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ORIGINAL ARTICLE

Problem-based learning as a didactic strategy to develop the skill of diagnostic imaging

Aprendizaje basado en problemas como estrategia didáctica para desarrollar la habilidad diagnóstico por imagen

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ABSTRACT

Background: Diagnostic imaging skills in Family Medicine residents present deficiencies, which affects clinical competence.

Objective: To evaluate the effectiveness of a didactic strategy centered on problem-based learning for the development of diagnostic imaging skills in Family Medicine residents at the Juana Naranjo León University Polyclinic.

Methods: A quasi-experimental study with an interrupted time-series design was conducted in 28 Family Medicine residents at the Juana Naranjo León University Polyclinic in Sancti Spíritus, Cuba. The ACTIVE DIAGNOSIS strategy was implemented over 42 weeks in four phases (diagnosis, immersion, application, consolidation) using a blended learning format (120 hours, 25 clinical cases). Three-dimensional assessment (cognitive, procedural, affective-motivational) used instruments validated by 15 experts (agreement 0.82; content validity 0.78). Theoretical methods (analytical-synthetic, systemic-structural), empirical methods (observation, surveys, focus group, portfolios), and statistical methods (paired-samples t-tests, repeated-measures ANOVA, Wilcoxon, Kruskal-Wallis, Pearson correlations, sensitivity analysis) were employed.

Results: Improvements ($p<0.001$) were observed in all dimensions. Cognitive ability increased from 48.3 to 82.4 points ($t(27)=18.45$, $d=2.34$); 78.6% of residents reached an advanced level in procedural skills (Wilcoxon $Z=4.68$); and self-efficacy grew from 2.1 to 4.3. Critical self-reflection was developed by 85.7%. A strong correlation was found between procedural skill and metacognition ($r=0.74$), and 71.4% applied the protocols in clinical practice. Sensitivity analysis confirmed the robustness of the findings.

Conclusions: The didactic strategy demonstrated high effectiveness for developing diagnostic imaging skills, thereby favoring meaningful and contextualized learning in clinical case resolution.

MeSH: internship and residency; education, medical, graduate; problem-based learning; strategies; community medicine; education, medical

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RESUMEN

Fundamento: la habilidad diagnóstico por imagen en residentes de Medicina Familiar presenta deficiencias, lo cual afecta la capacidad clínica.

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Objetivo: evaluar la efectividad de una estrategia didáctica centrada en el aprendizaje basado en problemas para el desarrollo de la habilidad diagnóstico por imagen en residentes de Medicina Familiar del Policlínico Universitario Juana Naranjo León.

Métodos: estudio cuasiexperimental con diseño de serie temporal interrumpida, en 28 residentes de Medicina Familiar del Policlínico Universitario Juana Naranjo León, en Sancti Spíritus, Cuba. Se implementó la estrategia DIAGNÓSTICO ACTIVO durante 42 semanas en cuatro fases (diagnóstico, inmersión, aplicación, consolidación) con modalidad semipresencial (120 horas, 25 casos clínicos). La evaluación tridimensional (cognitivo, procedimental, afectivo-motivacional) utilizó instrumentos validados por 15 expertos (concordancia 0,82; validez de contenido 0,78). Se emplearon métodos teóricos (analítico-sintético, sistémico-estructural); empíricos (observación, encuestas, grupo focal, portafolios) y estadísticos; (pruebas t para muestras relacionadas, ANOVA de medidas repetidas, *Wilcoxon, Kruskal-Wallis*, correlaciones de *Pearson*, análisis de sensibilidad).

Resultados: se observaron mejorías ($p<0,001$) en todas las dimensiones. La capacidad cognitiva aumentó de 48,3 a 82,4 puntos ($t(27) = 18,45$, $d=2,34$), el 78,6 % de residentes alcanzó nivel avanzado en habilidades procedimentales (*Wilcoxon* $Z=4,68$), y la autoeficacia creció de 2,1 a 4,3. El 85,7 % desarrolló autorreflexión crítica. Hubo fuerte correlación entre habilidad procedimental y metacognición ($r=0,74$), y el 71,4 % aplicó los protocolos en práctica clínica. El análisis de sensibilidad confirmó el rigor de los hallazgos.

