

Clinical ultrasound as an active learning tool in medical students: a quasi-experimental before-and-after study.

Ecografía clínica como herramienta de aprendizaje activo en estudiantes de Medicina: estudio cuasiexperimental antes-después.

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Summary.

Introduction: Point-of-care ultrasound (POCUS) has become increasingly established as a cross-cutting competency in contemporary medical practice. However, its integration into medical degrees remains uneven and is limited by the availability of instructors, curriculum time, and technical resources. The aim of this study was to evaluate the educational impact of EcoEduca, a hybrid educational intervention based on clinical ultrasound, active learning, and pre/post-intervention assessment. **Methodology:** A single-group, quasi-experimental study was conducted with pre- and post-intervention assessments and a cross-sectional post-intervention survey. The intervention combined asynchronous learning using online materials, analysis of ultrasound cases, structured practice guidelines, face-to-face sessions with ultrasound equipment, and a structured assessment of ultrasound interpretation consisting of 10 cases. Pre- and post-intervention scores, self-reported adherence, perceived self-efficacy, and satisfaction were analyzed using 5- to 1-Likert scales. The main analysis of pre- and post-intervention change was performed on students with paired responses. Descriptive statistics and the Wilcoxon signed-rank test for related samples were used. **Results:** Twenty-seven third- to sixth-year medical students were identified in the pre-intervention assessment and 29 in the post-intervention assessment. The exact paired analysis included 22 students. The mean score increased from 7.45/10 to 8.82/10, with a mean difference of 1.36 points (95% CI: 0.62–2.11; $p = 0.0019$). Thirteen students improved, eight remained unchanged, and one decreased their score. The post-intervention survey included 29 responses. Twenty-eight students (96.6%) reported completing the required materials, and 29 (100%) participated in more than five practical sessions. The mean overall self-efficacy score was 4.31/5, the mean overall composite satisfaction score was 4.78/5, and the mean overall satisfaction score specifically for EcoEduca was 4.93/5. **Conclusions:** EcoEduca was associated with a significant improvement in performance on a structured assessment of ultrasound interpretation, along with high adherence, high satisfaction, and good perceived self-efficacy. Given the single-group design and small sample size, these results should be interpreted as preliminary evidence of feasibility and potential educational impact.

Keywords: Medical education; Undergraduate medical education; Clinical ultrasound; Point-of-care ultrasound; Active learning; Educational assessment; Medical students.

Resumen.

Introducción: La ecografía clínica a pie de cama, o point-of-care ultrasound (POCUS), se ha consolidado progresivamente como una competencia transversal en la práctica médica contemporánea. Sin embargo, su integración en el grado de Medicina sigue siendo heterogénea y está limitada por la disponibilidad de docentes, tiempo curricular y recursos técnicos. El objetivo de este estudio fue evaluar el impacto formativo de EcoEduca, una intervención educativa híbrida basada en ecografía clínica, aprendizaje activo y evaluación pre/postintervención. **Metodología:** Se realizó un estudio cuasi experimental de un solo grupo con evaluación antes-después y encuesta transversal postintervención. La intervención combinó aprendizaje asincrónico mediante materiales en línea, análisis de casos ecográficos, guías de práctica estructurada, sesiones presenciales con ecógrafo y una evaluación estructurada de interpretación ecográfica compuesta por 10 casos. Se analizaron la puntuación pre/postintervención, la adherencia autoinformada, la autoeficacia percibida y la satisfacción mediante escalas Likert de 1 a 5. El análisis principal del cambio pre/postintervención se realizó en estudiantes con respuestas emparejadas. Se emplearon estadísticos descriptivos y la prueba de Wilcoxon para muestras relacionadas. **Resultados:** Se identificaron 27 estudiantes de Medicina de 3.º a 6.º curso en la evaluación preintervención y 29 en la postintervención. El análisis emparejado exacto incluyó 22 estudiantes. La puntuación media aumentó de 7,45/10 a 8,82/10, con una diferencia media de 1,36 puntos (IC 95%: 0,62–2,11; $p=0,0019$). Trece estudiantes mejoraron, ocho permanecieron sin cambios y uno redujo su puntuación. La encuesta postintervención incluyó 29 respuestas; 28 estudiantes (96,6%) refirieron haber completado los materiales obligatorios y 29 (100%) realizaron más de cinco sesiones prácticas. La autoeficacia media global fue de 4,31/5, la satisfacción media global compuesta de 4,78/5 y la satisfacción global específica con EcoEduca de 4,93/5. **Conclusiones:** EcoEduca se asoció con una mejora significativa del rendimiento en una evaluación estructurada de interpretación ecográfica, junto con alta adherencia, elevada satisfacción y buena autoeficacia percibida. Dado el diseño de un solo grupo y el tamaño muestral reducido, estos resultados deben interpretarse como evidencia preliminar de viabilidad y efecto educativo potencial.

