International Journal of Science and Research Archive
eISSN: 2582-8185
Cross Ref DOI: 10.30574/ijsra
Journal homepage: https://ijsra.net/

(RESEARCH ARTICLE)

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Project-based learning methodology: Impact on self-management of learning in pharmaceutical services students in Villa Clara, Cuba

Zaita FY [1], del Valle LD [2], Iznaga ZA [1], Vara MEJ [1], Vogt PR [3], Alemán FE [4] and Fimia DR [1,*]

[1] *Departments of Technical Specialties and Hygiene and Epidemiology, Faculty of Health Technology and Nursing (FHTN), University of Medical Sciences of Villa Clara (UMS-VC), Cuba.*
[2] *Department of Parasitology. Regional High Specialty Hospital (HARE), Dr. Juan Graham Casasús, México.*
[3] *Chairman of the Board of Directors of EurAsia Heart Foundation, Zurich, Switzerland.*
[4] *Department of Pharmaceutical Services, Municipal Direction of Pharmacies and Opticians. Santa Clara, Villa Clara, Cuba.*

International Journal of Science and Research Archive, 2026, 18(03), 1466-1481

Publication history: Received on 20 February 2026; revised on 28 March 2026; accepted on 30 March 2026

Article DOI: https://doi.org/10.30574/ijsra.2026.18.3.0634

Abstract

The objective of this research was to evaluate the Problem-Based Learning (PBL) methodology for the Pharmaceutical Services I course and its impact on self-directed learning, through triangulated validation with students in the Short-Cycle Higher Education Program in Pharmaceutical Services at the Faculty of Health Technology and Nursing (FTSE), University of Medical Sciences of Villa Clara (UCM-VC), Cuba. The research was conducted at this faculty and covered the 2025-2026 academic year. The evaluation of the PBL methodology was carried out in two complementary phases. In the first phase, the expert judgment method was applied, based on consultations with seven highly competent professionals. In the second phase, a pre-experimental pretest-posttest design was implemented with a single group, consisting of all first-year students (n=8). Expert evaluation strongly endorsed the developed PBL methodology, which also represents a modern, contextualized, and effective pedagogical tool for developing students' self-directed learning, motivation, and required competencies. The five dimensions analyzed showed remarkable improvement from the pre-test to the post-test. All eight students increased their total score, as well as their post-test grade, achieving higher scores at the end. It is concluded that the evaluated PBL methodology demonstrated a positive and significant evolution in students' perceptions across all dimensions, where they not only improved their self-perception but also developed strategies for facing collaborative challenges.

Keywords: Project-Based Learning; self-directed learning; pedagogical methodology; Pharmaceutical Services

1. Introduction

The paradigm of pharmaceutical practice has undergone a profound and accelerated transformation in recent decades (Da Costa and Goicochea, 2023; Zaita *et al*., 2024; Zaita *et al*., 2025). The traditional model, focused almost exclusively on the dispensing and management of medications, has given way to a new scenario, where the pharmacist stands as a healthcare professional, a manager of medication-related risks, and a leading health promoter and educator (Zaita *et al*., 2024). This change responds to the growing demands of the Cuban healthcare system, which require optimizing resources, improving patient safety, and addressing the challenge of chronic conditions and polypharmacy (Zaita *et al*., 2018a; Zaita *et al*., 2018b; Zaita *et al*., 2025).

However, there is a worrying discrepancy between these demands from the professional world and the predominant teaching methods in pharmacy services training, which often remain largely anchored in a one-way knowledge transmission methodology (PAHO, 2017; Zaita *et al*., 2018b), where the student adopts a passive role, dedicated to

* Corresponding author: Fimia DR

memorizing fragmented content in stagnant subjects (Solórzano, 2017; Leiva and Lariot, 2019; Pérez *et al*., 2024). While this knowledge base is indispensable, it is insufficient to prepare future pharmacists to solve the unpredictable and multidimensional problems that characterize real-world practice (Fernández, 2017; Estrada *et al*., 2018; Azpilicueta, 2020).

This disconnect creates a skills gap (Solórzano, 2017; Valiente *et al*., 2020; Leyva, 2024), which becomes evident when recent graduates enter the job market. They are often overwhelmed by the need to quickly integrate knowledge, make autonomous clinical decisions, and manage complex interpersonal relationships, for which their academic training has not always optimally prepared them (Chavez, 2014; Leiva and Lariot, 2019; Valiente *et al*., 2020). This situation not only impacts the professional's confidence and performance but can also compromise the quality of patient care and the safety of health outcomes (PAHO, 2017; de la Puente *et al*., 2020; Zaita *et al*., 2024).