Conclusiones: la estrategia didáctica demostró alta efectividad para el desarrollo de la habilidad diagnóstico por imagen, lo cual favoreció el aprendizaje significativo y contextualizado en la resolución de casos clínicos.

DeSC: internado y residencia; educación de postgrado en Medicina; aprendizaje basado en problemas; estrategia; medicina comunitaria; educación médica

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INTRODUCCIÓN

Postgraduate medical education recognizes the development of diagnostic skills as a foundation for professional performance.[1] Diagnostic imaging ability is conceptualized as an integrated system of cognitive, procedural, and evaluative actions that allows selecting, interpreting, and integrating imaging studies to establish a reasoned diagnosis.[2] Problem-based learning (PBL) emerges as a suitable didactic strategy for developing complex skills through the analysis of real or simulated situations.[3,4]

Internationally, the integration of imaging into the medical curriculum is gaining importance, driven by technological advances and the need to optimize diagnostic accuracy. However, challenges persist, such as the fragmentation between theory and clinical practice, and limited practice in correlating radiological findings with patient symptoms.[1,5] Lawal *et al*.,[6] and Bisbee *et al*.,[4] underscore the urgency of implementing active methodologies that overcome rote learning.

In the Latin American context, initiatives to strengthen diagnostic imaging development face limitations: material constraints, curricular overload, and insufficient faculty development. Bernal Bastidas *et al*.[7] point out the need to design flexible didactic strategies adapted to local realities, prioritizing not only technical mastery but also the capacity for epidemiological and sociocultural contextualization, characteristic of Primary Health Care (PHC). In Cuba, although the Family Medicine model is advancing in human resources training, diagnostic imaging teaching does not achieve the required systematicity. There is a disconnect between theoretical training and its practical application in problem-solving;[8] this translates into difficulties for residents in interpreting basic studies, producing coherent reports, and communicating findings effectively.[9]

At the Juana Naranjo León University Polyclinic in Sancti Spíritus, previous pedagogical diagnoses show that Family Medicine residents have a low level of development in the aforementioned skill. Identified problems include insufficient systematization of imaging content, limited practice in the methodical interpretation of images, and poor integration of clinical knowledge with radiological findings.[8,9,10] These deficiencies not only affect the

quality of specialized training but also directly impact patient care and the problem-solving capacity of the primary care level.

In accordance with the above, this research aims to: evaluate the effectiveness of a didactic strategy centered on problem-based learning for the development of diagnostic imaging skills in Family Medicine residents at the Juana Naranjo León University Polyclinic.

METHODS

A quasi-experimental study with an interrupted time-series design and repeated measurements, based on the socio-critical paradigm, was conducted at the Juana Naranjo León University Polyclinic in Sancti Spíritus, Cuba, between September 2024 and June 2025 (42 weeks). The intervention was structured into 30 weeks of intensive activities and 12 weeks of consolidation and follow-up. The setting included a specialized classroom, a digital image archive, and support from imaging specialists as facilitators.

The sample size was calculated using the finite population formula, with parameters: n=42, Z=1.96 (95% confidence), p=0.5 (maximum variability), and e=0.05 (maximum error), obtaining a requirement of 38 participants. Thirty were selected through stratified random sampling, by year of residency and prior academic performance. The final selection included 10 residents per year, with high, medium, and low levels.

Selection criteria:

- Inclusion criteria: active residents for the entire period, informed consent, commitment to participate ≥80%, and initial assessment showing educational needs (score <60 on cognitive test or level 1 on procedural rubric).
- Exclusion criteria: prior formal imaging experience >6 months, concurrent participation in other intervention studies, limiting medical conditions, or external rotations for >30% of the period.

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- Elimination criteria: protocol non-compliance, resignation from residency, unjustified absences >20%, or voluntary withdrawal from the study.

