecting the pragmatic component, which impedes holism and the creation of relevant solutions for urban environments.

From a systemic approach, it has been recognized that problems in cities and in architecture cannot be solved in an isolated, segmented or fragmented way, so there is a need to understand the multiplicity of dimensions of the same problem that brings together cultural, environmental, social, etc. variables, which has led to maintaining a comprehensive vision that does not only have isolated projects with specific techniques since it can be the generator of proposals disconnected from the multidimensional realities that are presented, so the classroom must be permeated with models that allow active collaboration skills and above all adaptability to problems.

However, it is recognized that these types of thinking and methodologies train students to work with different environments and social actors to ensure that, in learning, appropriate solutions are developed to the problems posed in the classroom. The central challenge, then, is the implementation of these comprehensive models in traditional architecture schools to pursue a culture of architectural design based on systems thinking to overcome the barriers of pedagogical paradigms and address real-life case studies in needy locations. Presenting the comprehensive model of systems thinking in the classroom helps develop students' ability to design solutions with a systemic understanding that maintains diverse guidelines for solving emerging problems, eradicating fragmented and disconnected

thinking and thereby incorporating pedagogical innovations in the field of architecture toward a commitment to solving real-life problems.

From Problem-Based Learning to Problem Solving to Systems Structuring

Problem-Based Learning (PBL), initially formulated by Howard Barrows, has proposed that learning is achieved when the student faces real and complex challenges and problems that represent a broad study of the subject, research, discussion and the formulation of solutions to large-scale problems, which in architecture translates into project-based architectural design to help creativity to propose a solution for the exercise planned in the classroom.

In this context aimed at architecture, the teaching of design must start from the principle that any problem presented in the classroom is not an isolated entity since, as Senge (1990) comments, the recurring problems in organizations and cities are not isolated events but underlying systemic patterns, hence the notion of moving from *problem solving to structuring systems* to understand the phenomena, mechanisms and interdependencies.

Thinking in a systemic way is a way in which students conceive the solution as a series of relationships, rather than static objects, for example, Meadows (2008) has proposed systems as a set of interconnected elements to detect patterns, which allows architectural design to make decisions and establish relationships between materials, spatiality, functions, aesthetics, etc., which can contribute to the final presentation of a proposal. However, it is emphasized that this perspective reproduces a way in which the architecture student identifies variables, observes relationships, generates scenarios and critically evaluates possible solutions in a non-linear but evolutionary way.

In this systemic paradigm, Avsec et. Al (2024) has developed their proposal in a way in which systemic thinking is focused on human needs to improve architectural sustainability under social and environmental dynamics, which has helped to design spaces for human inhabitation with their environment. In this sense, Del Río Calleja (2022) proposes in his doctoral thesis an integrative model for the architectural design process based on complex systems that allows addressing the fragmentation of knowledge in architecture, facilitating a more relational and creative knowledge in the conception of buildings, that is, it maintains thinking directly to the building process in architecture as a way of understanding the building phenomenon.

Systems thinking also outlines a way of understanding society itself. Cleto Garza et. al. (2025) has proposed this reflection in which post-pandemic urban architecture is rethought, emphasizing the connection between spaces, social vitality, and resilience in the face of global crises. Likewise, some studies by researchers, focused on by Lira López (2019), have demonstrated the importance, in case studies, of research where systems thinking has been key to solving complex problems through interdisciplinary collaboration in architectural projects.

Systems thinking has truly sparked a wealth of research to address phenomena that are sometimes difficult to explain; Zavoleas (2021) analyzes biosystemic design as a response to the contemporary challenges of green architecture, thereby discussing and proposing a convergence between natural patterns and systems thinking for resilient urban and landscape structures. Likewise, Buchanan (2019) has explored the relationship between

systems thinking and design thinking and visualizes how both approaches can be integrated to address complex architectural problems from a holistic and adaptable perspective.

