Revista Española
de Educación Médica

Academic effectiveness of the problem-based learning *(PBL) method* in the subject of Medical Genetics in a Cuban medical university.

Academic effectiveness of the problem-based learning (PBL) method in the Medical Genetics subject at a Cuban medical university.

Roberto Lardoeyt Ferrer[1*], Maritza Domínguez Méndez[2], Keny Alfonso Díaz[3], Zulema Quesada Soto[4], Tomás da Costa[5], Jovelino Kuanzambi[6]

1. "Alvorecer da Juventude" Higher Polytechnic Institute (ISPAJ). Luanda. Republic of Angola; lardgen72@gmail.com; https://orcid.org/0000-0002-4921-5630
2. Manuel Fajardo School of Medicine mdomen2014@gmail.com; https://orcid.org/0000-0003-1846-9352
3. Municipal Service of Medical Genetics. Plaza de la Revolución Polyclinic. Havana. Cuba; kenyalfonso594@gmail.com; https://orcid.org/0000-0002-2915-4412
4. Municipal Service of Medical Genetics. Plaza de la Revolución Polyclinic. Havana. Cuba; zulqs66@gmail.com ; https://orcid.org/0000-0003-2222-4710
5. Higher School of Health Castelo (ESSCA). Luanda. Republic of Angola; tomasdacosta84@gmail.com; https://orcid.org/ 0009-0003-0873-5562
6. Higher School of Health Castelo (ESSCA). Luanda. Republic of Angola; ikcabim@hotmail.com; https://orcid.org/ 0000-0002-6775-1023

* Correspondence: lardgen72@gmail.com

Received: 2/24/25; Accepted: 3/12/25; Published: 3/14/25

Abstract: Background: Problem-Based Learning (PBL) is a student-centered educational methodology that promotes active learning through the resolution of real and relevant problems. Objective: to evaluate whether the acquisition of knowledge, skills and professional competencies in students who received the PBL learning method is superior to the group that received the traditional methodology, as well as to verify whether the method requires time for the maturation of knowledge. Methods: A quasi-experimental epidemiological design of hybrid strategy was carried out (longitudinal with repeated measurements and transversal with the use of equivalent parallel groups). The control group consisted of 39 students who received the traditional method and the experimental group by 39 students who received the PBL method. Results: In the first measurement there were significant differences ($p < 0.05$) in favor of the PBL method in all subjects and in the global evaluation. In the second measurement there were no significant differences in the subjects except for inheritance patterns. Significant differences were observed between the measurements of both times (T0 and T1) in favor of higher grades in the second evaluation moment. Conclusions: The superiority of the PBL method is demonstrated compared to the traditional method in the teaching-learning process of topic 3 of the Medical Genetics subject, however, it takes time for the student to acquire knowledge and skills.

Keywords: Problem-based learning, PBL, Medical Genetics, Teaching-Learning Process

Resumen: Antecedentes: El Aprendizaje Basado en Problemas (PBL, por sus siglas en inglés) es una metodología educativa centrada en el estudiante que promueve el aprendizaje activo a través de la resolución de problemas reales y relevantes. Objetivo: evaluar si la adquisición de conocimientos, habilidades y competencias profesionales en los alumnos que recibieron el método de aprendizaje PBL es superior al grupo que recibió la metodología tradicional, así como verificar si el método requiere de un tiempo para la maduración de los conocimientos. Métodos: Se realizó un diseño epidemiológico cuasi experimental de estrategia híbrida (longitudinal con mediciones repetidas y

transversal con el empleo de grupos paralelos equivalentes). El grupo control estuvo conformado por 39 alumnos que recibieron el método tradicional y el grupo experimental por 39 alumnos que recibieron el método PBL. Resultados: En la primera medición hubo diferencias significativas ($p<0,05$) a favor del método PBL en todos los temas y en la evaluación global. En la segunda medición ya no hubo diferencias significativas en los temas excepto para los patrones de herencia. Se observaron diferencias significativas entre las mediciones de ambos tiempos (T0 y T1) a favor de calificaciones superiores en el segundo momento evaluativo. Conclusiones: Se demuestra la superioridad del método PBL en comparación con el método tradicional en el proceso de enseñanza-aprendizaje del tema 3 de la asignatura de Genética Médica, sin embargo, se requiere de un tiempo para que el estudiante adquiera conocimientos y habilidades.

Palabras Clave: Enseñanza basado en problemas, PBL, Genética Médica, Proceso Enseñanza-Aprendizaje

1. Introduction

problem-based teaching method, known by the acronym *PBL* , from the English *Problem Based Learning* (1), which will be used from now on to refer to the method (5), is an active teaching methodology, which has its roots in Socrates, since he applied a teaching strategy in which individuals learned by discovering things for themselves, by asking questions to the "supposed wise men" and with a sequence of questions they showed their ignorance (this stage is known by historians as irony) that forced them to search for the unknown and in this way transform knowledge (this stage was called maieutics) (4). Since then, multiple active teaching methods have been developed, among which are the following: the inverted classroom, project-based learning (PjBL), team-based learning (TBL), gamification and the participatory integrated panel, among others (1). Among its characteristics are that it is based on constructivism. This methodology allows for the integration of diverse content in a single module, and teaching is centered on the student. The problem is a real situation or a simulation close to reality, covering several areas of knowledge (4). For the development of the PBL method, the teaching staff defines the topics, and each of these topics will be transformed into a problem. The problems are carefully prepared by the subject group. To do this, experts in the subject in question can be consulted. As many problems as possible should be prepared according to the topics that the student is expected to master in order to practice the profession in the future.

