Designing for Learning: Experimental Microarchitectures for the Creation of Flexible Educational Spaces

Daniela Ladiana[1], Chiara Iacovetti[2]

University of "Gabriele D'Annunzio" of Chieti and Pescara, Italy[1]
A3S Progetti Srl, Italy[2]

Abstract

During the International Design and Building Workshop at the École Nationale d'Architecture de Marrakech (8-18/12/2023), a pedagogical and design experiment was launched in collaboration with the master's degree Course in Architecture at the University of Chieti-Pescara. The goal was to explore ways to transform common school spaces into dynamic learning environments, allowing students to meet and study in a freer manner through the inclusion of micro-architecture. These interventions aimed to enhance the experience of existing interior spaces, fostering a more interactive and supportive environment for learning. Studies explore multidisciplinary concepts, including using play to build social learning infrastructure and creating supportive, wellness-focused environments that enhance the effectiveness of space as an educational tool [2]. In fact, they as elements as neither exclusively architecture nor simple furniture but a hybridization of the two scales that are proposed as an effective tool that, thanks to the experience of self-construction, can bring young pupils closer to the themes of circular economy, taught within a fully integrated pedagogical framework [15]. Through the act of aggregating construction elements, it is indeed possible to develop a new learning perspective for the reconfiguration of inclusive school spaces that place the pupil at the center of the learning process [1]. Within the framework of the objectives, this study presents the results of work developed with students from the Master of Architecture degree course in which classes were involved in an experimental activity based on the innovative use of digital design and fabrication with sustainable materials for the collective design and construction of small pavilions.

Keywords: *Educational spaces, Pedagogy, Ephemeral architecture, Self-construction*

1. Introduction

The COVID-19 pandemic significantly impacted on the educational experiences of young people worldwide. The prolonged closure of schools and the consequent confinement at home for several weeks exerted a profound psychological toll on the mental health of children and adolescents [2]. Therefore, it became urgent to identify alternative and sustainable approaches to overcome the detrimental effects of the functional inadequacies of educational spaces, particularly considering the limited investments in school infrastructure. Within the framework of the International Design and Building Workshop, held at the École Nationale d'Architecture de Marrakech from December 8 to 18, 2023, and as part of two technological courses in the Degree Program in Architecture at the University of Pescara, a process of academic reflection and didactic experimentation was initiated.
This initiative aimed to explore how architectural research and education might actively contribute to addressing the challenges and needs arising from what can now be considered a genuine international emergency. The pandemic, in fact, acted as a magnifying lens, exposing, first and foremost, the inadequacies of existing school facilities, which are increasingly incapable of meeting long-standing demands for a more harmonious integration of pedagogy and architecture. Educational environments are not merely physical spaces for study and work but are also fundamental settings for social interaction, knowledge construction, and personality development. Consequently, their design must reflect a complex vision that addresses the diverse educational, cultural, and psychological needs of their users. Indeed, it is widely recognized that the school environment, including teaching quality, facilities, and classroom dimensions, plays a critical role in determining student outcomes [5]. Within the context of international design and theoretical discourse, innovative spatial configurations are emerging. These are characterized by greater diversification and articulation of environments, as well as an emphasis on multifunctionality and the inclusion of furniture and spaces that are

manageable even by young children. Northern European countries, followed by Anglo-Saxon nations, have established some of the most forward-thinking guidelines in this domain. Countries such as Portugal (Parque Escolar), England (Building Schools for the Future), and the State of Victoria in Australia (Building the Education Revolution) have developed national plans specifically aimed at improving school infrastructure.

Despite these significant developments in the relationship between architecture and pedagogy at the international level, their impact on the quality of Italian school buildings remains limited, primarily due to insufficient investment in both new construction and the renovation of existing facilities. It has thus appeared necessary to contribute to the design of low-cost, easily constructible mobile equipment, capable of reclaiming educational spaces. This includes the introduction of innovative technologies such as parametric design and experimental applications of virtual and physical modeling. To enhance the quality of school environments, the working group aimed to develop criteria and prototypes for the creation of ephemeral architecture.