Operationalized variable system:

Independent variable: ACTIVE DIAGNOSIS didactic strategy based on PBL, characterized by: intensity (120 hours over 30 weeks), frequency (2 weekly sessions of 2 hours each), modality (60% face-to-face, 40% virtual), sequencing (progression of increasing complexity), and resources (operational manual, 25 anonymized real clinical cases, validated rubrics).

Main dependent variable: level of development of diagnostic imaging skill, operationalized three-dimensionally:

1. Cognitive dimension: objective test of 50 items (0-100 points) assessing: physical/technical principles (16 items), radiological semiology (22 items), and study selection criteria (12 items).
2. Procedural dimension: structured observation rubric with 12 specific criteria rated on a four-level scale (1=Incipient, 4=Expert), organized into four domains: systematic interpretation, clinical-imaging correlation, diagnostic report issuance, and complementary study selection.
3. Affective-motivational dimension: self-efficacy and attitudes questionnaire with 20 items on a 5-point Likert scale, assessing four constructs: perceived self-efficacy, attitude toward autonomous learning, collaborative work skills, and anxiety level.

Methods and techniques used:

Theoretical methods:

- Analytical-synthetic: systematically applied to process and organize bibliographic sources, enabling the deconstruction and reconstruction of theoretical references.

- Inductive-deductive: recursively implemented to generate conclusions based on empirical evidence, creating logical bridges between particular findings and general theoretical frameworks.
- Historical-logical: for the diachronic reconstruction of the evolution of the object of study, identifying regularities and trends in its temporal development.
- Systemic-structural-functional: used as a basis for the coherent design of the integrated didactic strategy, considering interrelationships between structural and functional components.
- Modeling: for the abstract representation of the skill development process, allowing visualization of essential dimensions and their internal relationships.

Empirical methods:

- Documentary analysis: conducted on study programs, teaching guides, and evaluation records using a validated documentary analysis form that considered 12 specific analysis criteria.
- Scientific observation: performed in structured and participant modalities, using an observation guide with 15 predefined categories complemented by field diary entries.
- Self-perception skills questionnaire: with adequate psychometric validation, demonstrating content validity of 0.85 and reliability of 0.88 in pilot tests.
- Pedagogical test: an instrument for assessing practical skills was designed and implemented, including eight standardized cases and a detailed correction rubric.
- Semi-structured interview: with tutors and teaching coordinators, using a thematic guide containing 10 core questions to explore qualitative aspects in depth.
- Focus group: organized for the qualitative evaluation of the implementation process, based on a discussion guide structured around six thematic axes.
- Analysis of activity products: diagnostic reports were systematically evaluated using an eight-criterion quality rubric. Electronic portfolios were assessed with a specific rubric that included metacognitive self-reflection; this criterion was later used to analyze its correlation with procedural skills.

- Methodological triangulation: systematically implemented to achieve convergence of sources, methods, and analytical perspectives, thereby strengthening the internal validity of the study.

For qualitative analysis of focus group data, semi-structured interviews, and portfolios, the thematic analysis method was employed. Two researchers independently performed coding, and discrepancies were resolved by consensus. Thematic saturation was achieved in the qualitative data.

Statistical-mathematical methods:

1. Descriptive statistics: measures of central tendency (mean, median), dispersion (standard deviation, interquartile range), and distribution (skewness, kurtosis) were calculated.
2. Statistical inference: for pre-intervention / post-intervention comparisons, paired-sample Student's t-test (with Cohen's d effect size) was used for normally distributed variables, and Wilcoxon signed-rank test for ordinal rubrics. Baseline differences between years were analyzed using the Kruskal-Wallis test.
3. Repeated-measures ANOVA: analyzed the improvement trend across evaluation time points. Sphericity was verified with Mauchly's test, and Greenhouse-Geisser corrections were applied when necessary.
4. Correlation analysis: Pearson correlation coefficient was used to evaluate bivariate relationships between dimensions of the dependent variable.
5. Sensitivity and imputation analysis: to manage the 6.7% participant loss, a worst-case scenario imputation approach was applied, and main analyses were repeated with these data to verify consistency of findings.
6. Software and significance: all quantitative analyses were processed with SPSS v.25, and a statistical significance level was set at $p < 0.050$.
7. Subgroup analysis: given the sample size, non-parametric methods (Kruskal-Wallis and Wilcoxon tests) were used to compare between years and pre-/post-intervention. Stratified analyses by year were also performed to identify differential effectiveness patterns.