Each tutorial group is made up of a tutor and 8 to 10 students, and there is a coordinator among the students and a lecturer. These roles will change so that all students have the opportunity to perform these functions. The role will be selected by the students themselves. The problem is handled in the tutorial group following two important stages. In the first stage, the students formulate learning objectives based on group discussion of the problems. These must coincide with the program objectives. In this element, the tutor teacher plays an important role as the leader or facilitator of the activity (4). In this phase, the students are challenged to formulate hypotheses about possible explanations of the problem based on previous teaching-assistance experiences. In a second stage, the students return to the problem and analyze it under the concept of systematized knowledge in independent study.

At both times, the exploration of the problem is carried out taking into account the methodology of the seven steps: 1) Clarify unclear terms and concepts; 2) define the problem; 3) analyze the problem; 4) prepare a systematized inventory of the inferred explanations or hypotheses and proceed to the distribution of tasks that each student must perform in order to solve the problem; 5) formulate learning goals, 6) gather original information outside the group and 7) synthesize and research new information (5-9).

Medical science disciplines seem to have the characteristics that best adapt to PBL, which is why it is essential in the training of health professionals (10). Medical genetics was established as an

independent subject in the medical curriculum in 2004, since it was previously included as a subject in the pathological anatomy subject. It consists of 54 declared teaching hours over 14 weeks and eight subjects whose contents range from molecular and medical genetics to understanding the community genetics programs that are part of the National Health System. When the subject program and its methodological guidelines are reviewed, theoretical conferences are organized by subject, where the new content is introduced, and then theoretical and practical evaluative activities, where both theoretical and practical questions are developed. The accumulated scientific and empirical experience and knowledge reflect that students are not always prepared for these teaching activities, so the professor sometimes has to invest a significant amount of time clarifying concepts in order to solve the exercises presented. Students report that there is not enough time between the lecture and the theoretical and practical activity, which does not give them time to master the content taught. Furthermore, students are not used to frequent partial assessments based on problems. Many report that this is the first time they have faced this type of assessment.

During this period, 2004-2025, the teaching staff has noticed that students are concerned about the presentation of the PowerPoint lecture, there is an inadequate knowledge base of previous subjects that contribute to medical genetics, and, what is far from reality, they perceive that the subject of medical genetics is only for geneticists, it is not linked to their future professional performance as a doctor. They perceive it as abstract content with no connection to practice. In addition to the above, the analytical program states the objectives and skills by subject, however, these skills do not always respond to the profile of the graduate in primary health care (PHC). All the elements referred to above were motivational sources for a paradigm shift in the teaching-learning process (PEA) using the *PBL method* in a particular subject of the medical genetics subject.

The objective of this research is focused on evaluating whether the acquisition of knowledge, skills and professional competencies in students who received the PBL learning method is superior to the group that received the traditional methodology, as well as verifying whether the method requires time for the knowledge to mature. In this sense, two statistical hypotheses were defined: Ho (There are no differences in the average grades of the three topics and the overall between both groups at the two measurement times, or intragroup differences between the two measurement times; and Ha, which coincided with the working hypothesis, that there are differences in the average grades between both groups measured at the two times and that there are differences in the averages between the two times T0 and T1 in both groups.

2. Methods

Type of study. Universe and sample

This research is part of an intervention project not associated with a program, of the applied research level, with a quantitative or positivist approach. A quasi-experimental epidemiological design with a hybrid strategy was carried out (longitudinal with repeated measurements and transversal with the use of equivalent parallel groups) (Figure 1). The educational intervention lasted one month, in which three topics were taught: inheritance patterns, factors that make it difficult to interpret an inheritance pattern and biological interferences. After the intervention, the first intergroup measurement was carried out (time T0). After one month, the second intergroup measurement was carried out (time T1) with the aim of analyzing the superiority of the *PBL method* over the traditional one. Intragroup measurements were carried out between both times (T0 vs T1) with the aim of demonstrating whether the academic results at time T1 are superior to T0 (Figure 1). The universe was made up of the enrollment of fourth semester students of the medical degree at the Manuel Fajardo Faculty of Medical Sciences during the 2023-2024 academic year (n= 136). A sample size of 78 students was calculated, taking into account the following parameters: 95% reliability, 8% precision, a proportion of p=q=0.5, which maximizes the sample size, and an expected proportion of losses of 8%. Through simple random sampling, that number of students was chosen and half was distributed to the control group and the other half to the experimental group.

To ensure the randomization of the sample, a database was created in SPSS with the nominal list of all the students and through the statistical package SPSS in its version 27.0, the nominal list of the students who were part of the study was obtained. It is important to clarify that the control group received the traditional method like the rest of the students not chosen for the research, so their designation was important in the measurement of the different analytical variables. To form both groups, we assigned the same sample size for the experimental group and for the control group, and randomly assigned the first 39 on the list to the experimental group and the remaining 39 to the control group. The control group consisted of 39 students who adopted the traditional teaching model according to the methodology established in the analytical program of the subject, perfected in its latest version in January 2019. The experimental group consisted of 39 students, who were distributed in small tutorial groups of 10 with the participation of five teachers as tutors, who received the PBL method.