These are characterized by their small scale and child-friendly dimensions, environmental sustainability, and ease of assembly and disassembly. Such structures are envisioned as potential mediators between children and their surrounding spaces during various educational activities, especially those that benefit from rich and articulated spatial configurations, thus alleviating the monotony of the widespread "classroom-corridor" layout and facilitating the return to school following the post-pandemic reopening. If it is true that our bodies, and their emotional foundations, both conscious and preconscious shape the way we think and interact with the world, and that in our urban cultures this shaping typically occurs in architect-designed environments [7], then particular attention must be paid to the quality of the built environment, especially in educational contexts. Accordingly, the conceptual framework of school architecture must be restructured to reflect the evolving living conditions and emerging needs, enabling users to benefit from high-quality, flexibly organized spaces responsive to daily demands. Moreover, applying these theoretical insights in practice fosters the creation of inclusive, proactive, and harmonious environments, where collaboration shapes the activities occurring within these social spaces.

Microarchitectures, therefore, are neither purely architectural nor merely furniture, they represent a hybrid between the two scales. Despite their compact size and limited structural impact, these design elements can transform spaces into meaningful ways, defining new zones, creating pathways, and modulating light and acoustics. At the same time, they differ from traditional architecture in their greater flexibility, modularity, and ease of implementation, aligning more closely with the domain of furniture. These microarchitectures, modular, lightweight, combinable, and disassemble by the users themselves, were conceived to be fabricated from cardboard panels using exclusively dry-assembly techniques, including interlocking systems. They are proposed not only as effective tools for equipping school spaces but also, through self-building experience, as a means of introducing young students to the principles of circular economy within a fully integrated pedagogical framework [15]. The ongoing research draws from a range of multidisciplinary concepts, including the use of play as a tool to construct a social infrastructure for learning and the creation of environments that are more attentive to the spatial effectiveness as an educational medium [4]. In this regard, several studies, such as those by Moos (1979), Steele (1973), Weinstein et al. (2011), and Higgins et al. (2005), specifically examine the relationships between students and their physical environment. Moos's model emphasizes the crucial role of the environment in shaping the experiences of its users, asserting that "architecture and physical design can influence psychological states and social behaviors" (Moos, 1979). In alignment with this perspective, Steele (1973) and later Higgins et al. (2005) conducted in-depth analyses focused on the functional aspects of spatial design, particularly the impact of materials on well-being, and the quality of teaching and learning. Based on these insights, along with those of Weinstein et al. (2011), five key themes consistently emerge in research on educational environments: a sense of safety and shelter, pleasure, symbolic identification, instrumental task orientation, and social interaction.

However, according to Higgins et al. (2005), "cultural and geographical differences also highlight the importance of contextual sensitivity. For these reasons, it is very difficult to determine which areas are 'worthy' of attention." This observation underscores the complexity and relevance of the theoretical challenges faced by contemporary design. It is, therefore, essential to develop educational pathways that aim not only to transmit theoretical knowledge or practical skills, but which are rooted in two fundamental concepts: transversality and continuity.

2. Statement of the Problem and Study Aim

Architecture and education are deeply intertwined. The recent resurgence of constructivist, student-centered learning has generated renewed interest in flexible learning environments [14]. In particular, the construction of meaning and the expression of emotions through interaction with physical building materials is a key aspect in developing a new perspective on learning, one in which creativity emerges as a critical factor in reimagining school spaces. The importance of this aspect lies in the growing recognition of the inadequacy of the traditional classroom in the contemporary educational process, thereby highlighting the need for spaces that enhance children's relational capabilities [9]. Such spaces, using reconfigurable elements, enable flexible arrangements by aggregating or disaggregating components. This allows young users to become active participants in the creation of different spatial configurations, shaping the environment they encounter daily. Furthermore, this type of microarchitecture supports the formation of small working and discussion groups, facilitates the integration of all elements within the classroom, and enhances learning by making the school environment less monotonous and more stimulating. The social dimension of this activity lies in helping children regain a sense of belonging to the classroom and to the school itself. It also encourages attention to adjacent areas, reopening the public discourse on the relationship between school and city, both of which function as educational spaces where collective and environmental learning experiences take place [12].