In other studies, Van der Bijl Brouwer & Malcolm (2021) have addressed the principles of systemic design in social innovation, analyzing the practices and rationales of experts in the field. In addition, they demonstrate systemic methodologies that facilitate integrated solutions to complex social problems. Their results highlight the importance of holistic approaches, multidisciplinary collaboration, and adaptability in the design process, thus contributing to defining the best practices and fundamental principles for social innovation based on systemic design.

This way of thinking, applied to architecture, has reinforced the ideas of Inan et al. (2024), who introduced systems thinking into architectural teaching, promoting an understanding of infrastructure as a living and relational system, highlighting the contributions of Peter Senge. In this sense, the design process always requires evaluation and critical reading to understand the conditions, speculations and emergencies that shape the guidelines of the various agents found in the city and thus seek the approach that encourages the interaction of architecture students in the form of networks, constellations and associations in contemporary cities (Inan , Ucar, & Yuncu, 2024).

Systems thinking has even been considered to study ways of addressing habitat in architecture as an application in Mexico City where it allows to analyze the consumption of resources in homes and generate proposals for systems and services through graphic models to manage the possible potential for improvement (Sattele Gunther, 2019) to raise the scales to cities like the work of Batty (2008), whose recent research shows that cities are complex systems that grow from the bottom up and that the integrated theory of the evolution of cities has linked urban economics and transport behavior with advances in network science, allometric growth and fractal geometry (Batty, 2008) and that cities should be understood not simply as places in space, but as systems of networks and flows (Batty, 2013).

Systems thinking has also developed processes in which city processes are understood as urban metabolisms that react to interactions, synergies and emergencies within the cities themselves (John , Luederitz, Lang, & Von Wehrden, 2019) and from which laboratories have been developed to understand the activities connections such as the ETH Zurich with the Systems Design Labs that has a set of hybrid and adaptive methods between science and design and whose research approach is based on basic research to promote hybrid methods and develop didactics to learn and teach systemic design, in addition to maintaining a transdisciplinary and fluid approach, by collaboratively identifying ways and interventions to address complex systems and activate systemic innovation (systemicdesignlabs, 2025).

Finally, we recognize works that have cemented these activities in Mexican academies, for example, that prepared by Avsec et. Al. (2024) who examined systemic thinkers in architecture students and how it affects design with digital skills and the development of inclusive practices and where they suggest changing the focus of architecture study programs to promote systemic thinking in students and encourage course designers to create novel and personalized, integrated and human-centered design and systems thinking, enhanced by technology (Avsec, et.al. 2024).

The academy of architecture as a systems laboratory

Based on the context that frames the importance of systems thinking, the architecture academy reiterates the need for this way of responding to problems, since it must function as an *urban systems laboratory*, where project workshops are responsible for becoming spaces where students simulate the complexity of the territory by articulating all technical, social, environmental, cultural, and environmental knowledge.

Sarquis (2016), for example, argues that the architecture workshop is a space for epistemic construction where project-based thinking and complex thinking converge, so teachers should not be transmitters of solutions but rather mediators in student processes, especially cognitive ones, to build mental models of the systems involved (Sarquis Mele, 2016), And in this sense, contemporary tools have also helped develop co-design in classrooms, such as BIM systems, GIS, or Urban Simulations, to systematically understand the environment rather than just the creation of objects and lead to the best possible solutions.

In the clearest sense, teaching must be based on systemic processes to achieve a change in the way project solutions are conceived. This means that buildings must not only be designed, but also the very system that the territory or city presents must be intervened in order to achieve dialogue between the different stakeholders, which must represent coherence and a systemic evaluation.

Talking about systems thinking, which emerged in the second half of the 20th century as a response to the fragmentation of scientific knowledge, has become a response and a tool for understanding and designing complexity in urban architectural projects. Ludwig Von Bertalanffy (1968), in his *General Systems Theory*, postulated that every organized entity must be understood as an open system, in constant interaction with its environment. This premise, applied to architectural design, implies that projects cannot be conceived as isolated objects, but rather as interdependent structures within networks of material, social, ecological, and cultural relationships.