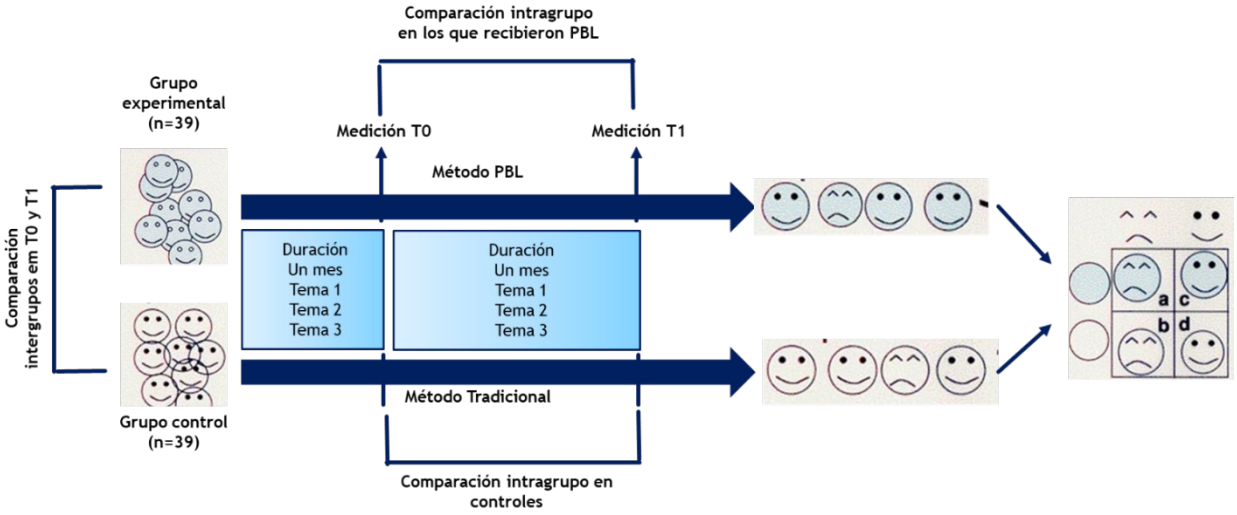

Figure 1. Hybrid quasi-experimental research design.

Variables and their operationalization

The variable "grade" was taken into account based on the score of 15 items, 5 for each topic; both in the measurement of the first moment (T0) and in the second moment (T1). The variable was categorized as a continuous quantitative variable taking into account a maximum score of 5 points, and a minimum of 0 points. The items whose answer was correct obtained the value of one point, and the incorrect answers 0 points. The variable was operationalized taking into account the absolute value of the score per topic, which is nothing more than the sum of each of the values reached in each item and the average obtained between the scores of the three topics for the overall score.

Ethical aspects

This research was part of the project "Effectiveness of the Problem-Based Teaching Method (PBL) in the subject of Medical Genetics: First Cuban experience", approved by the Scientific Council and the Ethics Committee of the Manuel Fajardo Faculty of the University of Medical Sciences of Havana. This research respected the ethical principles of beneficence, since in both methods the contents provided in the analytical program of the discipline were taught, as well as the objectives were met; autonomy, since the student who was part of the experimental group was offered the possibility of changing to the traditional method, without affecting his academic performance; justice, since everyone had the right at the end of the experiment to all the teaching materials provided in both methods. Care was taken to comply with what was established in the program of the discipline. The

autonomy of the students to participate in the research was respected, signing the informed consent form.

Techniques and procedures for obtaining, processing and analyzing information

The survey was applied through a self-administered questionnaire of closed, single-choice questions made up of 15 items, which comprehensively evaluated the three topics (Annex). The questions were created by the group of teachers taking into account the thematic objectives and the skills and competencies that a basic general practitioner should have in the subject of medical genetics. It was taken into account that the questionnaire applied in the second moment (T1), 15 days after having applied the first questionnaire, was made up of other items, different from the initial questionnaire, but that responded to the same thematic objectives. A database was created on the *Statistical Package of Social Science* SPSS platform (version 27.0) with the objective of performing the statistical processing. The grade of the three topics and the overall grade per student were recorded.

Statistical methods

Descriptive statistics were used for continuous quantitative variables such as the arithmetic mean as a measure of central tendency and the standard deviation as the dispersion mean. As for the traditional inferential statistics tools, the non-parametric Mann-Whitney U test was used to compare the average scores within groups between times T0 and T1, and between groups at both measurement times. This test was used because it was found in the data analysis that the variable "grade" was not normally distributed, with probability values less than 0.05 being obtained in the Kolmogorov Smirnov and Shapiro Wilks test. Finally, Bayesian inference was applied to support traditional inferential statistics for independent normal samples with the aim of providing evidence of how true it is to accept or reject the null hypothesis. This result quantified how much better the alternative hypothesis fits than the null and vice versa. The two hypotheses were directly compared and evidence was provided for both. The value of the Bayesian factor was estimated as the quotient: FB=evidence of Ho/evidence of Ha. Table 1 reflects the criteria frequently used when assessing the importance of the evidence for both Ho and H1.

Table 1. Interpretation of the Bayesian factor.

Bayesian factor	Evidence of the category
>100	Extreme Evidence of Ho
30-100	Very Strong Evidence for Ho
10-30	Strong Evidence for Ho
3-10	Moderate Evidence for Ho
1-3	Anecdotal Evidence of Ho
1	No Evidence
0.33-1	Anecdotal Evidence for H1
0.1-0.33	Moderate Evidence for H1
0.033-0.1	Strong Evidence for H1
0.01-0.033	Very Strong Evidence for H1

Source: quote 11

Procedures for educational intervention using the PBL method

- Work groups made up of ten students and led by a tutor were defined.
- Delivery of problem situations to students.
- Work in tutorial groups, in which student coordinators and rapporteurs were defined for each problematic situation so that everyone performed these functions.
- Minimal intervention by the tutor teacher
- The tutorial work was assessed based on the reports, so that the students did not realize that they were being assessed.