Palabras clave: Educación médica; Educación médica de grado; Ecografía clínica; Ecografía en el punto de atención; Aprendizaje activo; Evaluación educativa; Estudiantes de medicina.

1. Introduction

Point-of-care ultrasound (POCUS) has evolved from a technique restricted to certain specialties to a cross-cutting tool supporting clinical reasoning, physical examination, and decision-making. Its non-invasive nature, the absence of ionizing radiation, the portability of the equipment, and its applicability in multiple clinical settings have facilitated its expansion into emergency departments, internal medicine, critical care, primary care, and other healthcare areas (1).

In parallel, several international recommendations have advocated for the early and longitudinal introduction of ultrasound into medical degrees, not only as a technical skill, but also as a tool to reinforce living anatomy, applied physiology, clinical reasoning, and the integration between basic sciences and clinical practice (2). The available literature suggests that medical students can acquire basic skills in ultrasound when structured strategies, supervised practice, and assessment systems adapted to their level of training are used (3).

However, the curricular integration of POCUS presents significant barriers. These include a shortage of trained instructors, limited teaching time, the need for ultrasound equipment, and the difficulty in ensuring supervised practice and individualized feedback. In response to these

limitations, hybrid models have been proposed that incorporate microlearning, peer learning, asynchronous resources, and objective assessment through hands-on stations or structured tests (3–6). These models can reduce the workload of face-to-face instruction and improve the scalability of the training.

EcoEduca was designed as a hybrid educational intervention aimed at introducing clinical ultrasound into the Medicine degree through digital resources, supervised practice, active learning and structured assessment, taking advantage of existing institutional resources to minimize teaching load and additional investment.

The primary objective of this study was to evaluate the impact of EcoEduca on student performance in a pre/post-intervention ultrasound assessment. Secondary objectives included analyzing adherence to the intervention, perceived self-efficacy, and student satisfaction.

2. Methods

2.1 Study design

A single-group quasi-experimental study was conducted, with pre- and post-intervention assessments, supplemented by a post-intervention cross-sectional survey on use, self-efficacy, and satisfaction. The study was designed as an evaluation of educational innovation.

2.2 Teaching context

The intervention was carried out within the framework of the EcoEduca project: “Transforming Medical Education with Ultrasound as a Cross-Cutting Tool,” linked to the Autonomous University of Madrid and the Clinical Teaching Unit of La Paz University Hospital. The project was aimed at medical students, especially those in their third to sixth year of clinical training, and utilized existing resources such as an ultrasound lab, the university's ultrasound machine, digital materials, and faculty with experience in point-of-care ultrasound (POCUS).

2.3 Participants

Medical students, mostly third-year students, who participated in the intervention and completed at least one of the project's assessment instruments were included. Only students with a linkable identifier in both measurements were included in the pre/post-intervention analysis. Responses without sufficient identifiers were analyzed only in aggregate when appropriate. Individual demographic variables and structured information on prior ultrasound experience were not systematically collected to preserve anonymity in a teaching evaluation. This omission limits the characterization of the sample and the assessment of its homogeneity.

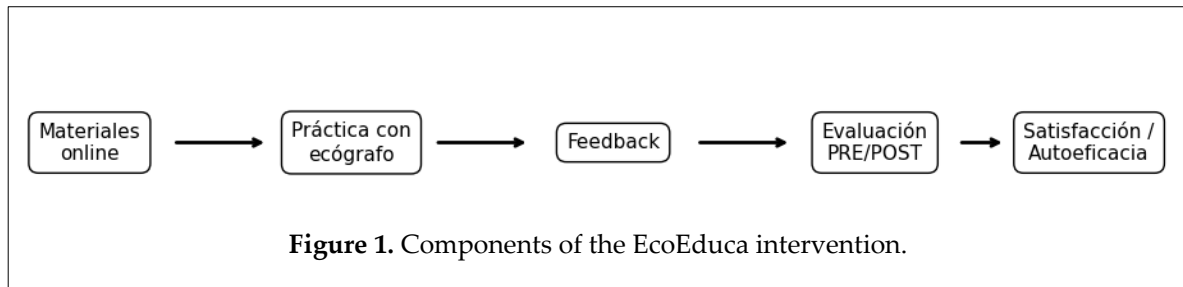
2.4 Description of the educational intervention

