ADVANCES IN BUILDING EDUCATION
INNOVACIÓN EDUCATIVA EN EDIFICACIÓN

Participatory Learning through "participation, action, research" (PAR) for the design of bioclimatic solar protection prototypes for the PUCEM campus

Aprendizaje participativo a través de la "investigación, acción, participación" (IAP), para el diseno de prototipos bioclimáticos de protección solar para el campus PUCEM

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TITULARES

- La IAP mejora la comprensión y participación en diseño bioclimático sostenible.
- Construir prototipos fortalece el aprendizaje práctico de conceptos teóricos.
- El trabajo colaborativo impulsa la reflexión crítica y soluciones arquitectónicas

HIGHLIGHTS

- IAP enhances understanding and participation in sustainable bioclimatic design.
- Building prototypes strengthens the practical learning of theoretical concepts.
- Collaborative work fosters critical reflection and architectural solutions

RESUMEN

Este estudio exploró la efectividad de la metodología Investigación-Acción-Participación (IAP) en la asignatura de bioclimática en la carrera de Arquitectura de la Pontificia Universidad Católica del Ecuador, sede Manabí. El objetivo principal fue analizar cómo la IAP, a través de la construcción de un prototipo de protección solar, influye en la participación, comprensión y aprendizaje de los estudiantes. Los resultados de una encuesta aplicada a 13 estudiantes demostraron una valoración destacada de la IAP en cuanto a la promoción de la participación y comprensión conceptual, con una amplia mayoría los estudiantes manifestarón estar de acuerdo o totalmente de acuerdo con estos aspectos. En cuanto a la construcción del prototipo, los estudiantes coincidieron en que esta experiencia fue significativa para el aprendizaje, destacando su relación con los conceptos teóricos impartidos en clase. En conclusión, la IAP se presenta como una valiosa estrategia pedagógica para la enseñanza de bioclimática, especialmente al permitir la integración entre la teoría y la práctica. No obstante, se identificaron áreas de mejora, particularmente en la gestión del trabajo colaborativo y en la retroalimentación, lo que abre espacio para futuras investigaciones y ajustes en su implementación.

Palabras clave: IAP, *Investigación, bioclimática, arquitectura, aprendizaje, prototipo*

ABSTRACT

This study explored the effectiveness of the Participatory Action Research (PAR) methodology in the Bioclimatic Design course within the Architecture program at the Pontifical Catholic University of Ecuador, Manabí campus. The primary objective was to analyze how the PAR approach—through the construction of a solar protection prototype—enhances student engagement, conceptual understanding, and overall learning outcomes. Findings from a survey conducted with 13 students revealed a strong appreciation for the PAR methodology, particularly in its capacity to foster active participation and deepen conceptual comprehension. A significant majority of students expressed agreement or strong agreement regarding these positive impacts. Regarding the prototype construction, students consistently identified the experience as meaningful, emphasizing its relevance to and reinforcement of theoretical concepts addressed in class. In conclusion, PAR emerges as a valuable pedagogical strategy for teaching bioclimatic design, especially by bridging the gap between theoretical knowledge and practical application. However, areas for improvement were identified—particularly in collaborative work management and the provision of timely feedback—which suggest promising avenues for further research and refinement of the methodology's implementation.

Keywords: *Participatory Action Research, bioclimatics, architecture, learning, prototype.*

1. INTRODUCTION

The Architecture program at the Pontificia Universidad Católica del Ecuador, Manabí (PUCEM), integrates approaches that combine sustainability, technology, and construction into its academic training, aiming to foster meaningful learning. Within this framework, the *Bioclimatic Design* course, offered in the eighth semester, serves as a key platform for applying sustainable design principles. Through the unit on solar shading design, the fundamental relationship between architecture and climate is addressed, encouraging an environmentally conscious design perspective.