- The classroom was organized in the form of a round table, so that the tutor was at the same level as the students.
- The student coordinator read the problematic situation
- Another student wrote down on the board or in a notebook the contribution made by each student, without being contaminated by conjectures or personal reflections.
- The students gave hypotheses or possible answers for each of the unknowns.
- The students defined the objectives, the content system, and then reviewed the available bibliography.
- In a second stage, the content was then evaluated.
- The evaluation was carried out by the student himself, by the rest of the students and by the teacher.

Training of teachers for the method

- was discussed *online* after a previous study of the document through the *WhatsApp group*
- A video conference was sent to asynchronously train teachers in the roles and procedures of the method mentioned above.
- A methodological teaching activity was then carried out to culminate the preparation with a simulation.

Training of students for the method

- The leaders of the various brigade groups were summoned to the teacher training meetings.
- The rest of the students were then explained the different roles and the methodology itself.

3. Results

Taking into account the distribution of the sample according to age and biological sex, it was characterized by having an average age of 20.15 years; 61.0% were female and 39.0% male. One of the elements that was taken into account to have a comprehensive assessment of the PBL method was the academic performance of the students for each of the subjects evaluated and in general it is striking that according to the results of the traditional inference through the Mann-Whitney U Test, differences are obtained for the first two subjects in favor of the experimental group. There were no significant differences for topic 3 and for the general grade (table 2). However, in this first measurement (T0) regardless of the study group, the grades were low.

However, if we delve deeper into the results where there were supposedly significant differences and the statistical decision was made to accept the alternative hypothesis (Ha), from the perspective of Bayesian statistics there is anecdotal evidence to accept that there are differences in the averages between both groups for topic 2 and global evaluation according to the values of the Bayesian factor of 0.58 and 0.82 respectively and there is moderate evidence that there are differences in the grades for topic 1 (FB = 0.25), that is, in none of the cases was there strong evidence or extreme evidence that there are differences in the grades between both groups.

When the analytical variables were measured in a second time, there were significant differences in topic 1 of inheritance patterns, with a higher average score in the experimental group ($p=0.04$). The value of the Bayesian factor of 0.79 shows anecdotal evidence to accept that there are statistical differences. Although the average scores were higher in the experimental group, there were no significant differences in the rest of the topics in both statistical methods (table 3).

In order to demonstrate whether there were significant differences in the average grades between both periods in the two analytical groups, to a certain extent to demonstrate the importance that a flexible time could have for the student to mature the acquired knowledge, in the experimental group

statistically higher average grades were obtained in the second period (p <.001) , except for term 1 of inheritance patterns. The overall evaluation increased from 3.74 points to 4.38 (p <.001).

Table 2. Intergroup comparison of average academic performance according to the topics covered in the first measurement.

Topics	Control group	Experimental group	Traditional Inference		Bayesian inference	
			OR	p	FB	p
Inheritance patterns	3.7	4.3	902.5	0.01*	0.25	0.009*
Phenomena that make it difficult to interpret an inheritance pattern	3.3	3.7	949.0	0.03*	0.58	0.02*
Biological interferences	3.2	3.2	1231.5	0.89	6.44	0.89
Overall evaluation	3.4	3.7	994.0	0.07	0.82	0.03*

U (Mann-Whitney U Test Estimator), FB (Bayesian Factor), p (Probability Value) *Statistical significance

Table 3. Intergroup comparison of average academic performance according to the topics covered in the second measurement.

Topics	Control group	Experimental group	Traditional Inference		Bayesian inference	
			OR	p	FB	p
Inheritance patterns	3.65	4.08	738.5	0.04*	0.79	0.03*
Phenomena that make it difficult to interpret an inheritance pattern	4.34	4.64	839.5	0.19	1.79	0.10
Biological interferences	4.11	4.40	817,, 5	0.16	2.67	0.18
Overall evaluation	4.04	4.38	695.0	0.02	0.42	0.01

U (Mann-Whitney U Test Estimator), FB (Bayesian Factor), p (Probability Value) *Statistical significance

From the perspective of Bayesian statistics, extreme evidence was obtained to accept the alternative hypothesis that there are significant differences (FB <0.01) and for the overall rating very strong evidence (FB=0.02) (Table 4).

Similar results to those above were obtained when the two times were compared in the traditional group. Except for topic 1, the average scores of the others were higher for the rest of the topics with extreme evidence to accept the hypothesis that there are significant differences between both measurement times (table 5).

Table 4. Comparison of average academic performance according to the topics addressed in the experimental group between both periods

Topics	Time 0	Time 1	Traditional Inference		Bayesian inference	
			W	p	FB	p
Inheritance patterns	4.30	4.08	-1.57	0.11	2.91	<,001
Phenomena that make it difficult to interpret an inheritance pattern	3.69	4.64	-3.69	<,001	0.002	<,001
Biological interferences	3.22	4.40	-4.07	<,001	0.001	<,001
Overall evaluation	3.74	4.38	-3.42	<,001	,0220.	<,001

W (Wilcoxon Assigned Rank Test Estimator), FB (Bayesian Factor), p (Probability Value)

Table 5. Comparison of average academic performance according to the topics covered in the traditional group between both periods.