This process of spatial adaptation and enhancement, through the act of building, leads to the formation of emotional and behavioral associations with the school institution and the urban context. It progressively and organically re-establishes students' interaction with their environment by restoring their spatial control over it. Indeed, the application of ephemeral architecture in educational settings generates lasting value in the collective memory of the intervention site and allows everyday users to become aware of the space and begin to perceive it as their own.

The use of space as a platform for enrichment represents an opportunity for cultural dissemination and promotion, social inclusion, and the development of user awareness. This design strategy challenges the notion of permanent architecture, traditionally conceived to fulfill a specific function with a defined purpose. Ephemeral architecture exists to reinvent a place and renew the relationships that users establish with it, thus transforming the perception of space and fostering a new way of seeing and interacting with the built environment. It has the power to create shifts in our collective memory in relation to a given place.

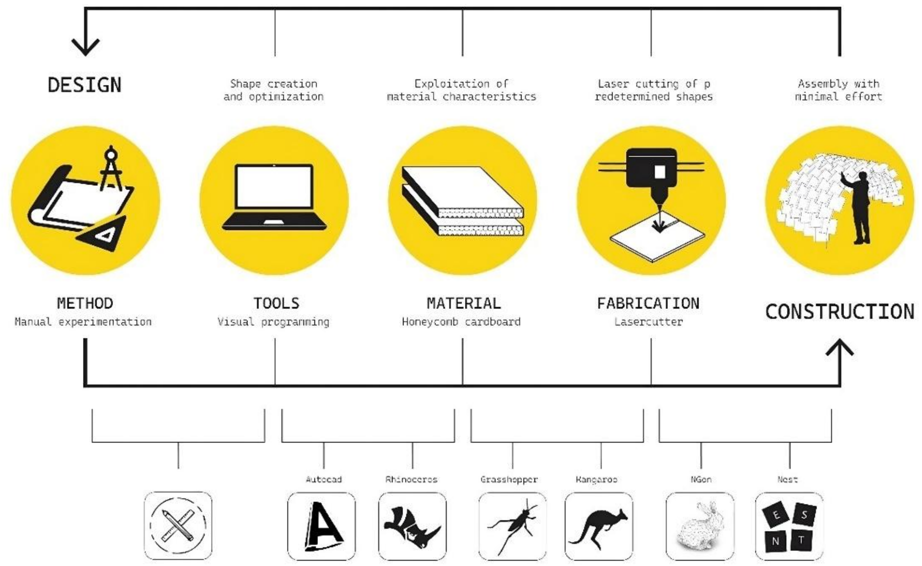
Within the framework of practical experimentation aimed at achieving these theoretical objectives, this study describes the work carried out by first-year students in the course Materials and Construction Element Design in collaboration with fifth-year students enrolled in the thesis studio Design and Construction, both part of the Master's Degree Program in Architecture at the Department of Architecture, University of Pescara. The students participated in an experimental learning activity based on the innovative use of digital design and fabrication techniques, alongside sustainable materials, for the design and construction of small pavilions. These pavilions were conceived with a social purpose: to support and enable cultural and social activities, particularly in response to the post-pandemic conditions previously outlined. Cardboard architecture, in this context, proposes that classrooms can host construction projects capable of temporarily transforming a portion of the space. These building zones offer opportunities for active and engaged participation; the open-ended nature of hands-on construction also promotes the development of learning autonomy [3].

3. Methodology and Work Steps

The experimental process was articulated through sequential phases, logically organized within a clearly defined educational framework, and punctuated by the interaction of various methodologies that provided mutual compensation and enrichment. Considering these considerations, it can be stated that the design process followed a circular model in which manual skills, through drawing and model-making, both initiated and concluded the workflow, accompanied by using digital tools that enhanced and complemented the empirical stages of the project (Fig. 1).