This educational experience is further enriched by incorporating the Action Research Participation (IAP) methodology, which promotes a reflective, collaborative, and transformative learning process in which students become active agents in their own education. Through the development of a physical prototype, students are provided with an opportunity to cultivate sustainable design competencies by effectively bridging theory and practice in a real-world context. This pedagogical approach enables the exploration of how ARP strengthens the achievement of learning outcomes related to bioclimatic design.

Institutional Context

The Pontificia Universidad Católica del Ecuador, Manabí campus (PUCEM), is a private higher education institution located on the Ecuadorian coast, specifically in the city of Portoviejo, in the province of Manabí [14]. The Architecture program was established in 2019, with a vision centered on fostering learning capacities through academic and research-oriented processes aimed at the comprehensive education of future professionals.

Within the program's academic curriculum, the courses known as *Itineraries*, which belong to the technology, sustainability, and construction track, offer an educational perspective focused on environmental awareness and learning. This approach enables courses such as *Bioclimatic Design* to be effectively integrated into the academic training process. Offered in the eighth semester, this curricular component constitutes a fundamental part of the program's professional specialization phase.

The course is guided by an analytical syllabus, which identifies as one of its key learning outcomes: *"to apply bioclimatic criteria related to the project site in order to seek sustainable construction solutions"* [13]. Adopting a theoretical-practical learning approach, the syllabus serves as a foundational tool in the teaching-learning process and constitutes an essential part of the planning undertaken prior to the 2024-2 academic term. This document outlines the structure of the course through a series of units that define its core content, with particular emphasis on Unit Two: *"Design Principles"*. This unit addresses critical topics such as solar radiation, orientation, solar geometry, and shadow calculation in the context of solar shading design.

Theoretical Framework

Within the teaching-learning process established by the program, the integration of such components fosters the development of design-related skills and projective thinking based on the constraints of building in response to climatic conditions [1]. This approach facilitates the connection with bioclimatic design methodology, serving as a bridge toward designing and constructing in harmony with the local environment. As noted in [9], *"it is developed in relation to architecture, under climatic constraints and the capacities of the* *natural environment and its various forms of utilization, which imply specific solutions"* (p. 362).

The term *bioclimatic* has been used since the earliest known efforts in environmental conditioning, dating back to ancient Egyptian civilization around 3000 BCE [2]. Over time, several key milestones have marked its evolution, including the 4th CIAM Congress (Athens Charter) in 1933, which *"highlighted the need for a shift away from an unsustainable path"* [11] (p. 11).

Among the most notable pioneers are Hungarian architect Victor Olgyay, author of *Design with Climate: Bioclimatic Approach to Architectural Regionalism*, and Israeli architect Baruch Givoni, who published the *Building Bioclimatic Chart* in 1969 [11].

The energy crisis of the 1970s marked a historical turning point, fostering the reemergence of architects such as Glenn Murcutt and Brenda Vale, the latter of whom published *The Autonomous House* in 1975, driving significant advancements in this area. A key milestone followed in 1980 with the initiation of the Passivhaus standard. Despite the decades that have passed, the refinement and innovation in the application of tools and methodologies for bioclimatic design continue to evolve. This ongoing development is of vital importance in the training of future architects, who represent a generation increasingly attuned to environmental issues.

Given the breadth and depth of knowledge encompassed within bioclimatic design, there is a growing emphasis on incorporating an Participation Action Research (PAR) approach within the teaching-learning processes of higher education.

According to [10], as cited by [8], action research (AR) is *"a circular process of inquiry and analysis of reality, which, starting from practical problems and from the perspective of those who experience them, leads to reflection and action on the problematic situation with the aim of improving it. Those affected by the problem are involved in the process and become authors of the research"* (p. 59).

Action Research Participation (ARP) is distinguished by its participatory and democratic nature, as well as by its simultaneous contribution to both knowledge generation and practical application. Numerous scholars recognize Kurt Lewin (1890–1947) as the pioneer of this research approach [8]. It is important to highlight that Action Research (AR) possesses specific characteristics that define and distinguish it, contributing to education in three fundamental domains:

1. Aspects related to action
2. Aspects related to research
3. Aspects related to change (Carr & Kemmis, 1988)

According to [10], Participation Action Research (PAR) can be understood as a systematic process involving the analysis of the situation, identification of problems, and the development of planned action strategies, which are subsequently implemented and systematically subjected to observation, reflection, and modification.