In the field of education, specifically in the higher education of Pharmaceutical Services Technicians, there is a growing demand for professionals who not only possess technical knowledge but are also autonomous learners, capable of constantly updating their skills in a regulated and rapidly evolving field (PAHO, 2017; Zaita *et al*., 2018a; Zaita *et al*., 2018b). Training institutions, including the University of Medical Sciences of Villa Clara, with its Faculty of Nursing and Health Technology, face the challenge of transforming traditional pedagogical practices, centered on the transmission of knowledge, towards active methodologies aimed at collaborative learning that develops the ability to learn how to learn (Zaita *et al*., 2018a; Zaita *et al*., 2018b; Zaita *et al*., 2025).

At the graduate profile level: learning autonomy skills appear declared (Zaita *et al*., 2018a; Zaita *et al*., 2018b), but in evaluation and teaching practice methods that do not systematically promote them predominate.

Preliminary observations and internal diagnoses of the study programs for the integrative subject Pharmaceutical Services I (Zaita *et al*., 2018a; Zaita *et al*., 2018b; Zaita *et al*., 2025) suggest a significant dependence on the instructor for work organization, information retrieval, and progress assessment (Zaita *et al*., 2024; Zaita *et al*., 2025). Students often show difficulties in planning complex projects or self-regulating their learning in unstructured environments.

Furthermore, according to available resources and current trends, the University has limited access to cloud-based educational platforms (such as Google or Moodle). Their frequent use is restricted to distributing materials and receiving assignments, without fully exploiting their potential to create active and self-directed learning environments (Zaita *et al*., 2024; Zaita *et al*., 2025). At the same time, Project-Based Learning (PBL) is recognized in pedagogical discourse (Cascales and Carrillo, 2018; Botella, 2019; Leyva and Lariot, 2019), but its implementation is sporadic, does not always effectively integrate available digital tools, and lacks rigorous evaluation systems to measure its real impact on developing students' self-directed learning skills (Fernández, 2017; Estrada *et al*., 2018; Azpilicueta, 2020).

This disconnection between the theoretical potential of these tools and the absence of validated active methodologies to evaluate their effectiveness generates an educational practice that does not fully utilize the available resources to develop the critical competence of learning to learn (Villavicencio, 2004; Barría *et al*., 2017; Calcines *et al*., 2017).

Although it is theoretically postulated that PBL can develop self-management of learning (Chavez, 2014; Barría *et al*., 2017; Dinsmore, 2017), the following are unknown: the usefulness of a triangulated evaluation that combines quantitative measurement of change, expert validation of the design and qualitative analysis of the student experience, to understand the impact of PBL (Gavilanes *et al*., 2022; Guaicha *et al*., 2024; Sosa *et al*., 2025), as well as the specific pedagogical mechanisms and intervention factors that, from the perspective of the actors, facilitate or hinder the development of self-management of learning.

In the context of contemporary higher education, the development of skills for autonomous learning and knowledge management has become a strategic focus for training professionals capable of adapting to changing environments and solving complex problems (Fernández, 2017; Bosch and Rodríguez, 2023; Guaicha *et al*., 2024). Self-directed learning, understood as the student's ability to plan, regulate, and evaluate their own knowledge acquisition process, is an essential 21st-century competency, particularly in health-related fields, where continuous professional development and informed decision-making are crucial for quality care (Gavilanes *et al*., 2022; Cancino, 2024; Sosa *et al*., 2025).

In this context, PBL emerges as an active methodology that fosters knowledge construction from authentic and meaningful situations, simultaneously promoting collaborative work skills, communication, and the practical application of knowledge (Carmona *et al*., 2024; Zapata *et al*., 2024; Tapia *et al*., 2025). Numerous studies have demonstrated its potential to stimulate critical thinking and autonomy in health science students by placing them at the

center of the teaching-learning process and linking theory with real professional scenarios (Villavicencio, 2004; de la Puente *et al*., 2020; Zaita *et al*., 2024).

However, in the Cuban context, the training of short-cycle senior technicians in Pharmaceutical Services faces particular challenges. While the curriculum recognizes the need for graduates capable of self-managing their learning and solving problems specific to pharmaceutical practice, limitations persist in the development of these skills during the training process. First-year students often exhibit low initial levels of autonomy, difficulties working in teams, limited ability to search for and synthesize reliable information, and insecurity in communicating and defending arguments (de la Puente *et al*., 2020; Zaita *et al*., 2024; Zaita *et al*., 2025).

The objective of the research was to evaluate the PBL methodology for the subject Pharmaceutical Services I, and its impact on self-management of learning, through triangulated validation in the students of the Short Cycle Higher Education in Pharmaceutical Services of the Faculty of Health Technology and Nursing, University of Medical Sciences of Villa Clara, Cuba.

2. Methodology

2.1. Sample Selection and Context Analysis

The research was conducted at the Faculty of Nursing and Health Technology (FNHT) of the University of Medical Sciences of Villa Clara, Cuba. The study period covered the 2025-2026 academic year and focused on the first year of the Short-Cycle Higher Education Program in Pharmaceutical Services.