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Expert validation process:

Instrument and strategy validation was conducted through a multidisciplinary panel of 15 experts, selected using the competence coefficient method (K ≥ 0.6). The panel integrated specialists in Medical Education (5), Imaging (4), Educational Research (3), and Family Medicine (3), who verified the relevance and fairness of the instruments for each year of residency.

Experts were chosen using an algorithm with weighted criteria: professional experience ≥15 years (weight 0.5), Doctor of Sciences degree (0.3), and indexed publications on the topic (0.2). The panel had an average experience of 18.7 ± 3.2 years; 100% held main teaching qualifications, 86.7% had publications in Scopus or Web of Science, and 73.3% had prior experience in instrument validation.

The validation process was conducted in three consecutive iterative rounds:

Round I: assessment of theoretical relevance and contextual adequacy using a 5-point Likert scale on 12 relevance dimensions. Response rate 100%.
Round II: analysis of internal consistency and construct validity using consistency matrices and a modified Delphi method with two evaluation cycles.
Round III: establishment of final agreements on applicability and feasibility using the nominal group technique, with a consensus criterion of ≥80%.

The resulting quality indicators were: inter-judge agreement index (IA) of 0.82 (95% CI 0.78-0.86); internal consistency coefficients α=0.89 for cognitive instruments, α=0.84 for affective-motivational ones, and α=0.87 for procedural rubrics; and an overall content validity ratio (CVR) of 0.78, exceeding the Lawshe cut-off point (0.49). The process concluded with a unanimous favorable opinion.

Design and implementation of the didactic strategy:

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It was conceptualized as an instructional system structured into four interconnected phases that incorporated pedagogical differentiation mechanisms to accommodate the different experience levels across the three residency years:

Phase I: Comprehensive diagnosis (6 weeks) (September–October 2024):This phase established the formative starting point through an initial multidimensional assessment (objective test, structured observation, and self-assessment), and an individual and group needs analysis using a SWOT matrix. As a result, initial skill profiles with specific gaps were elaborated, heterogeneous collaborative groups were formed, and individualized learning contracts with negotiated goals were signed.

Phase II: Progressive immersion (12 weeks, 40 total hours) (October–December 2024):
A gradual immersion process in essential contents was developed, structured into three sequential modules:

Module 1: Physical and technical fundamentals (12 hours, 6 sessions)
Module 2: Systematic radiological semiology (16 hours, 8 sessions)
Module 3: Principles of contextualized interpretation (12 hours, 6 sessions)
Instructional strategies included collaborative learning, guided case studies, and basic simulations, supported by an interactive digital atlas, a bank of normal images, and standardized reading protocols.

Phase III: Application in real context (18 weeks, 56 total hours) (January–April 2025): This phase was oriented toward knowledge transfer to authentic professional situations. Eight problem scenarios of increasing complexity were developed, simulating real practice contexts. Activities included:

- Critical image reading sessions (20 hours, 10 sessions)
- Clinical-imaging correlation workshops (20 hours, 10 sessions)
- Diagnostic report writing laboratories (16 hours, 8 sessions)

The process was complemented with personalized mentoring and structured feedback using the validated rubrics.

Phase IV: Consolidation and transfer (6 weeks, 14 total hours) (May 2025 – June 2025): This phase consolidated learning and facilitated its professional transfer. Integrative evaluation was carried out through objective structured clinical examination (OSCE) stations. Each participant developed an electronic portfolio with 15 required products, guided metacognitive reflection sessions were implemented, and a continuous professional development plan with objectives to be met within six months was designed.