Authors such as Senge (1990) have also strengthened the view of *organization* as a way of ordering the different elements analyzed and whose view has an impact on architecture in such a way that it should not be resolved as a single habitable or spatial project, but rather articulates a lot of information, different levels and multiple scales. Manzini (2015) has also proposed that design should be understood as a way of connecting actors, resources and knowledge as an ecosystem of social innovation and it should not be surprising that in Latin America we operate under uncertainties where the designer is presented in inaccessibility to build real knowledge (Sarquis Mele, 2016).

Faced with a design that can be inconsistent, variable, or oscillating, the paradigm of problem-based learning (PBL) and systems-based design (SBD) is integrated as a response to ensure resolution in complex environments and current contexts. This structure or synergy between learning models has triggered the notion of specific interventions that modify or change an entire system *as levers of change* (Meadows, 2008). In other words, an important part is finding the point within the system that can significantly activate some transformations, so that, in classrooms, the sense of a structural teaching of problems looking at flows, interactions, and relationships between the agents of the urban context must permeate.

Methodology of systemic thinking in Ibarra students

In Latin America, and in this case in Ecuador, applying this vision for pedagogical transformation and a paradigm shift has presented a blank canvas. In cities like Ibarra, Quito, and Cuenca, heritage has reflected a form of intervention and has become a niche for applying systems thinking to students. The historic center of Ibarra, a city located in northern Ecuador, constitutes a space where multiple dimensions of the territory converge: memory, landscape, mobility, ecology, and culture, as well as economic elements that determine a unique process in the transformations of its historic center.

It should be noted that the urban structure of Ibarra has been marked by processes of constant reconstruction and reconfiguration since the 1868 earthquake, which has generated an urban fabric with historical overlaps and contemporary dynamics of expansion and fragmentation. In this context, the parks of the historic center emerge as strategic elements that condense the relationships between society and the environment, acting as nodes of the urban system. Some of the most important nodes as meeting points are Parque de la Merced and Parque Pedro Moncayo, which maintain a connection with social cohesion within Ibarra. Therefore, the systemic thinking methodology represents a way of understanding the urban context through pragmatic models for architecture students to visualize the urban system of Ibarra's Historic Center in different multi-scale systemic models.

Within the framework of the International Congress of Architecture, Civil Engineering and Design (EARQ), held in Ibarra, a workshop entitled "Resilient and Emerging Systems in Urban Architectural Projects" was used as a basis. The author applied this tool to students from different degrees in the Faculty of Architecture at PUCE IBARRA. Initially, it was translated into systemic thinking as a master plan that articulates different activities based on an understanding of the perceived flows and actions that can modify the physiognomy of each sector of the historic center.

From this perspective, Pedro Moncayo and La Merced parks are viewed as small nodes that are modified or trigger, in a symbiosis, the transformations of the historic center. For this reason, the students structured two-dimensionally the urban voids or risk zones that can damage the system at different scales, constructing one structure for daytime activities and another for nighttime activities. They highlighted the problems in the urban system by selecting each element of the system as a problem. Among these, they highlighted insecurity due to theft, pedestrian insecurity, areas without urban lighting, pedestrian discontinuities, and facades that disrupt the urban image, among others.

Once the divergences that constitute systemic thinking in urban voids have been generated, the design process transforms into a three-dimensional conception based on hierarchies where each detected problem develops as an element of greater or lesser relevance, and each importance is interpreted as a subsystem with similar functions and characteristics, whether ecological, social, or symbolic, interdependent. From this perspective, the design methodology proposed for architecture students in Ecuador consists of a three-dimensional representation of the urban system of the historic center, assigning each detected problem (lack of shade, insecurity, infrastructure deterioration, pedestrian obstacles, or deterioration of urban image) to an element of the system represented by a circle of a different color. Likewise, the multiple problems detected function as a project that is not isolated but rather as a *multi-scale systemic model.*