The evaluation of the Problem-Based Learning (PBL) methodology, designed for the teaching and learning process of the Pharmaceutical Services I course in the Short-Cycle Higher Education Program in Pharmaceutical Services, was carried out in two complementary phases. In the first phase, the expert judgment method was applied, based on consultations with seven highly competent professionals.

In the second phase, a pre-experimental pretest-posttest design was implemented with a single group, consisting of all first-year students (n=8).

Analysis and processing of information

In the first phase, the expert judgment method was applied, based on consultation with seven highly competent professionals (K coefficient ≥ 0.80), selected using the competence coefficient (K = ½ (Kc + Ka)). These experts, with extensive experience in PBL teaching, pharmaceutical services curriculum, educational technology, competency assessment, and professional performance, evaluated the proposal using a structured instrument with key indicators and a qualitative scale (Very Suitable to Unsuitable).

In a second phase, a pre-experimental pretest-posttest design was implemented with a single group, consisting of all first-year students (n=8). The intervention, which took place over 18 weeks, was structured in phases according to the developed methodological guide. Data was collected using a questionnaire administered at two points in time (week 1 and week 18), which assessed five dimensions (motivation and interest, collaborative work, autonomy and learning management, communication skills, and knowledge application) using a Likert-type scale and open-ended questions.

The quantitative analysis included descriptive statistics, the Wilcoxon signed-rank test for related samples, the coefficient of variation, and internal consistency using Cronbach's alpha, all processed with SPSS version 22. Additionally, a content analysis of the open-ended responses was conducted using methodological triangulation, allowing for the integration of a qualitative perspective into the assessment of the methodology's effectiveness in stimulating self-directed learning within the specified educational context.

Each method contributed distinctive elements to the conception, structuring, and foundation of the didactic proposal, in accordance with its respective epistemological functions.

2.2. Ethical aspects

For the conduct of the research, informed consent was taken into account, as well as the ethical standards that made it possible to promote and ensure respect for all participants in the study, so that their criteria/opinions and individual

rights were respected, in order to generate new knowledge without violating the ethical principles of privacy and confidentiality of personal information (DHAMM, 2024).

3. Results and discussion

The evaluation and structuring of the methodology were carried out through the application of the expert judgment method, which is based on consulting those with extensive knowledge of the subject of study and is essentially subjective (Armiñana *et al*., 2024; Cutiño *et al*., 2025).

In this research, an expert is defined as a person or group of people capable of offering, with maximum competence, assessments of a given problem, making objective and realistic predictions about the effect, applicability, feasibility, and relevance that the proposal may have in practice, and providing recommendations for its improvement (Valdez *et al*., 2020; Yánez, *et al*., 2023; Armiñana *et al*., 2024).

To facilitate the work of the experts, an instrument was developed that reflects a series of indicators for evaluating the Problem-Based Learning (PBL) methodology. The evaluation criteria are based on the following scale: Very Adequate (MA), Quite Adequate (BA), Adequate (A), Somewhat Adequate (PA), and Inadequate (I).

To determine the experts' level of competence, the K coefficient was calculated (Table 1). This coefficient was determined from each applicant's self-assessment of their own knowledge level related to the problem being evaluated (Torres & Zelada, 2021; Tovar, 2022; Armiñana *et al*., 2024).

Table 1 Competence coefficient of the experts who assessed the methodology

Experts	Knowledge coefficient (Kc)	Argumentation coefficient (Ka)	Competition coefficient (K)	Valoration
1	0.91	1.00	0.90	HIGH
2	0.92	1.00	0.95	HIGH
3	0.90	1.00	0.95	HIGH
4	0.97	0.90	0.85	HIGH
5	0.98	0.80	0.80	HIGH
6	0.98	0.90	0.95	HIGH
7	0.92	1.00	0.95	HIGH

GCI. (Kc) Level of knowledge and information. K. Competition coefficient. Ka. Coefficient of argumentation or fundamentation = ½ (Kc + Ka)

The evaluative criteria used to determine the experts' level of competence were: high competence (0.8 to 1); medium competence (0.5 to 0.7); and low competence (less than 0.5).

As a critical unit, experts scoring less than 0.8 were excluded from the study (Herrera, 2022; Travieso & Ortiz, 2023; Armiñana *et al*., 2024). The seven-member panel that evaluated the developed PBL methodology consisted of two experts in Problem-Based Learning (PBL) didactics, two in Pharmaceutical Services curriculum, one expert in educational technology, one expert in competency assessment, and one in the area of professional performance in Pharmaceutical Services.

It is important to highlight in this research that, of the seven experts selected, 100% have more than 15 years of experience in their field. 85.71% of them are involved in teaching. 42.85% hold a PhD and 42.85% hold a Master's degree. One of the experts is currently pursuing a doctorate.