The research was governed by the ethical principles established in the Declaration of Helsinki.[11] Informed consent was obtained from all participating physicians. Strict confidentiality of personal and professional data was guaranteed, with protocols established for exclusive use for research purposes. The complete protocol received formal approval from the Research Ethics Committee of the health institution.

RESULTS AND DISCUSSION

The intervention achieved an adherence rate of 93.3%. Of the initial sample of 30 residents (10 per year), two (6.7%, one from each of the first two years) withdrew from the study. Consequently, post-baseline analyses were performed with 28 participants (9 first-year, 9 second-year, 10 third-year), while baseline analyses included the initial 30. A sensitivity analysis confirmed the validity of the findings despite this loss.

Documentary analysis of study programs, teaching guides, and evaluation records confirmed the disconnect between theoretical training in imaging and its practical application in the residency curriculum in the studied context.

Scientific observation of the procedural dimension (n=30) showed that at baseline, 76.7% (n=23) of residents were at level 1 (Incipient), with a differentiated distribution by year: 40% of third-year residents (n=4) at level 2, compared to 10% (n=1) in first year and 20%

(n=2) in second year. Inter-observer consistency was good (Kappa=0.78; 95% CI 0.72-0.84).

Table 1 shows the procedural evolution during the intervention, assessed through continuous observation of clinical case resolution (n=28), which evidenced progressive improvement, confirmed by a repeated-measures ANOVA $F(3.81)=45.23$, $p<0.001$, $\eta^2=0.63$).

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Table 1. Evolution of procedural indicators during implementation by case quartiles (n=28). Juana Naranjo León University Polyclinic. Sancti Spíritus. September 2024-junio 2025

Indicators	Cases 1-2 (Mean ± SD)	Cases 3-4 (Mean ± SD)	Cases 5-6 (Mean ± SD)	Cases 7-8 (Mean ± SD)	p trend
Relevant findings identified per case	3,2 ± 1,1	4,8 ± 1,3	5,9 ± 1,0	6,7 ± 0,8	<0,001
Well-founded diagnostic hypotheses (%)	28.6 %	52.4 %	71.4 %	85.7 %	<0,001
Clinical-imaging correlations per case	2,1 ± 0,9	3,5 ± 1,1	4,3 ± 1,2	5,2 ± 0,9	<0,001
Report quality (scale 1–4)	1,4 ± 0,5	2,1 ± 0,6	2,8 ± 0,5	3,3 ± 0,4	<0,001
Interpretation time (minutes)	24,3 ± 6,7	19,8 ± 5,2	16,2 ± 4,1	13,5 ± 3,3	<0,001

Source: PBL session records and formative evaluations. October 2024 – April 2025.

Repeated-measures ANOVA: $F(3.81)=45.23$, $p<0.001$, $\eta^2=0.63$

From the third case onward, the formulation of well-founded hypotheses improved from 28.6% to 52.4%. Third-year residents managed to integrate up to 5.8 ± 0.7 correlations per case ($\beta=0.76$, $p<0.001$, $R^2=0.58$). Collaborative work improved (participation index: from 0.42 ± 0.15 to 0.78 ± 0.11; $p<0.001$). In the final procedural assessment (n=28), 78.6% (n=22) reached the "Advanced" level or higher, as shown in Table 2, with an overall improvement (Wilcoxon $Z=4.68$, $p<0.001$).

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Table 2. Distribution of residents (n=28) according to final mastery level by procedural domains. Juana Naranjo León University Polyclinic. Sancti Spíritus. September 2024 – June 2025

Procedural domain	Level 1 (Incipient) n (%)	Level 2 (Developing) n (%)	Level 3 (Advanced) n (%)	Level 4 (Expert) n (%)
Systematic interpretation	0 (0.0)	2 (7.1)	18 (64.3)	8 (28.6)
Clinical-imaging correlation	0 (0.0)	4 (14.3)	16 (57.1)	8 (28.6)
Diagnostic report issuance	0 (0.0)	6 (21.4)	17 (60.7)	5 (17.9)
Complementary study selection	0 (0.0)	5 (17.9)	15 (53.6)	8 (28.6)

Source: Validated rubric (May–June 2025).