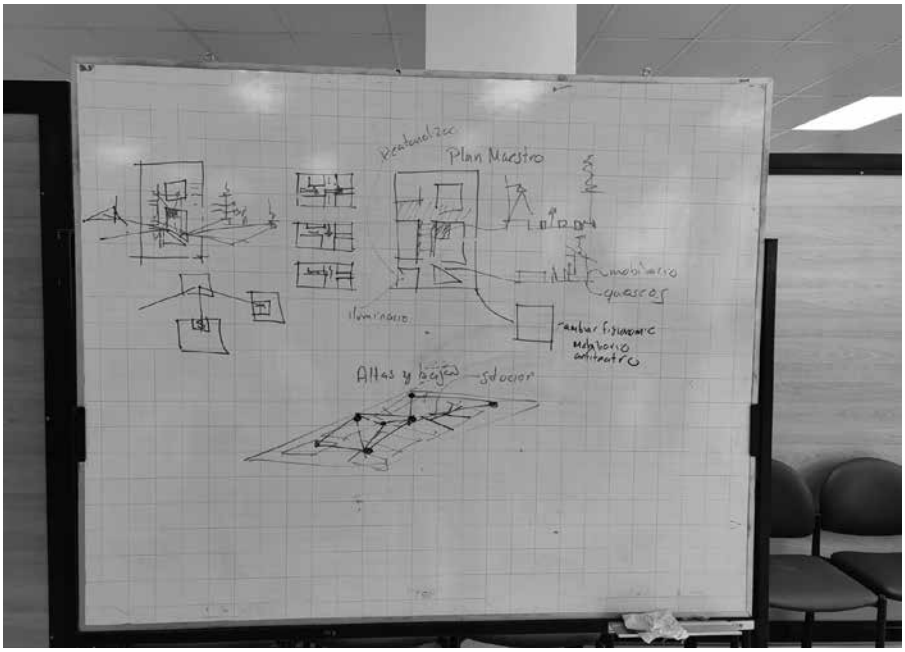

Figure 1. Explanation of systems thinking. *Prepared by the author*

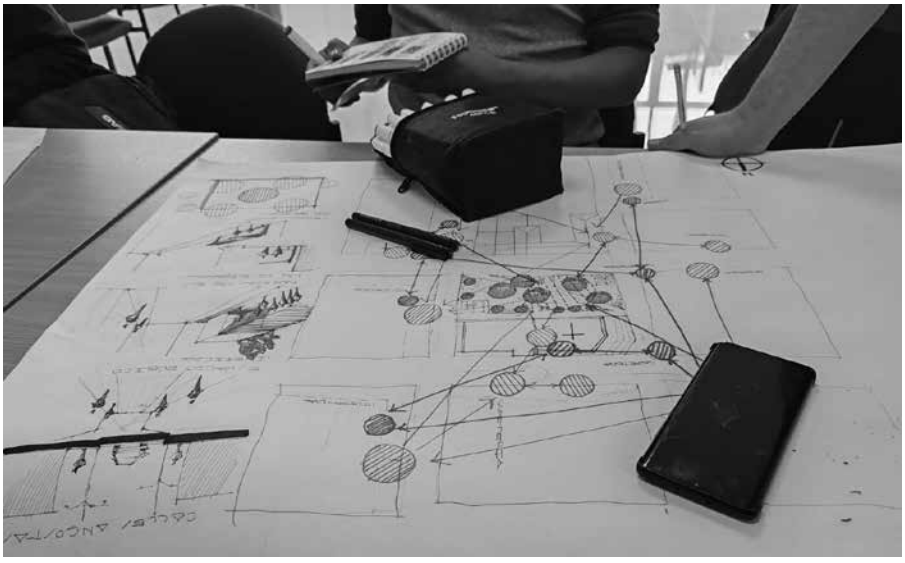

Figura 2. Development of the two-dimensional system. *Prepared by the authors.*

Figura 3. Multi-Scale Systems Thinking Models. *Prepared by the author.*

At this point, the student integrates and develops in the workshop the visualization of the factors that determine the park's flow, interconnections, and functioning as a whole. This enables students to understand the simultaneity of processes to promote and generate comprehensive problem-solving strategies. Some students built green corridors, urban plans, and improved facilities and infrastructure, understanding that any intervention in the system could solve one or more problems within Ibarra's historic center, since understanding the system generates interesting, resilient, and adaptive proposals.