Characteristics of Participatory Action Research (PAR)
Action

1. **Integration of Theory and Practice**: Participatory Action Research integrates theory and practice within a shared framework. In the educational context,

incorporating PAR into teaching practice involves merging research and pedagogy into a continuous process of theory–practice interaction (p. 59) [10]

2. **Focus on Practical Problems**: PAR begins with everyday situations and develops as a process aimed at resolving them, actively engaging the individuals involved in the context (p. 59) [10].

Research

1. **Broad and Flexible Research Approach**: This type of research is defined by the process itself, allowing for the integration of diverse sources and perspectives. The methodological design is developed progressively as the research unfolds.

Change

1. **Collaborative Dimension**: This involves active engagement and ownership of the various contexts by those involved, with the aim of achieving the proposed objectives. This process unfolds as the research group commits to a transformative task within the reality they inhabit. According to Moroni & Curtino (2005, p. 59) and Martínez & Marroquín (2022), PAR is fundamentally a collective endeavor in which participants shift from being subjects of study to becoming agents of their own transformation.

Pedagogical Application

Participatory Action Research (PAR) serves as a fundamental framework for learning through the systematization, reflection, and reconstruction of educational practice. By employing techniques that foster strategic planning and problem-solving, PAR creates spaces for understanding, critical reflection, analysis of diverse perspectives, and joint planning to develop projects grounded in collective consensus [8]. This approach requires a meaningful alignment with the content addressed in Unit 2 of the analytical syllabus for the Bioclimatic Design component.

Within this context, the following question arises: *¿How can students, through the development of a solar protection prototype, engage in a learning process grounded in PAR that enables them to achieve the intended learning outcome?*

To address this question, the activity must be structured around a methodological process consisting of four consecutive and interactive phases based on PAR: **Action – Research – Practice – Evaluation**.

2. MATERIALS AND METHODS

The implemented methodology consists of four consecutive and interactive phases, applying Participatory Action Research (PAR) in an integrated manner throughout the teaching–learning process, alongside the materials and resources used for its development.

2.1 First stage

Action: This phase is structured around two complementary dimensions: theoretical and praxis. The theoretical dimension encompasses curriculum planning and academic content, while the practical dimension focuses on the design and construction of the prototype.

Theory: theotryical foundation

a) Planning: According to the syllabus document, whose purpose is to optimize the organization and structuring of content throughout the 2024-2 academic term, this instrument establishes the expected learning outcomes: *"applies bioclimatic analysis of the project site to seek sustainable construction solutions appropriate to the context"* [13]. This approach aims to systematically develop the competencies outlined in the academic curriculum.

b) Contents: The learning process was based on the flipped classroom methodology, focusing on two particularly relevant topics: solar geometry and shadow projection. Through various bibliographic sources and practical exercises conducted in class, understanding and comprehension were facilitated from theoretical, graphical, analytical, design, and constructive perspectives, all integrated within the bioclimatic approach (Figs. 1, 2, 3).