Note: Percentages correspond to residents (n=28) per domain; the 78.6% with an overall level ≥3 resulted from an integrated rubric that weighted the four domains.

There was a significant overall improvement (Wilcoxon $Z=4.68$, $p<0.001$) and high inter-rater consistency (ICC=0.84; 95% CI 0.79-0.88).

The baseline survey (n=30) showed ambivalent attitudes: 73.3% (n=22) recognized the importance of the skill (4.2±0.6), but with low self-efficacy (2.1±0.8) and high anxiety (1.8±0.9). The factor model was adequate (KMO=0.84; $p<0.001$).

The final assessment (n=28) showed improvements in self-efficacy (4.3±0.5 vs. 2.1±0.8; $t(27)=12.34$, $p<0.001$, $d=1.87$) and reduced anxiety (3.8±0.6 vs. 1.8±0.9; $t(27)=9.87$, $p<0.001$, $d=1.56$). Satisfaction with PBL was 92.9% (n=26). Self-efficacy was the strongest predictor of final procedural performance ($\beta=0.62$, $p<0.001$).

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The baseline cognitive pedagogical test (n=30) showed a mean of 48.3±8.7 points, with significant differences by year (Kruskal-Wallis $\chi^2(2)=8.45$, $p=0.001$). A total of 76.7% (n=23) were below the cut-off point (60 points). The results are presented in Table 3.

Table 3. Distribution of residents according to initial level of cognitive mastery (n=30). Juana Naranjo León University Polyclinic. Sancti Spíritus. September 2024 – June 2025

Year of residency	Low Level n (%)	Medium Level n (%)	High Level n (%)	Mean ± SD
First year	9 (90,0)	1 (10,0)	0 (0)	42,1 ± 6,8
Second year	8 (80,0)	2 (20,0)	0 (0)	47,2 ± 7,5
Third year	6 (60,0)	4 (40,0)	0 (0)	58,3 ± 7,2
Total	23 (76,7)	7 (23,3)	0 (0)	48,3 ± 8,7

Source: Initial pedagogical test of the complete sample (n=30). (September 2024)

Kruskal-Wallis test: $\chi^2(2)=8.45$, $p=0.001$.

The two residents who withdrew from the study were excluded from the analysis following this baseline assessment.

The final cognitive assessment (n=28) showed a mean of 82.4 ± 6.3 points (range: 68-94), with an absolute improvement of 34.1 points from the initial assessment ($t(27)=18.45$, $p<0.001$, $d=2.34$). A total of 75% of residents (n=21) reached the high level of ability. Repeated-measures analysis confirmed a significant main effect of the evaluation time point ($F(1,27)=340.56$, $p<0.001$, $\eta^2=0.93$).

Thematic analysis of interviews and focus groups (n=28 participants, plus tutors) revealed a positive perception of the development of autonomy, clinical reasoning, knowledge integration, usefulness of real cases, and increased diagnostic confidence, achieving thematic saturation.

Portfolio and report analysis (n=28) showed that 85.7% of residents (n=24) developed critical self-reflection, and 71.4% (n=20) consistently transferred the protocols to clinical practice.

Correlation analysis (n=28) confirmed positive and significant associations (p<0.010) between all dimensions. The strongest correlation was between procedural skill and metacognition (r=0.74; p<0.001). The figures are shown in Table 4.

Table 4. Bivariate correlation analysis between dimensions (n=28). Juana Naranjo León University Polyclinic. Sancti Spíritus. September 2024 – June 2025

Dimensions	Cognitive	Procedural	Affective-Motivational	Metacognition
Cognitive	1,00	0,68**	0,59**	0,63**
Procedural	0,68**	1,00	0,72**	0,74**
Affective-Motivational	0,59**	0,72**	1,00	0,66**
Metacognition	0,63**	0,74**	0,66**	1,00

Source: Pearson correlation analysis based on post-intervention data. June 2025. ** p < 0.010