28.57% hold the rank of Full Professor, 57.14% Associate Professor, and 14.28% Assistant Professor, with the latter in the process of being promoted to Associate Professor. All of the experts belong to different universities in the Republic of Cuba.

The aforementioned analysis allowed for the characterization of the experts as follows:

- Professors and researchers with mastery of content related to didactics, active teaching methodologies, digital tools, competencies, and the pharmaceutical profession.
- A high percentage of experts with more than 15 years of experience as professors at different universities in the Republic of Cuba.
- Knowledgeable about the proposed topic.
- Scientific and teaching category endorsed by obtaining the degree

The results of the survey applied to the seven selected experts are described below:

The first indicator, related to the structuring of the PBL Methodology, in a proposed illustrated and interactive Guide (6/85.71%) (Figure 1) of the experts indicates that it is very adequate, while (1/14.28%) indicates that it is quite adequate.

Figure 1 Cover of the Interactive Illustrated Guide: Project-Based Learning in Pharmaceutical Services

The observation noted that phase three includes multiple tasks, workshops, iterations, and deliverables. It is necessary to ensure that students have sufficient time and resources to complete them without becoming overwhelmed.

100% of the experts agreed that the indicator related to the alignment of interpretations of scientific concepts, laws, ideas, and explanations of facts and phenomena with the current level of PBL development is very appropriate.

100% of the experts rated the indicator regarding the alignment of technical vocabulary with the university level as very appropriate.

The arguments presented include:

- Regardless of the high level of depth with which different topics are addressed, the course is very accessible to students in the Short-Cycle Higher Education Program in Pharmaceutical Services, fostering the development of self-directed learning as a 21st-century skill.
- The incorporation of progress logs and evaluation milestones, which facilitate monitoring of the process throughout all its phases, proved to be a highly innovative feature.
- The integration of active, contextualized methodologies is evident and innovative. The operational tasks are designed to be implemented in practical work settings, where the connection to real-world environments is notable, thus reducing the gap between theory and practice.

The indicator regarding the contribution of PBL to self-directed learning (5/71.42%) categorizes it as very suitable and (2/28.57%) as quite suitable.

The experts considered that the methodology contributes significantly to the development of self-directed learning by using an authentic context that demands real, not simulated, autonomy. A progressive process design that accompanies the growth in autonomy is evident, which agrees with the results obtained by other authors on this topic (Mora *et al*., 2019; Barbachán *et al*., 2020; Meneses, 2023).

Expert 2 suggests adding unstructured spaces where students must fully define their research path (e.g., Choose an aspect not covered and research it on your own).

Although 71.42% of experts consider the indicator concerning the updating of the content in the Problem-Based Learning (PBL) Methodology with respect to the content of the Pharmaceutical Services I course to be very adequate and 28.57% to be quite adequate, it is deemed appropriate to consider the feedback provided by some experts in order to improve its subsequent implementation.

Three experts agree that a national consensus should be reached regarding the generalization of the proposal. Expert 7 states, "The contribution to the graduate profile is evident, as it trains pharmacists capable of continuously self-managing their learning, with skills to integrate technical and human aspects, competencies to adapt to changing contexts, and a willingness to innovate in pharmaceutical services."

Expert 6 states that the methodology presented a design that addresses the development of the most critical and difficult skills to teach in pharmacy.

The indicator that addresses the contribution of the PBL Methodology to student motivation for the subject Pharmaceutical Services I and for the Short-Cycle Higher Education in Pharmaceutical Services was rated as very adequate by 100% of the experts.

Expert 2 states: “I am satisfied with the PBL Methodology presented to me for evaluation. It is the first result I am aware of that was developed for the teaching and learning process of the Short-Cycle Higher Education in Pharmaceutical Services that incorporates PBL as a method, starting with the subject Pharmaceutical Services I, fostering the development of self-directed learning, and directly linking it to professional practice in solving real-world problems”.

The general consensus was that the learning activities and tasks designed in the workshops were highly motivating, placing the teacher in the role of guide and facilitator, and the student in a more active role in their learning process.

Therefore, the developed PBL methodology should spark students' interest and motivation in studying the subject.

Regarding the indicator that refers to the contribution of the PBL methodology to the development of computer skills, 85.71% rated it as very adequate, and 14.28% as quite adequate. Expert 3's suggestion is based on the recognition that the use of the Cloudida platform can enhance pharmaceutical training if employed strategically and complementarily, always focused on developing the skills required in the profession. However, the fact that it is a local cloud limits its use (Franco & Guerrero, 2024; Qiu, 2025; Troncoso *et al*., 2023).

The examination of the results obtained for the suggested indicators, together with the analysis of the additional opinions expressed by the experts, constituted a moment of reflection for making significant modifications to the components initially conceived in the development of the PBL Methodology.

Considering the results obtained and the proposals made by the experts, the following adjustments were made:

Include an intermediate feedback session between iterations to adjust the direction of the research and creation. Incorporate digital tools for portfolio management and templates.