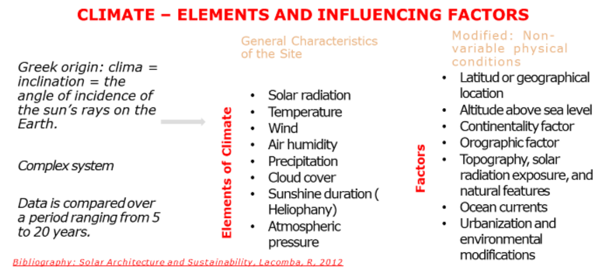

***Fig. 1**: Introduction to Climate Concepts*
Note. (Lacomba et al., 2012)

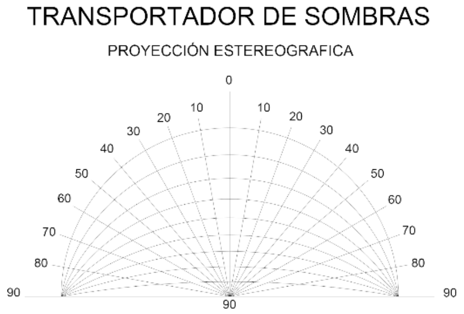

***Fig. 2:** Shadow Protractor*
Note. Extracted as an Exercise. (Porras, 2022)

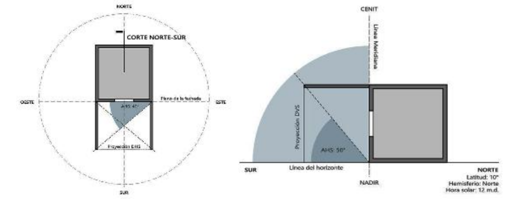

***Fig. 3:** Horizontal and Vertical Shading Devices*
Note. Extracted as an exercise ((Porras, 2022)

c) Praxis: The problem is identified, and the guidelines (Fig. 4), constraints, and planning for the prototype design are established. This phase is structured into different stages, each with specific objectives and scope.

a) Design of a full-scale bioclimatic solar protection prototype**,** corresponding to the previously identified space, with multimedia documentation recording the entire development process.

b) Detailed development of the components, including: **D:** Architectural design (roof–structure); **C:** Construction (construction system, material selection, construction planning, integrated management of design, construction, and delivery, budget analysis); **U:** Use (implementation of horizontal solar protection) Table 1.

Transversally, the identified problem is defined as follows: At PUCEM, the student rest areas lack adequate solar shading for their benches, resulting in significant discomfort due to direct exposure to solar radiation and markedly reducing the usability of these spaces. This situation highlights a clear deficiency in the planning and design of outdoor rest areas.

***Fig. 4**: Identification of the Space for the prototypes*

2.2 Second stage

Research: Grounded in a broad and flexible investigative process, a comprehensive analysis is conducted of the natural environment constraints "implementation site" (Figs. 5, 6, 7), encompassing both architectural design and an appropriate construction system, with the rigorous application of bioclimatic principles. This methodological process is complemented by a transversal and progressive review of relevant projects, enabling the conceptual enrichment of the proposal and the incorporation of solutions validated in similar contexts.

2.3 Third stage

Change: This collaborative and participatory process focuses on the effective appropriation of the applied settings within the PUCEM campus, aiming for the meaningful transformation of communal spaces, specifically in the sports areas. The development is initially organized into three working groups, each consisting of 4–5 members.

***Fig. 5:** Model of Prototype 1*

The initial prototype is based on the previously established guidelines and constraints. This phase includes the identification of potential challenges in the prototype's execution by each working group, taking into account that the students...

They implement the practical component in accordance with the phases and objectives outlined in the syllabus document that was shared. During this stage, representation techniques such as sketches and conceptual models are applied (Figs. 8, 9,10).

a) **Assertion:** Regarding the theoretical foundation, the researched

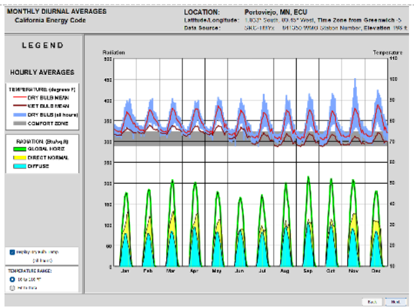

***Fig.6**: Monthly diurnal averages 2021-2023*
Nota.(Climated Consultant, 2025)

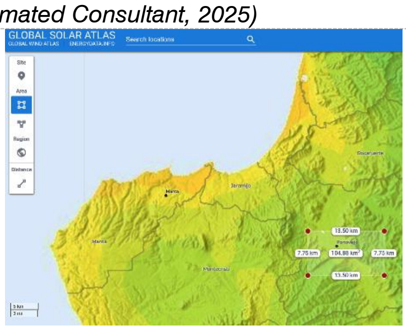

***Fig.7**: Global solar atlas*
Nota. (Energydato.info, 2025). Validación y contraste de información

***Fig. 8:** Shadowmaps*
Nota.(Shadowmap, 2025) Validación y contraste de información

information is reaffirmed, leading to a reanalysis and readjustment for the development of a new prototype. However, by unanimous decision, the materials in the best condition are recycled until the final prototype is achieved. The prototype from Group 1 is selected as the basis for a unified design for the entire course, grounded in the comprehensive analysis of points 1) Action and 2) Research.