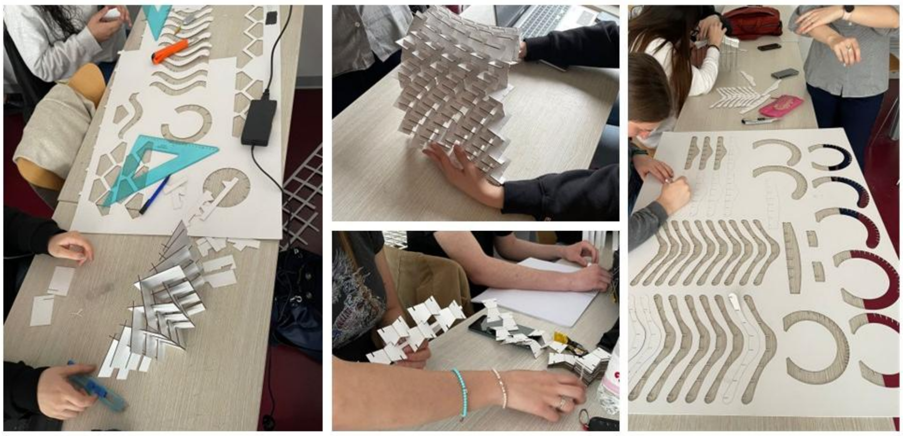
The starting point was an initial hands-on experimentation phase, allowing students to test different proposals related to the basic elements that would eventually comprise the final structure. The goal of this initial stage was to explore new forms through manual experimentation and traditional drawing tools, thereby encouraging the physical and tangible search for innovative architectural solutions, specifically, construction elements characterized by flexible and resilient modes of aggregation.

Fig. 1. Conceptual map of the project cycle



The construction process became a space for discussion, in-depth analysis, and student growth within this perspective, enabling the identification and stimulation of individual potential (Fig. 2). A cubic pavilion model was developed to serve as a central element for aggregation, socialization, and play, aligned with the theoretical implications previously discussed. The first version of the structure was entirely developed through empirical methods, primarily relying on manual work and experimentation. This led to the creation of several study prototypes before arriving at the final design, which was later built at a 1:1 scale using honeycomb cardboard panels. The design process began with the theoretical selection of the desired shape and dimensions of the final structure, in this case, a cube, and proceeded to the analysis of the base unit, the matrix of the entire pavilion. This also included the definition of the cuts necessary to enable dry assembly and the formation of the intended structure. Following these initial elaborations, it became necessary to utilize digital tools capable of providing a precise description of the object.

Fig. 2. Manual experimentation with pavilions



The transition from manual to digital phases marked a pivotal moment in which the empirically conceived architectural element was analyzed and validated using CAD software (AutoCAD). The original information was transferred to obtain an updated and finalized version of the design. Due to the organic nature of the process, the design of the forms could not be separated from the material selected for its construction: cardboard. This recyclable, eco-friendly, and lightweight material offers a high level of toughness and impact resistance, along with good thermal and acoustic insulation properties. Given these characteristics, cardboard proved to be the most suitable material for the final pavilion construction, as it is cost-effective, sustainable, and lightweight enough to be assembled and

disassembled quickly and safely by virtually anyone without the need for specialized tools. The focus lies in a material that necessitates a specific construction technique. The importance of this consideration is evident in the final definition of the structural components. After refining the characteristics of the base unit using digital control tools, it became essential to test an initial virtual assembly of the structure using 3D modeling software. This allowed for a spatial visualization of the internal rooms and the identification of potential functional or aesthetic criticalities.
This step was further complemented by a methodological deepening that involved parametric variations to the previously defined design using plug-ins such as Grasshopper, Kangaroo, and N-Gon. The aim was to support a simple, non-standard, and responsible development process fully aligned with the principles of the circular economy. In this context, the potential of digital tools for creating and optimizing structural elements was maximally exploited, making it possible to generate complex forms with relative ease. Once all previously outlined criteria were met, the process returned from software to materiality, with the physical realization of the conceived forms using laser-cutting techniques, first at a 1:10 scale (Fig. 3), and ultimately at full scale 1:1 (Fig. 4). Both the mechanical precision and the speed of production for the required components, which were ready for immediate use after cutting, represent key innovations of the proposed methodology. Moreover, by utilizing CNC machines, it was possible to maximize the number of pieces obtained from the cardboard sheets (via nesting), significantly reducing both error margins and material waste.