In this context, the Ibarra case at the EARQ became a laboratory for systemic learning where the design process acts as a tool for diagnosis and transformation. Architecture ceases to be the ultimate goal and becomes a means of articulation between parts of the urban system and an instrument of mediation between society and nature.

With the three-dimensional model, workshop students begin to understand that each element can be solved symbiotically without being isolated. For example, the problem of insecurity due to lack of lighting and the problem of pedestrian danger were solved by installing road infrastructure, which makes it clear that systemic thinking helps resolve problematic flows with the least amount of project interventions.

Debate and conclusions

Contemporary architectural design, especially in architecture classrooms, is at a breaking point, viewing problems in highly interconnected environments. This perspective has triggered a shift in epistemological paradigms in architecture, which maintains a perspective where relationships between phenomena must be analyzed to propose solutions, rather than objects. Given this scenario, systems thinking is not just a way of designing but a way of understanding the environment and teaching architecture.

Rational, structuralist, or fragmented thinking has been a legacy in academia, where systems thinking confronts these issues to propose a multi-scale perspective of knowledge where reality, problems, and cities are understood as networks of independent relationships. This, for architecture, has implied that everything that happens in buildings, urban centers, and public spaces functions within an urban metabolism, whose energies and synergies are at the heart of designs with social impact.

Thinking systemically creates a balance between the synapses of urban phenomena and the design that solves problems posed in the workshops. In this context, the projects developed by students in settings like Ibarra, characterized by the complexity of circumstances like many Latin American cities, allow for the construction of a pedagogical process based on observation, adaptation, evaluation, and representation of urban flows.

For this reason, transforming and shifting design thinking toward a systemic approach does not mean abandoning the basic principles of architecture, such as aesthetics, materiality, or functionality, but rather integrating other dimensions in the search for meaningful relationships to better understand urban problems. This approach strengthens the students' design process by generating a more solid and comprehensive proposal.

One of the most valuable and significant contributions of the systemic approach applied to teaching architecture in workshops at the PUCESI school in Ecuador is the *three-dimensional representation of the urban system* as a pedagogical and methodological tool. This strategy, implemented in project workshops, allows students to simultaneously visualize the relationships between seemingly invisible or everyday elements that can formulate a synergy to solve problems such as mobility flows, vegetation, sunlight, cultural flows, infrastructure, among others.

Under these considerations, the urban environment is truly considered a network of configurational relationships that are interpreted as systems by the students who analyze it, since the selection of elements is part of the search for influence between elements. In this case, when applied to the parks in Ibarra, as central nodes of the system, it became a logic represented by nodes and interactions to configure systemic relationships.

The three-dimensional representation is also part of a model that shows relationships at different scales, some with stronger dependencies than others, but ultimately, it is a process that helps understand groupings or similarities for project resolution and maintains a critical and reflective mind with constant feedback. Likewise, the three-dimensional representation is not only an analytical tool but also a space for project experimentation where solutions emerge through understanding the relationships between the detected nodes.

In other words, the detection of central nodes, such as parks, are part of an urban organization that makes up the urban metabolism of historic city centers. In Batty's (2013)

view, cities are complex systems where all flows can be modeled, understood, and redesigned simultaneously.

The contemporary debate surrounding systems thinking in architecture focuses on its capacity to *transform and modify* design practice as a process and not merely a representation, which can abound in critique and decision-making, exerting its true operational potential as a relationship between design and the generated proposals. Furthermore, it becomes a way to confront traditional pedagogical models of fragmented design, and the systems approach promotes a reading along different axes to not only propose solutions but also develop strategies that operate at multi-scale and simultaneous levels.

In this environment, academia must recognize systems thinking to maintain students' ability to consider interdependencies and diagnose the economic, social, and environmental environments that must be integrated into the design process, which impacts the very ethics of this process. Systems thinking, then, is not only a work strategy but a thinking stance toward contemporary processes where the architect acts as a mediator between the different existing systems with a holistic perspective.