b) **Final Prototype:** A new collective prototype is constructed as a result of the analysis, interpretation, and holistic understanding of the process. The challenges encountered provided valuable learning opportunities for the students, significantly contributing to the improvement of the proposal and culminating in the bioclimatic solar protection prototype that effectively meets the established requirements.

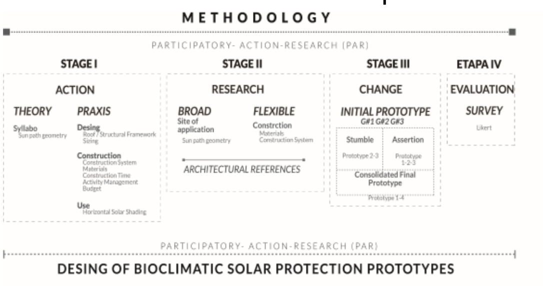

__Fig. 9:__ Methodology Employed by the Authors

__Fig.10:__ Research and Design of Prototype 3

3. RESULTS AND DISCUSSION

Given the existence of a consecutive and interactive methodology in Participatory Action Research (PAR), the obtained results are explained.

The final prototypes were developed considering an initial prototype that from the outset met the established guidelines. Conversely, prototypes 2 and 3 encountered some setbacks, representing a critical moment for the students, as they had to return to Stages I and II. This process prompted reflection, analysis, and a retrospective evaluation of their initial work.

As prototypes 2 and 3 did not meet satisfactory standards, an assessment was conducted based on the students' deliverables. The instructor evaluated Stages I, II, and III up to the assertion phase using a rubric, applying the grading scale presented in Table 1:

5:Outstanding
4:Satisfactory
3:Partially meets expectations
2:Deficient
1:Insufficient

__Table 1:__ Instructor's Assessment Based on the Deliverables

PRACTICE ITEMS ASSESSMENT	PROTOTYPE 1	PROTOTYPE 2	PROTOTYPE 3
D: ROOF (CORRECT RESOLUTION)	5	1	2
D: STRUCTURE (CORRECT AND DIMENSIONED)	5	2	2
C: CONSTRUCTION SYSTEM	5	1	1
C: MATERIALS	5	1	1
C: CONSTRUCTION PLANNING	5	1	1
C: MANAGEMENT IN DESIGN, CONSTRUCTION, DELIVERY	4	2	2
C: BUDGET	5	2	1

U: HORIZONTAL SOLAR PROTECTION	**5**	2	2

In collaboration with the instructor and the students from the first prototype, who initially met the requirements satisfactorily, a participatory feedback process was developed. This process included reviews, reinterpretations of the experiences, and reflections on the lessons learned. As a result, collective agreements and consensus were reached within the working groups.

These groups focused on classifying, reusing, and incorporating new ideas for the design, materials, and construction of the new Prototype 4, based on the insights gained from the previous prototypes.

Prototype 4 was developed following the same Participatory Action Research (PAR) methodology and was divided into several stages:

First stage

Action:

a. **Planning:** The planning was adjusted to new deadlines established by the instructor, as many groups were consolidated. Consequently, a team of ten individuals was formed, with assigned roles in areas such as design, construction, final finishes, and budgeting. The group that had worked on the previous prototype acted as supervisors and provided support on the construction site.

b. Praxis: Ideas from all groups were gathered and organized through classification, synthesis, and elimination of unnecessary elements. This stage involved a thorough reformulation of prototypes 2 and 3.