Fig. 3. Pavilion first real model

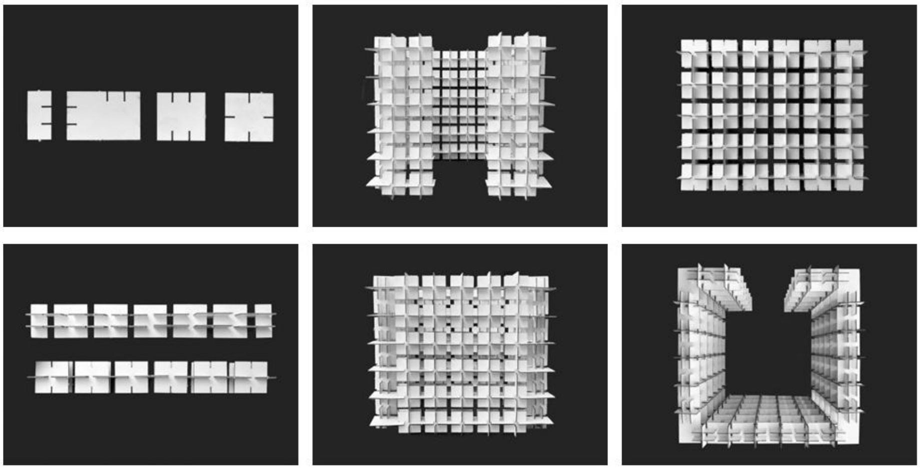


Fig. 4. Assembly of the cubic pavilion in the university halls

Indeed, the design process recognizes that digital technologies are now involved in most activities within the manufacturing sector, which is moving toward a new industrial paradigm, one focused on

implementing innovation and testing its scalability. In the context of academic research, this evolution aligns with the principles of Industry 4.0, where production processes are highly digitized, and technology becomes an "enabler," making it possible to automate most mechanized operations. This allows for numerous benefits across the supply chain, including improved product quality, process efficiency, and resource optimization.
In this regard, the introduction of digital technology into the construction materials sector could lead to significantly more efficient execution of operations, both in terms of time and accuracy, which were previously reliant on manual labor. This new form of organization could reduce the rate of errors and imperfections in the finished product, thus minimizing the dispersion of resources and limiting material waste. If the phases described above have been properly carried out, the physical construction of the pavilion prototype can be completed simply by assembling the individual components. This final stage of the project serves a dual purpose: on one hand, it enables students to experience the project through hands-on assembly; on the other, the proposed method allows for the identification, during fabrication, of any residual flaws or untapped potential inherent in the structure's real-world expression.
As emphasized from the outset, the key concepts underpinning this type of design are temporariness, interconnection, and cyclicality. In the concluding act of the process, the flexibility of human thought enables a dynamic exploitation of the structural potential of cardboard, one that is organic, complex, and context-specific, while remaining connected to the original paper-based design conceived in the early conceptual phase. In this way, it also becomes possible to enhance the final product by returning, in a sort of design ring composition, to the initial experimentation phase to revise and reproduce it.

4. Results and Conclusions

A The approach adopted in the educational experimentation on the technological design of microarchitectures for school spaces, essentially based on a learning by doing methodology, can be summarized through several key aspects: social objectives were clearly defined; collaborative design work was encouraged between first-year and final-year students; seminars and lectures on construction techniques closely related to project development were planned; the alternation between virtual and physical modeling was established as part of the form-generating process; and the 1:1 scale construction of the microarchitecture was organized and funded, involving all participating students in the final building phase. This comprehensive methodology led to the full engagement of the students, who took on responsibility for the construction of their own knowledge and skills, perceived not as abstract or future-oriented, but as immediately useful tools for affecting real-world change. The final prototype selected for 1:1 realization was a small cubic pavilion measuring three meters per side, which was publicly exhibited for the first time during the 2024 Researchers' Night at the Chieti Campus of the University of 'G. D'Annunzio' (Fig. 5).