The intermediate activities called "Critical Coffee, Checkpoint" are introduced in phase 3, Research and Creation, which allows for adjusting the direction after the first product and before delving deeper into the contextual research. Its objective is to offer structured and agile feedback to adjust the direction of the research and creation, promoting self-directed learning. A modality is proposed that can be in-person or synchronous virtual, using Cloudida or a social group.

Reflecting on the cognitive load of students, based on the number of activities generated, a closing workshop is introduced in phases 2 and 3 to conclude phase two, synthesizing and connecting the learning. This workshop will be held in person (in a specialized pharmacy classroom) and will involve students and instructors. Its objective is to

synthesize the key learnings of phase two through a structured reflection that connects workshop experiences, work practice, and independent work for the transition to phase three.

Regarding the suggestion that the Cloudida platform has limitations due to its local nature, the authors of this research reaffirm that precisely because it is local, it offers a controlled, secure, and stable environment, especially valuable for PBL projects in Pharmaceutical Services that require regulatory rigor, data management, and controlled clinical environments. However, its cost, maintenance, and access require a careful evaluation of institutional feasibility. If the platform can be anchored to the University's or INFOMED's cloud, this would not constitute a limiting factor.

In summary, expert evaluation strongly endorsed the developed PBL methodology, confirming that it not only meets the training needs of the graduate profile but also represents a modern, contextualized, and effective pedagogical tool for developing students' self-directed learning, motivation, and the competencies required in contemporary pharmaceutical services. The methodology is considered ready for implementation, with the recommended adjustments that enhance its applicability and educational impact.

3.1. Methodology for evaluating the implementation

A pre-experimental pretest-posttest design with a single group was applied, given the exploratory nature of the study and the real educational context (López & Fachelli, 2015; Cruz, 2020; Leyva & Proenza, 2021). The sample consisted of all first-year students in the Short-Cycle Higher Education Program in Pharmaceutical Services (n=8), with no prior experience in PBL, which allowed the changes to be attributed to the intervention.

The PBL methodology was implemented over 18 weeks, focusing on projects applied to the pharmaceutical field based on the content of Pharmaceutical Services I. The preliminary phases outlined in the methodological guide were developed, with structured weekly sessions and progress records.

A perception survey (1-5 scale) was used as a data collection method, administered at two points in time: week 1 (pretest) and week 18 (posttest). The instrument assessed five dimensions:

- Motivation and interest (3 items)
- Collaborative work (3 items)
- Autonomy and management (self-directed learning) (3 items)
- Communication skills (3 items)
- Application of knowledge (3 items)

For the analysis of the rating scale survey (1-5), mean scores and significance were calculated for each item and dimension, for both the pretest and posttest. To compare the scores achieved in the pretest and posttest across the five dimensions included in the experimental group study, and to test the study hypothesis, the Wilcoxon signed-rank test (Rode and Ringel, 2019; Ramírez and Polack, 2020; Benítez and Peña, 2024) was applied. This test proved to be the appropriate choice because:

- Small sample size (n=8)
- Ordinal data (Likert scale 1-5)
- Pretest-posttest design with related samples
- Does not require normality in the data distribution

The study began by establishing the general hypothesis, the basis for the test (González & Reyes, 2024).

H_0: The PBL methodology proposed for the teaching and learning process of the Pharmaceutical Services I course, within the Short-Cycle Higher Education program in Pharmaceutical Services, which considers the specific characteristics of the future graduate's profession, does not have a significant impact on stimulating students' self-directed learning.

H_a: The PBL methodology proposed for the teaching and learning process of the Pharmaceutical Services I course, within the Short-Cycle Higher Education program in Pharmaceutical Services, which considers the specific characteristics of the future graduate's profession, has a significant impact on stimulating students' self-directed learning.

Significance level

NC = 0.95

Margin of error = 0.05

Decision criterion

If p-value < 0.05, reject H0

If p-value ≥ 0.05, accept H0 and reject Ha

Statistical significance (p-value) was determined for related samples, according to the total value of each dimension. The results of the Wilcoxon test are shown in table 2.

Table 2 Wilcoxon signed-rank test results for the total of each dimension

Dimensions	W	p-valor	Significance
A. Motivation and interest	0	0.0078	p < 0.01
B. Collaborative work	0	0.0078	p < 0.01
C. Autonomy and management	0	0.0078	p < 0.01
D. Communication skills	0	0.0078	p < 0.01
E. Application of knowledge	0	0.0078	p < 0.01

The W=0 statistic across all dimensions indicates that 100% of the students improved, reflecting a highly consistent effect of the intervention. These results are consistent with those obtained by Ramírez and Polack (2020) and Benítez and Peña (2024).