Second stage

Research: The information was expanded by seeking reference examples to better understand and clarify the concept of solar shading in architecture. Additionally, the construction system of Prototype 1 was improved, particularly regarding joints and materials.

Third stage

Change: Through the appropriation of the consolidated design, an improved proposal was generated based on the previous stages. The outcome was a summary sheet aimed at fostering greater ownership of the sports spaces.

Fourth stage

Evaluation: Questions were administered using a Likert scale format alongside direct yes/maybe/no responses. The survey consisted of 11 questions, distributed across Likert scale categories and closed-ended questions. The sample included 15 students; however, due to the finite population size, the minimum number considered was 10. Ultimately, 13 participants took part in the study, from whom the results and corresponding quantitative analysis were obtained.

Question 1. Participation and Understanding
A large majority (69.23%) agreed that Participatory Action Research (PAR) helped them participate more actively and better understand the concepts, while 23.08% strongly affirmed this. Only one participant remained neutral. This suggests that the methodology had a significant impact on students' engagement and comprehension (Fig. 11).

Question 2. Willingness to Repeat the Experience

76.92% expressed willingness to participate in another activity based on Participatory Action Research (PAR), while 23.08% responded "maybe." No participants showed reluctance, indicating a generally favorable reception (Fig. 12).

Question 3. Sense of Belonging
92.31% affirmed that this methodology fosters greater participation and a stronger sense of belonging. Only one participant expressed doubts. This reflects a strong emotional and academic connection to the process (Fig. 12).

Question 4. Impact on Design and Construction
An overwhelming majority (84.62%) considered that Participatory Action Research (PAR) was key in making critical decisions in design and construction. Only one student completely disagreed, suggesting an isolated and distinct experience (Fig. 11).

Question 5. Meaningful Learning
61.54% acknowledged that building the prototype helped them learn better than through theory alone. The practical work was highly valued for its ability to reinforce learning (Fig. 11).
Question 6. Real-World Problem Solving
Similarly, 84.62% felt that working as a team helped them tackle real-world architectural challenges. However, a small group did not share this view, indicating a diversity of experiences (Fig. 11).

Question 7. Feedback
This was one of the most divided points. Only 61.54% considered the feedback received to be useful, while 23.07% found it either unhelpful or were indifferent. This highlights a clear area for improvement in the methodological implementation (Fig. 11).

Question 8. Learning from Mistakes
92.31% positively valued learning through errors and difficulties, demonstrating a resilient and open attitude. Only one participant expressed doubt (Fig. 12).

Question 9. Teamwork Climate
69.23% stated that teamwork fostered a positive environment. However, 23.08% were indifferent and 7.69% disagreed, indicating that not everyone experienced the collaboration in the same way (Fig. 11).

Question 10. Teacher Support
84.62% emphasized the key role of the teacher in the process. Nevertheless, 15.38% were indifferent, suggesting that the support was not equally perceived or relevant to all participants (Fig. 11).

Question 11. Application of PAR in Other Subjects
Finally, 76.92% expressed interest in applying Participatory Action Research (PAR) in other courses. The remainder showed an open attitude but with reservations, possibly due to the nature of other subjects or workload considerations (Fig. 12).