Topics	Time 0	Time 1	Traditional Inference		Bayesian inference	
			W	p	FB	p
Inheritance patterns	3.74	3.65	-0.83	0.40	4.99	0.30
Phenomena that make it difficult to interpret an inheritance pattern	3.25	4.34	-4.30	<,001	0.000	<,001
Biological interferences	3.19	4.11	-3.27	0.001	0.014	<,001
Overall evaluation	3.39	4.04	-3.45	<,001	0.20	<,001

W (Wilcoxon Assigned Rank Test Estimator), FB (Bayesian Factor), p (Probability Value)

It is important to note that these Bayesian results were more significant when comparing the two intragroup times than when comparing the two groups at each time, demonstrating that regardless of the method, there is indisputable time for the student to mature the new knowledge received. This finding is exceeded in average values by the experimental group.

4. Discussion

Recently, there has been a concerted effort within medical schools to move away from conventional lecture-based learning approaches and adopt alternative teaching methods, such as PBL, with the goal of improving both student engagement and instructional effectiveness (2). *PBL* emerge as an innovative educational methodology that transforms the way students acquire knowledge and skills. Unlike traditional teaching approaches, which often focus on transmitting information in a unidirectional manner, *PBL* promotes active and collaborative learning, where students become protagonists of their own educational process.

In this discussion, key findings are explored, analyzing how the *PBL method* not only improves students' conceptual understanding, but also prepares them to face challenges in professional contexts. Topic 3, chosen for the experiment, is a controversial content that meets the requirements for practical problem solving involving reasoning and interpretation by students, which justifies the use of the PBL method. It is a content that is exceptionally learned through theory; it requires solving exercises to apply the acquired knowledge. Tables 2 and 3 demonstrate the superiority of the PBL method when compared to the traditional method of the teaching-learning process at both times.

According to the authors of this article, there are reasons that justify the superiority of the method. First, *PBL* involves students in solving real problems, allowing them to apply the characteristics that define each inheritance pattern in practical situations, facilitating a deeper understanding (12-13). Second, they develop critical and analytical thinking skills, essential for interpreting phenomena as complex as the factors that hinder the interpretation of inheritance modes and biological interferences (14). Third, the method encourages group work, allowing them to It allows them to discuss and debate to enrich their learning through different perspectives (15). Fourthly, it encourages them to investigate, to look for information on their own to understand better (16). Fifthly, by presenting problems related to inheritance in real contexts, they can see the relevance of what they are learning. are learning, which increases their motivation and commitment (17). Sixthly, in the PBL method the assessment focuses on the learning process and not only on the results. It then offers the possibility to reflect on their understanding and to continuously improve. Lastly, and not least, PBL can be applied to various areas of study. It also provides students with the integration of knowledge from biology, embryology and other relevant fields for a more holistic understanding of heredity.

When reviewing the scientific literature, there are investigations with similar results where the PBL method was applied alone or combined with other methods, such as the research by Ding R et al (12), who demonstrated that it is an effective method combined with open and massive online courses capable of improving the learning effectiveness in university students of Prophylactic Medicine; Gumisirizah N et al (19) by demonstrating its effectiveness in high school students in Uganda; Barnawi A et al (20) whose professional performance of the tutors was evaluated by the students, obtaining positive results in all aspects of the PEA evaluated; and Mohammed MA et al (21). Qu M et al (22) carried out an experimental research similar to that of the present study, but applying the hybrid model of problem-based learning (hPBL), a combination of problem-based learning (PBL) and lecture-based learning (LBL), as a novel approach in the panorama of the reform of medical education in China, and higher scores were obtained in the hPBL model when compared to the LBL method. The hPBL model effectively amplified students' self-learning ability, practical application skills, and communication competencies. Another similar quasi-experimental research was conducted by Falahan SN et al (23) who involved 80 final year nursing students from Hamadan University of Medical Sciences, Iran. They comprised a control group of 40 students and an experimental group with the same number, however, these were further subdivided into different *WhatsApp subgroups* . After the intervention, both immediately and one month later, the experimental group showed remarkable improvements in the mean scores of CPR performance. A research developed by Li X. (24) compared two groups of 60 clinical medicine residents, these participants were randomly assigned to the combined teaching group Problem-Based Learning-Case-Based Learning (PBL-CBL) and Mini Clinical Evaluation Exercise (Mini-CEX) (experimental group) or to the traditional lecture-based teaching group (control group). The results were with significantly higher scores in the control group. Feng X et al. (25) investigated the effectiveness of the bridge, objective, pre-assessment, participatory learning, post-assessment and summary model combined with problem-based learning (BOPPPS-PBL) with traditional undergraduate teaching, and concluded that the BOPPPS-PBL method was effective in improving students' problem-solving ability and comprehensive practical ability compared to the traditional method.

Another research was conducted by Vasudevan J et al (26) to analyze the effectiveness of three innovative small group teaching models: tutorial technique (TT), problem-based learning (PBL) and fishbowl technique (FBT) in teaching basic concepts of epidemiology to third year medical students of a private medical college in Puducherry, South India. The superiority of PBL method over other methods was surprising. Yang Y et al (27) conducted a quasi-experimental study to demonstrate the effectiveness of combining case-based learning (CBL) and problem-based learning (PBL) with simulation teaching methods in improving the technical competence of midwives in training in management of postpartum hemorrhage at Peking University Third Hospital and concluded the superiority of the experimental group method.

In conclusion, all the reviewed research demonstrates the effectiveness of the PBL method alone or combined with other active teaching methods, consistency demonstrated in meta-analysis studies conducted by Zhang SL (28) and Cheng Y (29), who referred to the PBL method among the six best active teaching methods, as well as in the teaching of geriatric nursing.