The Wilcoxon test confirms that the PBL methodology implemented during the pre-experiment had a statistically significant impact on all evaluated dimensions, with a confidence level greater than 99% (Rode & Ringel, 2019; Ramírez & Polack, 2020; Benítez & Peña, 2024).

Table 3 summarizes the results obtained, including means and differences, as well as the significance level for each dimension, allowing for subsequent comparison and interpretation of the values.

Table 3 Means and statistical significance by dimension (Pretest vs. Post-test)

Dimensions	Pretest median (total)	Pretest median per item	Post-test mean (total)	Media post-test per item	Mean differences per item	Significance (p-value) Wilcoxon
A. Motivation and Interest	12.38	4.29	15.00	5.00	+0.71	< 0.01
B. Collaborative Work	6.63	2.21	12.00	4.00	+1.79	< 0.01
C. Autonomy and Management	6.75	2.25	12.50	4.17	+1.92	< 0.01
D. Communication Skills	5.38	1.79	11.75	3.92	+2.13	< 0.01
E. Application of Knowledge	6.88	2.29	12.50	4.17	+1.88	< 0.01

3.1.1. Dimension A: Motivation and interest

Students initially had a very high perception (4.29/5). After the intervention, they reached the maximum possible score (5.00/5). All students responded "strongly agree" to items A1 (motivation), A2 (relevance), and A3 (preference for learning by solving problems). The change, +0.71 points per item, although numerically smaller than in other dimensions, is statistically significant and shows a consolidation of interest on the part of the students, results that coincide with those obtained by other authors (Oseda *et al*., 2020; Leyva & Proenza, 2021; Ramos *et al*., 2022; Bosch & Rodríguez, 2023).

3.1.2. Dimension B. Collaborative work

This dimension showed one of the most notable improvements, moving from a low perception (2.21/5) to a positive perception (4.00/5). In the pretest, discomfort and insecurity were observed (e.g., in B1, six out of eight students disagreed or strongly disagreed with feeling comfortable working in teams). In the posttest, this perception reversed, with seven out of eight students expressing agreement or strong agreement on the items regarding task distribution (B2) and conflict resolution (B3) (Pérez *et al*., 2024). The observed change was +1.79 points per item. The significance value ($p < 0.01$) qualitatively validates the students' observations about the improvement in team dynamics (Rode & Ringel, 2019; Ramírez & Polack, 2020; Benítez & Peña, 2024).

3.1.3. Dimension C. Autonomy and management

This dimension, the central focus of the self-directed learning thesis, showed the second greatest improvement. Students moved from a low self-perception (2.25/5) to a high self-perception of competence (4.7/5) in their ability to plan, search for information, and solve problems independently. This represents a change of +1.92 points per item.

The significance achieved is crucial, as it validates the main objective of the research: PBL develops self-directed learning (Ramírez & Polack, 2020; Benítez & Peña, 2024). Item C2, "I can search for and select reliable information on my own," stands out. In the pretest, six students disagreed, while in the posttest, eight agreed. A similar positive evolution is observed in planning (C1) and confidence to solve problems (C3) (Chaves, 2014; Chois *et al*., 2023; Carmona *et al*., 2024).

3.1.4. Dimension D. Communication skills

This dimension had the lowest mean score in the pretest (1.79/5) and experienced the greatest absolute increase (+2.13). Students went from feeling insecure when communicating to feeling mostly competent (3.92/5).

Items D2. Synthesizing Information and D3. Defending Arguments, went from having all students disagree or be neutral to having the vast majority (seven out of eight students) agree in the posttest (Barría *et al*., 2017; Alvites, 2021).

The significance value ($p < 0.01$) confirms that the intervention had a profound impact on the ability to synthesize and defend arguments (Ramírez & Polack, 2020; Benítez & Peña, 2024; Zapata *et al*., 2024).

3.1.5. Dimension E. Application of knowledge

Similar to dimension C, a solid improvement was observed, moving from a low perception (2.29/5) to a high one (4.17/5). Students now feel capable of connecting theory with practice.

Students progressed from a perception of difficulty in connecting concepts (E1) and seeing applicability (E2, E3) to a majority perception of competence in these skills after the project (Leyva & Proenza, 2021; Ramos *et al*., 2022; Bosch & Rodríguez, 2023).

All dimensions showed significant improvements ($p<0.001$) (Rode & Ringel, 2019; Ramírez & Polack, 2020; Benítez & Peña, 2024). Dimension D (communication) experienced the greatest absolute growth, while dimension C (self-directed learning), central to the research, achieved a solid improvement of +1.92 points per item.

3.2. Internal consistency and agreement analysis

The Coefficient of Variation (CV) was determined for dimension C. In the pretest, the CV was 52.4% (high variability), confirming that participants started from very different levels of self-perception (Cappello *et al*., 2004; Martínez and González, 2017; Perdigón and Pérez, 2022). In the posttest, after the intervention, it decreased to 7.4% (high agreement), indicating that the students converged towards high and homogeneous levels of self-management.