Sensitivity and fidelity analysis

The intervention concluded with an adherence rate of 93.3% (n=28). For third-year residents, a flexible face-to-face attendance criterion (85%) was applied, while 100% of asynchronous activities were maintained. As mentioned, two residents (6.7%) withdrew from the study (one first-year and one second-year), so the final sample consisted of 9, 9, and 10 residents from the first, second, and third years, respectively. Sensitivity analysis, using worst-case scenario imputation (n=30), confirmed the validity of the results: pre-/post-intervention differences retained their statistical significance in the cognitive dimension (t(29)=15.32, p<0.001, d=2.1), procedural dimension (Wilcoxon Z=4.45, p<0.001), and affective-motivational dimension (t(29)=10.21, p<0.001, d=1.4). Multiple imputation

analysis yielded consistent results (d=2.28; Z=4.60; d=1.52). Evaluation using the CIPP model showed 88.3% fidelity to the protocol.

The most evident transformation occurred in the cognitive domain, where residents evolved from memorizing isolated findings to constructing coherent interpretative frameworks. This corroborates that PBL facilitates better-organized knowledge networks for practical application.[12] This advancement is crucial, as the main difficulty lay in integrating findings into contextualized clinical reasoning,[13] as reflected by the improvements obtained in clinical-imaging correlation.

The most significant finding lay in the evolution of procedural skills. The ability to generate well-founded hypotheses and issue structured reports suggests that PBL promoted "hypothetical-deductive reasoning" in the technical domain,[14] a finding consistent with the development of critical thinking reported by Arruzza *et al.*;[15] however, these results contrast with studies such as that by Patil *et al.*,[5] who found persistent difficulties in such correlation, suggesting that the longitudinal and progressive nature of the present strategy may have been key to overcoming this gap.

In fact, the experience of Patil *et al.*,[5] with PBL in radiology rotations corroborates the present findings, demonstrating that practical application in real or simulated contexts is essential for developing procedural skills. Along the same lines, Pedraza[2] emphasizes the importance of systematic and guided practice, which coincides with the gradual complexity progression approach of this study.

Another fundamental aspect is the notable improvement in perceived self-efficacy, a cornerstone of professional practice. As posited by the theory of García Cárdenas *et al.*,[3] self-efficacy beliefs determine levels of effort and perseverance when facing complex challenges. The fact that residents transitioned from an attitude of anxiety to reasonable confidence indicates that the strategy not only provided them with tools but also with the conviction that they could use them effectively.[12]

The valid correlation between procedural skill and metacognitive ability reinforces that diagnostic mastery is built upon continuous reflection, where residents not only learned to interpret images but also to monitor and evaluate their own thought process. This metacognitive dimension emerges as a critical component for learning transfer,[15] as demonstrated by Bisbee *et al*.,[4] with PBL in innovative environments. Together, the studies by Bernal Bastidas *et al*.[7] and Vilanova[1] provide a contextual framework that underscores the need for renewed methodological approaches and the relevance of active approaches such as the one implemented.

Despite the methodological rigor, limitations are acknowledged. The absence of a control group was a trade-off between rigor and feasibility in a real-world setting, mitigated by the time-series design. Likewise, the sample, although calculated, comes from a single center, which invites caution when extrapolating results.[4] Finally, the assessment of transfer to practice, although positive, would require longer follow-up to determine the sustainability of skills.

Scientific contribution

The study provides a validated didactic strategy that systematically integrates the cognitive, procedural, and affective-motivational dimensions, demonstrating that it is possible to overcome the theory-practice fragmentation characteristic of traditional teaching. These findings represent a significant contribution to the field of postgraduate medical education in Latin America by offering a replicable and contextualized approach to developing complex diagnostic skills in primary care settings with limited resources.

CONCLUSIONS

Problem-based learning as a didactic strategy demonstrated high effectiveness for developing diagnostic imaging skills in Family Medicine residents, with significant integration between theoretical knowledge, contextualized clinical practice, and the development of a reflective attitude. This supports the feasibility of implementing this problem-posing approach in the specialty's curriculum to train specialists capable of articulating clinical

reasoning with imaging interpretation for the benefit of care quality at the primary health care level.

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