The differences in the average score between both periods, higher in the second period, indicate that regardless of the method, time is needed to mature in the knowledge imparted. In the particular case of the PBL method, it requires time for the students to master the knowledge, as it involves an active and method-focused approach). This learning process can be longer compared to traditional methods, due to the need to research, collaborate and apply concepts in real-world contexts.

It is interesting to find that the content on inheritance patterns turned out to be the exception. Students get better grades in the first moment than in the second. This could be explained by the fact that it is the first topic taught and the first to be forgotten. In addition, they consider the content on biological interferences and phenomena that make it difficult to interpret a more complex

inheritance pattern, dedicating more study time to it. It is recommended that, based on the identification of inheritance patterns, the rest of the content of the topic be integrated.

The PBL method faces several challenges in today's education, such as the cognitive and emotional demands placed on students, the need for proper time management, and adaptation to virtual environments. In addition, effective implementation of PBL can be complex for teachers (30):

- In relation to the cognitive and emotional challenges related to students' ability to develop critical thinking and problem-solving skills, it can be overwhelming. The pressure of tackling authentic problems can lead to anxiety and stress, affecting their academic performance.
- Regarding time management factors, the nature of PBL requires students to spend significant time on research and collaboration, which can be challenging in an already packed curriculum. Instructors must balance time spent on traditional teaching with time needed for PBL, which can complicate lesson planning (31).
- The transition to online learning platforms can hinder student interaction and collaboration, key elements of PBL. Lack of adequate technological resources and connectivity can limit the effectiveness of PBL in virtual environments (32).
- Teacher training is important as many teachers are not familiar with the PBL approach, requiring additional training to implement it effectively. Resistance to change in teaching methodologies can be an obstacle to the adoption of PBL. The teaching staff shares their teaching duties with patient care, which makes it difficult to devote time to preparing content in active teaching methods.
- Finally, challenges related to the assessment component. Assessing learning in a PBL context can be complicated, as it focuses on processes and skills rather than just outcomes. (33)

Future research will be aimed at understanding the perception of teachers from other disciplines in which the method has not yet been implemented and the level of knowledge they have in relation to the challenges they might face in teaching practice, as well as applying the PBL method with other resources such as a *YouTube channel* with lectures designed for the subject.

Limitations of the research

It must be acknowledged that the classification bias could not be controlled by either the teachers or the students, especially the latter group, since many colleagues who were part of the experimental group participate in the study houses with their colleagues from the control group, and as much as this bias was taken into account when the project was drawn up and proposed in the training of the students, it was inevitable to transmit the experience among them. On the other hand, although to a lesser extent, the teachers of the experimental method were the same as those of the traditional method, so there was a risk of unconscious contamination of both methods during the process.

5. Conclusions

- The research demonstrates the superiority of the PBL method compared to the traditional method in the teaching-learning process of topic 3 of the Medical Genetics subject, which is a discipline whose analytical program allows the use of the method due to all the advantages it offers, however, it requires time for the student to acquire knowledge and skills.
- The PBL method was shown to have advantages over the traditional method, such as the promotion of motivation, an attractive teaching method for them, teamwork and deeper learning, by reviewing different bibliographic sources complementary to the subject, the visit to healthcare or research centres, where much of the acquired knowledge is verified in

clinical practice, was a motivating element that guaranteed the results achieved in the experimental method.

- The precept that is learned by doing is fulfilled. Academic skills are acquired in relation to the preparation of the family tree; communication through anamnesis to prepare the tree; identification of the inheritance pattern taking into account the characteristics of gene segregation, the factors that hinder Mendelian segregation and biological interferences; as well as estimating genetic risk, using probability theory.
- However, it is necessary to reflect on the weak points noted, based on the limited time of the analytical program that does not allow for its extension; the limited team of teachers on the faculty that prevents the formation of smaller tutorial teams with more personalized attention to learning needs; and the requirement for greater preparation on the part of the main actors in the process.

Supplementary material: Appendix. Questionnaire to assess knowledge at the first moment

Funding: No funding was available.
Acknowledgements: To the students who were subjects of the research. Without them, the study would not have been possible.

Declaration of conflict of interest: The authors declare that they have no conflict of interest.

Author contributions : Conceptualization: Roberto Lardoeyt Ferrer. Formal analysis: Roberto Lardoeyt Ferrer, Maritza Domínguez Méndez, Keny Alfonso Díaz, Zulema Quesada Soto. Supervision: Maritza Domínguez Méndez, Keny Alfonso Díaz, Zulema Quesada Soto, Tomás da Costa, Jovelino Kuanzambi. Writing-review and editing: Roberto Lardoeyt Ferrer, Maritza Domínguez Méndez, Keny Alfonso Díaz, Tomás da Costa, Jovelino Kuanzambi.