Cronbach's α for internal consistency (Table 4) was good or excellent in all dimensions, results that agree with those obtained by other authors in this regard (Soler and Soler, 2012; Castañeda *et al*., 2024), reaching values within the scale for pretest interpretation 0.85-0.95 and posttest 0.82-0.92, except in motivation, without variability due to homogeneous responses (Table 5), this confirms the reliability of the instrument, coinciding with other authors (Soler & Soler, 2012; Castañeda *et al*., 2024).

Table 4 Comparative results of Cronbach's α for all dimensions (Pretest) and (Post-test)

Dimensions	**α Cronbach's (Pretest)**	**Interpretation (Pretest)**	**α Cronbach's (Post-test)**	**Interpretation (Post-test)**
A. Motivation and Interest	0.000	No variability	indefinida	No variability
B. Collaborative Work	0.951	Excellent	0.822	Good
C. Autonomy and Management	0.954	Excellent	0.891	Good
D. Communication Skills	0.851	Good	0.923	Excellent
E. Application of Knowledge	0.932	Excellent	0.891	Good

Table 5 Scale for the Interpretation of Cronbach's α

Valor	**Interpretation**
0.9	Excellent
0.8-0.9	Good
0.7-0.8	Acceptable
0.6-0.7	Questionable
<0.6	Poor

In both assessments, students responded almost identically to the three items (A1, A2, A3). In the pretest, all students gave very homogeneous scores (mostly 4 and 5), and in the posttest, all students scored 5 on all items.

This indicates a lack of variability in responses, which prevents the calculation of internal consistency (Soler & Soler, 2012; Castañeda *et al*., 2024). One possible explanation for the results is that all students perceive their motivation very similarly, giving maximum scores.

In the pretest, the items in dimension B consistently measured collaborative work. In the posttest, although still acceptable, it decreased slightly. This could be because, after the intervention, students responded more homogeneously on some items, reducing variability.

It remains a reliable dimension, although with less consistency than at the beginning.

Dimension C showed almost perfect consistency in the pretest.

In the post-test, although it decreased slightly, it remains good. This indicates that the items are effective in measuring self-directed learning, but with somewhat more variability in the responses.

It is possible to state that students improved in autonomy, but unevenly, which increased variance but maintained internal consistency (Soler & Soler, 2012; Martínez & González, 2017; Castañeda *et al*., 2024).

Dimension D, corresponding to communication skills, improved its internal consistency in the post-test.

This suggests that, after the intervention, students responded more consistently across communication items.

The scale is highly reliable in the post-test, which reinforces the validity of the measurements in this area (Soler & Soler, 2012; Martínez & González, 2017; Castañeda *et al*., 2024).

Finally, dimension E, related to the application of knowledge, showed results similar to dimensions B and C: good consistency was maintained at both time points, although the post-test score was slightly lower than the pre-test score.

One possible cause may be related to the homogeneity of responses after the intervention, which reduces variance between items. It remains a reliable scale for measuring knowledge application (Soler & Soler, 2012; Martínez & González, 2017; Castañeda *et al*., 2024).

In summary, we can affirm that dimensions B, C, D, and E show good to excellent internal consistency at both time points, indicating that the items are well-constructed and adequately measure the constructs.

Dimension A shows no variability, so it is not possible to assess its consistency. It would be advisable to review the items or the scale used for this dimension.

Overall, the instrument is reliable for assessing skills in the pretest and posttest, with slight variations that can be attributed to changes in response dispersion after the intervention, results that coincide with those obtained by Martínez and González (2017), Perdigón & Pérez (2022), and Castañeda *et al*. (2024).

3.3. Analysis of critical items

Eight items with a pretest mean < 2.0 were identified, which makes them critical, with the lowest scores and are shown in table 6.

Table 6 Critical items in the pretest (mean < 2.0)

Dimensions	Item	Statement	Pretest average	Post-test average	Improvement
B	B1	I feel comfortable working in a team	1.75	4.0	+2.25
B	B2	I know how to distribute tasks equitably	1.63	3.88	+2.25
C	C2	I can search for reliable information	1.63	4.13	+2.50
D	D1	I feel sure explaining ideas	1.88	3.88	+2.00
D	D2	I can synthesize information	1.50	3.75	+2.25
D	D3	I can defend arguments	1.63	3.88	+2.25
E	E1	Connecting theoretical concepts	1.63	4.13	+2.50
E	E3	Explain "what it's for?"	1.88	4.0	+2.12

Comparing the results obtained in the pretest and posttest, it is clear that everyone improved substantially (>2 points) and reached adequate levels in the posttest (≥3.75), as shown in table 7.