Fig. 5. Pavilion presentation at Researchers' Night 2024 at UNICH

When designing, we consider and analyze the many interactions between human beings and their surrounding environment, be it buildings, installations, objects of interest, or natural elements.

According to the definition of ephemeral architecture, temporary constructions can significantly alter users' perceptions of space, particularly those of children, and can foster positive changes in how the space is experienced and inhabited. Specifically, through the principles of prototyping as a method for both design and material development, an ephemeral pavilion was conceived that, building on the studies previously described, evolved and was refined over time. This process culminated in the creation of a fully functional microarchitecture that effectively met the intended objectives set by the working group. In this regard, it is essential to actively engage the intended users throughout the entire design and construction process. This allows for the creation of a participatory project in which all aspects related to the correct use and positive perception of the built environment, especially by younger users, are carefully considered. Co-design with users represents a form of collective creativity applied across the entire design process [10]. Considering this, we can assert that temporary installations placed within educational environments not only serve to reactivate those spaces, but also open new possibilities for use, exploration, and play. This capacity for dynamic response, especially those of a positive nature coming from users, enables space to be perceived as a refuge, a place to be freely inhabited.
Through this experience of study and in-depth exploration, we understand the need to regard the approach of ephemeral architecture as an opportunity for educational experimentation and research. By thinking of architecture in these terms, we equip students with dynamic tools for understanding and analysis that, in addition to fostering an academic comprehension of the creative act behind the architectural object, allow them to analyze, understand, and inhabit space in a more profound and experiential way.

REFERENCES

[1] Arduini, G. (2020), "La didattica esperienziale come strategia inclusiva", in Italian Journal of Special Education for Inclusion, vol. 8, pp. 1-31.
[2] Colao, A., Piscitelli, P., Pulimeno, M., Colazzo, S., Miani, A., & Giannini, S. (2020), "Rethinking the role of the school after COVID-19", The Lancet Public Health, 5, 361-413.
[3] Deed, C., Edwards, D., Morse, M., & Townsend, R. (2018), "Translational Participation: Conceptualising and evaluating innovative learning environments", School Space and its Occupation, vol. 10, pp. 171-185.
[4] Golinkoff, D. G. S. R. M., & Hirsh-Pasek, K. (2006), "Play=learning: How play motivates and enhances children's cognitive and social-emotional growth", Oxford University Press.
[5] Higgins, St., Hall, E., Wall, K., Woolner, P. & McCaughey, C. (2005), "The Impact of School Environments: A literature review", The Centre for Learning and Teaching-School Education, Communication and Language Science. University of Newcastle.
[6] Lee, H.C., Park, S.J. (2018), "Assessment of importance and characteristics of biophilic design patterns in a children's library", Sustainability, 10, 987.
[7] Mallgrave, H. F. (2015), "Empatia degli spazi–Architettura e neuroscienze", Raffaello Cortina Editore.
[8] Moos, R. H. (1979), "Evaluating Educational Environments: Procedures, Measures, Findings and Policy Implications", Jossey-Bass Inc Pub.
[9] Palincsar, A. S. (1998), "Social constructivist perspectives on teaching and learning", Annual Review of Psychology, 49, 345-375.
[10] Sanders, E., Stappers, P. (2008), "Co-creation and the new landscapes of design", CoDesign, 4, 5-18.
[11] Steele, F. I. (1973), "Physical settings and organization development", Addison-Wesley.
[12] Tranter, P. J., & Malone, K. (2004), "Geographies of environmental learning: An exploration of children's use of school grounds", Children's Geographies, 2, 131-155.
[13] Weinstein, C. S., Romano Mignano, A. J. (2011), "Elementary classroom management. Lessons from research and practice", McGraw-Hill.
[14] Woodman, K. (2016), "Re-placing Flexibility", The translational design of School, vol. 1, pp. 51-79.
[15] Yates, A., Pedersen Zari, M., Bloomfield, S., Burgess, A., Walker, C., Waghorn, K., Besen, P., Sargent, N., Palmer, F. A. (2023), "Transformative Architectural Pedagogy and Tool for a Time of Converging Crises", Urban Science, 7(1), 1-20.