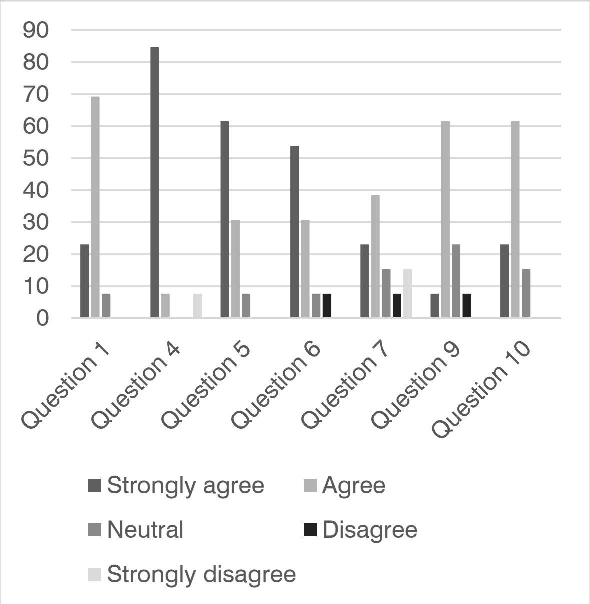

Fig.11: *Results on the Likert Scale*

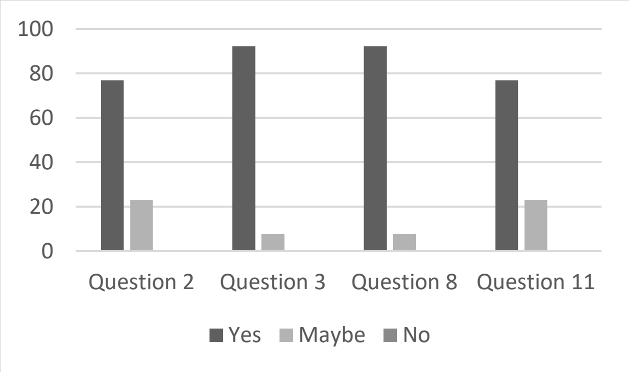

Fig. 12: *Results of Closed-Ended Questions*

4. CONCLUSIONES

Based on the implementation of the Participatory Action Research (PAR) methodology as a pedagogical approach for teaching bioclimatic design principles, the survey results demonstrate a positive correlation between the application of this methodology and students' perception of increased participation and comprehension of theoretical concepts.

This evidence suggests that PAR, with its emphasis on action, reflection, and collaboration, constitutes an effective pedagogical model for the internalization of complex sustainable design principles in architectural education. Future research could further explore the specific mechanisms through which PAR facilitates this learning process compared to more traditional teaching methods, analyzing variables such as long-term knowledge retention and the ability to apply these principles in diverse project contexts.

Experiential learning through prototype construction emerges as a key factor for meaningful learning in bioclimatics. The pronounced preference among students for learning through prototype building, as opposed to purely theoretical activities, highlights the value of experiential learning within the field of bioclimatic design.

This conclusion reinforces the theory of active learning and suggests that the materialization of abstract concepts through physical construction fosters a deeper and more significant understanding. Future research could focus on quantifying the impact of these practical activities on the development of sustainable design competencies by comparing learning outcomes and problem-solving skills between students exposed to prototype-based methodologies and those trained predominantly through theoretical approaches.

The dynamics of collaborative work and feedback processes are identified as critical areas for optimizing the Participatory Action Research (PAR) methodology. While the collaborative process was largely valued and feedback was seen as potentially instrumental, the varied perceptions among students in these areas highlight crucial aspects for improving PAR implementation.

Future research could delve deeper into the dynamics of workgroups in projects based on this methodology, identifying factors that contribute to effective collaboration and the development of a reciprocal learning environment.

Likewise, a detailed study on the feedback strategies employed and their impact on learning could inform the development of more effective and consistent feedback models within the Participatory Action Research (PAR) methodology, specifically in the context of architectural education.

The students' expressed interest in expanding the application of Participatory Action Research (PAR) stands as an indicator of its potential for facilitating learning transfer and enhancing motivation within architectural education. The participants' desire to engage with this methodology in other courses suggests that they perceive its benefits beyond the specific context of bioclimatics.

This finding highlights PAR's potential as a pedagogical approach that motivates students and fosters the transfer of skills and knowledge across different areas of the architecture curriculum. Future research could investigate the effectiveness of PAR across various courses within the program, examining how it adapts to diverse content and learning outcomes, as well as its impact on students' overall motivation and engagement with their professional training.

Therefore, these conclusions not only fulfill the general objective set forth in the study and synthesize the results obtained through the implementation of Participatory Action Research (PAR) in the Bioclimatics course, but also point toward promising avenues for future research. Such investigations could deepen the understanding of the effectiveness of this methodology and its transformative potential in architectural education and related disciplines.

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