Table 7 Analysis of improvement in problematic items

Items	Improvement	Does it reach an adequate level?
C2 Search information	+2.50	Sí (4.13/5)
E1 Connect concepts	+2.50	Sí (4.13/5)
B1 Team work	+2.25	Sí (4.0/5)
B2 Distribute tasks	+2.25	Sí (3.88/5)
D2 Synthesize	+2.25	Sí (3.75/5)

D3 Defend arguments	+2.25	Sí (3.88/5)
E3 Explain usefulness	+2.12	Sí (4.0/5)
D1 Explain ideas	+2.00	Sí (3.88/5)

The summary, the statistical methods used for the validation of the instrument made as a pretest and post-test during the pre-experiment, are presented in table 8.

Table 8 Validation summary

Aspects evaluated	Indicators	Results	Interpretation
Pretest agreement	Coefficient of variation	52.4 %	Low initial concordance
Post-test agreement	Coefficient of variation	7.4 %	High final agreement
Internal consistency	α of Cronbach's	0.87 – 0.92	Good/Excellent
Sensitivity to change	Improvement in critical items	+2.0 a +2.5	High sensitivity

This comprehensive analysis demonstrates that the instrument has good internal consistency, high sensitivity to detect changes, and that after the intervention, a high level of agreement is achieved among students, which supports the validity of the results.

3.4. Qualitative analysis: perceptions, challenges, and achievements

The content analysis of the open-ended questions allowed for triangulation and a deeper understanding of the quantitative findings.

3.4.1. Perceived achievements and positive evaluation

The students highlighted the development of practical skills as their main achievements: "I learned to research on my own and apply theory to a real-world pharmacy case," improved teamwork: "I learned to listen and reach agreements," and satisfaction with a tangible product: "Seeing the finished project and presenting it was the most rewarding part." This corroborated the quantitative improvements in dimensions B, C, and E.

3.4.2. Challenges faced and overcoming strategies

The most frequently cited challenge was time management and initial group coordination ("At first, we struggled to organize ourselves and divide the work effectively"). The students reported overcoming these obstacles through planning meetings, clear role assignments, and constant communication, demonstrating procedural learning in self-management and collaboration.

3.4.3. Suggestions for continuous improvement

The suggestions focused on providing more initial guidance on the PBL methodology and allowing more time for project development. These observations do not contradict the positive results but rather offer valuable benchmarks for optimizing future implementations.

3.4.4. Integration of results and overall measurement of change

To quantify the overall change in each student's perception, the scores for all items on the questionnaire were summed (15 items, maximum theoretical score: 75) (Figure 2).

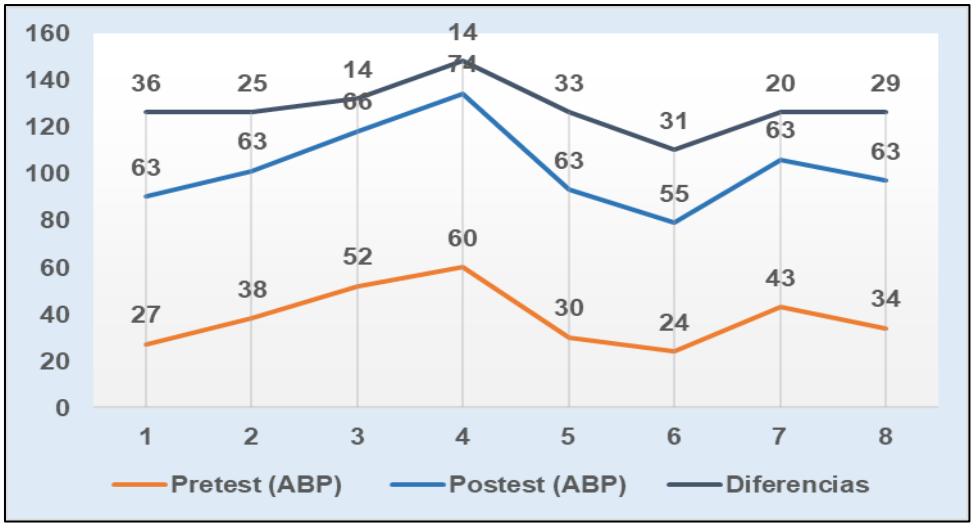

Figure 2 Individual evolution of the total score of each of the 8 students from the pretest to the post-test

All eight students increased their total score, with an average increase of 25.25 points (from a pretest mean of 38.5 to a posttest mean of 63.75). Student number six had the lowest initial score but showed the greatest absolute improvement.

4. Conclusions

The PBL methodology, as evaluated, showed a positive and significant evolution in the students' perception in all its dimensions, with the most outstanding advances in communication skills, learning autonomy, and application of knowledge, where the students not only improved their self-perception, but also developed strategies to face collaborative challenges.

Compliance with ethical standards

Acknowledgments

To Prof. David del Valle Laveaga, Ph.D., for his generosity and high altruism in assuming the payment of the manuscript without hesitation.

Disclosure of conflict of interest

The authors have declared that no competing interests exist.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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