References

1. Silva M, Almeida M, Ferreira J. Complete guide for the application of active methodologies in higher education. *Brazilian Higher Education Magazine*. **2022**, 14(2), 45-60. https://doi.org/10.1590/rbes.2022.0142 .
2. Zhang W, Wei J, Guo W, Wang Z, Chen S. Comparing the effects of team-based and problem-based learning strategies in medical education: a systematic review. *BMC Med Educ*. **2024**, 24(1), 172. https://doi.org/10.1186/s12909-024-05107-9 .
3. Admilson EP, Sávio EOM, Finelli LAC. Learner's view of the active "Problem Based Learning"–PBL methodology. *Humanities* **2016**, 5(2). https://revistahumanidades.com.br/arquivos_up/ artigos/a103.pdf
4. Santos AM, Salgado A, Barreto JF, Martins H & Dores AR. Problem-Based Learning and its implications: Brief theoretical review. *Proc. 1st ICH Gaia-Port* o, Portugal, **2010**. https://recipp.ipp.pt/entities/publication/72c820be-a450-4f75-94bf-bcec09ee7e42
5. Dos Santos RS. Or problem-based learning. *R. Bras. Educ. Med*. **2023**, 1, 86-95. https://www.scielo.br/j/rbem/a/CMdmWZgGQYY5TNSnpjDyM8F/
6. Kim MM, Kramer M. Should the concepts chosen to guide concept-based curricula be threshold concepts? *Nurse Education Today*. **2023**, 120. https://doi.org/10.1016/j.nedt.2022.105614
7. Athena L, Bilgic E, Keuh A and Sibbal M. Does your group matter? How group function impacts educational outcomes in problem-based learning: a scoping review. *BMC Medical Education* . **2022** , 22, 900. https://doi.org/10.1186/s12909-022-03966-8
8. Yan Y, Yuehong W, Kun L, Hongbo Z, Hongyu Z, Yingming Y and Zhili Z. Implementation of mind mapping with problem-based learning in prosthodontics course for Chinese dental students. *BMC Medical Education*. **2023**, 23, 530. https://doi.org/10.1186/s12909-023-04479-8
9. Choi YR, Lee YN, Kim D, Park WH, Kwon DY and Chang SO. An e-Problem-Based Learning Program for Infection Control in Nursing Homes: A Quasi-Experimental Study. *Int. J. Environ. Public Health Res.* **2022**, 19, 13371. https://doi.org/10.3390/ijerph192013371
10. Saidou II, Egodage Y, Pino GB. Problem-based learning. Its implementation in medicine and in the subject of pathological anatomy. *Rev. Cient estud Esc Latin Medicina.* **2020**, 3(1). https://revcienciaconciencia.sld.cu/index.php/ciencia-conciencia/article/view/3 2

11. Wagenmakers EJ, Marsman M, Jamil T, et al. Bayesian inference for psychology. Part I: Theoretical advantages and practical ramifications. *Psychon Bull* Rev. **2018,** 25(1), 35-57. https, //doi.org/10.3758/s13423-017-1260-2 .
12. Sánchez JA, García M. Problem-based learning in higher education, an analysis of its effectiveness. *Rev Educ Sup.* **2020,** 49(1), 45-62. https, //doi.org/10.1016/j.jes.2020.01.003 .
13. Ding R, Cheng H. Improving undergraduate education of occupational health and occupational medicine applying massive open online courses & problem-based learning. *BMC Med Educ.* **2024**, 24(1), 188. https, //doi.org/10.1186/s12909-024-05179-7 .
14. Hernández A, López M. Impact of problem-based learning on the academic performance of biology students. *J Biol Educ.* **2021,** 55(2), 123-35. https, //doi.org/10.1080/00219266.2020.1761234 .
15. Koh GCH, Barrows HS. The impact of problem-based learning on the development of critical thinking skills in medical students, A systematic review. *Med Educ.* **2021**, 55(3), 305-16. https, //doi.org/10.1111/medu.14345 .
16. Bennett D, O'Connor M. Enhancing student engagement and learning outcomes through problem-based learning in higher education. Int J Teach Learn High Educ. **2022**, 34(1), 1-12. Available at, https,://www.southwestern.edu/academics/ijtlhe/ .
17. Meyer JHF, Land R. Threshold concepts and troublesome knowledge, Linkages to ways of thinking and practicing within the disciplines. *High Educ*. **2020**, 79(3), 455-71. https, //doi.org/10.1007/s10734-019-00456-3 .
18. Ding R, Cheng H. Improving undergraduate education of occupational health and occupational medicine applying massive open online courses & problem-based learning. *BMC Med Educ*. **2024** , 24(1), 188. https, //doi.org/10.1186/s12909-024-05179-7 .
19. Gumisirizah N, Nzabahimana J, Muwonge CM. Students' performance, attitude, and classroom observation data to assess the effect of problem-based learning approach supplemented by YouTube videos in Ugandan classroom. *SciData.* **2024** , 11(1), 428. https, //doi.org/10.1038/s41597-024-03206-2 .
20. Barnawi A, Sonbol AM, Al-Shawwa L, Abulaban A, Asiri K, Bagasi A, Alafari R, Alamoudi AA. Employing students' evaluations and tutors' perceptions to evaluate a faculty development program on problem-based learning at the Faculty of Medicine, King Abdulaziz University. *BMC Med Educ*. **2024**, 24(1), 708. https, //doi.org/10.1186/s12909-024-05662-1 .
21. Mohammed MA, Ali IA. Problem-based learning is helpful in encouraging academic institutions to strive for excellence, perceptions of Sudanese physiologists as an illustration. *BMC Med Educ.* **2024**, 24(1), 1279. https, //doi.org/10.1186/s12909-024-06285-2
22. Qu M, Hou Q, Yu C, Li X, Xia J, Dong Z. Application and evaluation of the hybrid "Problem-Based Learning" model based on "Rain Classroom" in experimental courses of medical molecular biology. *Front Med* (Lausanne). **2024**, 11, 1334919. https, //doi.org/10.3389/fmed.2024.1334919
23. Falahan SN, Habibi E, Kamyari N, Yousofvand V. Impact of virtual problem-based learning of cardiopulmonary resuscitation on fourth-year nursing students' satisfaction and performance, a quasi-experimental study. *BMC Med Educ*. **2024**, 24(1), 425. https, //doi.org/10.1186/s12909-024-05375-5
24. Li X. Application of PBL-CBL and Mini-CEX methods in the standardized training of residents in nephrology department, A prospective study. *Pak J Med Sci*. **2024** , 40(9), 2046-2051. https, //doi.org/10.12669/pjms.40.9.9434 .
25. Feng X, Wu W, Bi Q. Reform of teaching and practice of the integrated teaching method BOPPPS-PBL in the course "clinical haematological test technique". *BMC Med Educ.* **2024** , 24(1), 773. https, //doi.org/10.1186/s12909-024-05765-9 .
26. Vasudevan J, Chellamuthu L, Anandaraj L, Chalil AK. Effectiveness of selected small group teaching methods for undergraduate medical students on basic concepts of epidemiology, A quasi-experimental study. *J Educ Health Promot.* **2024**, 13, 143. https, //doi.org/10.4103/jehp.jehp_1046_23 .