This project, located in the historic center of Ibarra, shows that systems thinking is not only a way to understand city sections but also a way to design city structures through analysis and three-dimensional representations as connected nodes. It is noteworthy that students were able to understand the interdependent relationships between public space, mobility, and social environments. They identified conflictive points where small interventions could have large urban effects. They developed comprehensive strategies and engaged in dialogue with a reflective design culture as a key point before submitting proposals.

This approach highlights several advantages, such as the ability to integrate multiple scales, promote interdisciplinary collaboration, and strengthen the critical vision of architecture students. It also fosters a deeper understanding of the territory as a network of processes, which allows for projecting from complexity without reducing it. In pedagogical terms, this contributes to the architectural design teaching model becoming an exercise in structural and strategic thinking so that the design process becomes a tool for diagnosis, research, and action.

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Resumen: El presente artículo contextualiza, critica y analiza la relevancia y pertinencia del pensamiento sistémico en los procesos de diseño arquitectónico dentro de contextos urbanos complejos, particularmente en experiencias académicas desarrolladas por estudiantes de arquitectura en la Pontificia Universidad Católica del Ecuador Sede Ibarra. En un entorno caracterizado por argumentos patrimoniales y de espacios públicos, como el centro histórico de Ibarra, la comprensión de los sistemas urbanos como estructuras interdependientes resulta importante para proyectar intervenciones coherentes y sostenibles. Desde una perspectiva teórica y metodológica, se plantea la manera en que la educación arquitectónica debe transitar hacia modelos de enseñanza basados en problemas (Problem-Based Learning), promoviendo el análisis, síntesis y representación integradora. Aunado a pensamientos de algunos autores se establece un puente entre pensamiento complejo, teoría de sistemas y práctica proyectual en ejercicios de talleres. A partir del estudio del centro histórico de Ibarra y sus parques urbanos como nodos del sistema, se propone una metodología de diseño que configura cada problemática detectada en un elemento sistémico y plantea soluciones simultáneas mediante modelos tridimensionales. Finalmente, se debate la necesidad de transformar el pensamiento sistémico en herramienta conceptual para comprender y actuar sobre la ciudad, concluyendo en los beneficios pedagógicos, sociales y urbanos de esta aproximación para la formación arquitectónica contemporánea.

Palabras clave: pensamiento sistémico - diseño arquitectónico - educación en arquitectura - urbanismo patrimonial

Resumo: Este artigo contextualiza, critica e analisa a relevância e a pertinência do pensamento sistêmico em processos de projeto arquitetônico em contextos urbanos complexos, particularmente em experiências acadêmicas desenvolvidas por estudantes de arquitetura da Pontifícia Universidade Católica do Equador, Campus de Ibarra. Em um ambiente caracterizado por patrimônio e espaços públicos, como o centro histórico de Ibarra, compreender os sistemas urbanos como estruturas interdependentes é importante para o projeto de intervenções coerentes e sustentáveis. De uma perspectiva teórica e metodológica, este artigo propõe como a educação em arquitetura deve transitar para modelos de aprendizagem baseados em problemas, promovendo a análise, a síntese e a representação integrativa. Além dos insights de diversos autores, estabelece-se uma ponte entre o pensamento complexo, a teoria dos sistemas e a prática projetual em exercícios de oficina. Com base no estudo do centro histórico de Ibarra e seus parques urbanos como nós do sistema, propõe-se uma metodologia de projeto que configura cada problema identificado como um elemento sistêmico e propõe soluções simultâneas utilizando modelos tridimensionais. Por fim, discute-se a necessidade de transformar o pensamento sistêmico em uma ferramenta conceitual para a compreensão e atuação na cidade, concluindo com os benefícios pedagógicos, sociais e urbanos dessa abordagem para a educação arquitetônica contemporânea.

Palavras-chave: pensamento sistêmico - projeto arquitetônico - educação arquitetônica - planejamento urbano patrimonial

[Las traducciones de los abstracts fueron supervisadas por el autor de cada artículo.]