27. Yang Y, Guo Z, Guo X, Zhao Y. Enhancing postpartum hemorrhage training by integrating case-problem based learning with simulation, a quasi-experimental study. *J Obstet Gynaecol.* **2025**, 45(1), 2443617. https, //doi.org/10.1080/01443615.2024.2443617 .
28. Zhang SL, Ren SJ, Zhu DM, Liu TY, Wang L, Zhao JH, Fan XT, Gong H. Which novel teaching strategy is most recommended in medical education? A systematic review and network meta-analysis. *BMC Med Educ*. **2024**, 24(1), 1342. https, //doi.org/10.1186/s12909-024-06291-4 .
29. Cheng Y, Sun S, Hu Y, Wang J, Chen W, Miao Y, Wang H. Effects of different geriatric nursing teaching methods on nursing students' knowledge and attitude, Systematic review and network meta-analysis. *PLoS One*. **2024**, 19(5), e0300618. https, //doi.org/10.1371/journal.pone .
30. Gürses, A., Sahin, E., & Günes, K. Investigation of the Effectiveness of the Problem-Based Learning (PBL) Model in Teaching the Concepts of «Heat, Temperature and Pressure» and the Effects of the Activities on the Development of Scientific Process Skills. *Education Quarterly Reviews*, **2022** , 5(2), 67-73.
31. Rivera, M. Using problem-based learning to identify challenges in research skills in graduate students. *TEKNÉ Journal of Social Sciences and Humanities*, **2024**, 1(1). https://revistas.unitec.edu/tekne/article/view/308
32. García R, Martínez A. The impact of problem-based learning methods in education. *Pol Conoc.* **2022,** 10(1), 45-60. https://polodelceso.com/ojs/index.php/es/article/download/8582/22355 .
33. Torres L, Sánchez P. Problem-based learning (PBL) as a predictor of skills development. Amelica. 2024, 12(3), 200-215. https://portal.amelica.org/ameli/journal/717/7174847004/html

Appendix. Questionnaire to assess knowledge at the first moment

Mark with a cross (X) the only correct answer in the following situations.

1. A pregnant woman and her partner receive the results regarding the type of hemoglobin at the family doctor's office. The pregnant woman has Hb AS and her husband AC. The pregnant woman asks you: What is the risk of having children with Hb SC? __0% __25% __50% ___100%
2. The couple remains anxious because they fear that their offspring will be sick with HSS. Do you believe in this possible hypothesis? ___Yes ___No.
3. If your answer is affirmative to the previous question, please mention the mechanism that supports it?: _____
4. If the ultrasound at 18 weeks determines the sex of the fetus, could this modify the genetic risk? ___Yes ___No
5. Suppose you are on a mission in Ecuador and you see a healthy woman who has been married twice and on both occasions has had a genetic disease such as achondroplasia, which has an autosomal dominant inheritance pattern. She asks you what risk she has of having a third child with the disease if she stays with her current man? __0% ___25% __50% __100%
6. Mention a genetic mechanism that could explain the previous selection:_____.
7. Petra comes to your office, pregnant, and in that first consultation you ask her about her family history of illnesses. She tells you that in all generations on her father's side, including her first child, bones are fragile and can fracture. You look in the literature and see that it is an Osteogenesis imperfecta, a disease whose gene is found on chromosome 17. She asks what the probability is of having healthy offspring like her if her husband is healthy and has nothing to do with her father-in-law's family. __0% ___25% ___50% ___100%
8. Mention a genetic mechanism that could explain the above selection:_____
9. In your office you see a young woman who appears to be healthy. She tells me that her father died of progressive muscle weakness. Her nephews have this disease (children of her two sisters). As do two paternal uncles who have two healthy boys. There is no history of this disease on her mother's side. She asks what is the probability of having daughters affected by the disease? __0% __25% __50% __75% __100%
10. In relation to the previous question, do you think it would be important and helpful to know the sex of the fetus in the ultrasound program? __Yes __No

11. Mention the inheritance pattern that could justify the previous answer? _____
12. Do you think it is wrong that the pregnant woman could have, like her sisters, clinical but mild manifestations of the disease? __Yes __No
13. Depending on the previous answer, explain the genetic mechanism that could justify your choice? _____
14. In your health area you see a large family with café-au-lait spots and peripheral nodules. You see in the literature that this is NF type 1. When you make the tree you notice that the descendants of the women have nodules and bone fractures in addition to the spots, however, the descendants of the men only have café-au-lait spots. What is the name of the genetic mechanism that demonstrates the spectrum or the wide range of clinical manifestations of the disease? _____
15. In the specific case of the previous question, the clinical manifestations are dependent on the parent who contributes the defective gene. What is this genetic mechanism called? _____