EcoEduca combined online learning, in-person practice, and structured assessment. The intervention included teaching materials focused on the fundamentals of clinical ultrasound and priority point-of-care (POCUS) examinations, including FAST/eFAST (Future Assessment with Sonography for Trauma and extended FAST, respectively, referring to structured ultrasound protocols used for the rapid detection of free fluid, pneumothorax, and other relevant abnormalities in emergency and trauma settings), basic cardiac, pulmonary, aortic, genitourinary, and vascular access ultrasound. The main teaching components were (Figure 1):

1. Digital materials and micro-content geared towards autonomous learning.
2. Clinical cases and annotated ultrasound images.
3. Guides and checklists to facilitate structured practice.
4. Practical sessions with ultrasound, carried out in pairs or small groups.

5. Teacher and peer feedback.
6. Pre/post intervention evaluation using a structured test of 10 cases with ultrasound images.

The intervention was designed to utilize existing institutional resources and minimize the need for additional investment. Basic equipment included an ultrasound machine, a practice space, digital storage for materials, and response collection tools.



2.5 Assessment instruments

Learning was assessed using a structured ultrasound interpretation test with 10 cases. Cases were selected by instructors experienced in point-of-care ultrasound (POCUS) to cover the domains included in the intervention: FAST/eFAST, lung ultrasound, basic cardiac ultrasound, aortic ultrasound, genitourinary ultrasound, and vascular access ultrasound. Each case included one ultrasound image or clip and one interpretation question with a single correct answer. The total score ranged from 0 to 10. The same test was administered before and after the intervention. The pre-intervention and post-intervention assessments used equivalent, but not identical, versions with the same structure, number of cases, ultrasound domains, and level of difficulty, with the aim of reducing the memory effect while maintaining comparability. The post-intervention survey included indicators of:

- Completeness of the required materials.
- Number of practical sessions conducted.
- Estimated number of POCUS scans performed.
- Approximate time spent on online content.
- Clinical contexts in which the student considered the learned material applicable.
- Perceived self-efficacy, using a Likert scale from 1 to 5.
- Satisfaction with the intervention, using a Likert scale from 1 to 5.

2.6 Variables analyzed

The primary variable was the change in the pre/post-intervention ultrasound assessment score, expressed as an absolute difference out of 10 points. Secondary variables were:

- Proportion of students who improved, did not change, or worsened.
- Self-informed completion of materials.
- Number of practical sessions.
- Self-reported online time.
- Average self-efficacy.
- Average satisfaction.
- Percentage of favorable responses, defined as scores of 4–5 on a Likert scale.

2.7 Statistical analysis

Quantitative variables were described using mean, standard deviation, median, minimum, and maximum. Categorical variables were expressed as absolute frequencies and percentages. The

distribution of differences was evaluated for the pre/post intervention analysis. Since the Shapiro-Wilk normality test showed a deviation from normality, the Wilcoxon signed-rank test for paired samples was used as the primary analysis. Additionally, the mean difference and its 95% confidence interval were calculated. A p-value <0.05 was considered statistically significant.

2.8 Ethical considerations

The study evaluated a teaching intervention without patient participation or use of clinical data. The data analyzed came exclusively from academic evaluations and faculty surveys. The analysis was performed on aggregated results, avoiding the individual identification of students in the presentation of the results. This study was reviewed by the Ethics Committee for Clinical Research (CEIm) of La Paz Hospital, which determined that, as it was an evaluation of teaching innovation without clinical data or patient intervention, it was exempt from formal approval. Identification code: 2026.563, minutes no. 12/2026, and date June 15, 2026. All data were analyzed in an anonymized and aggregated manner. Before the start of the clinical placements, a procedure was established for managing potential incidental findings, which included faculty supervision, the absence of clinical reports, and referral based on the judgment of the responsible faculty.

3. Results

3.1 Participation and availability of data

Of the 27 pre-intervention and 29 post-intervention records, 22 could be matched using a common anonymized identifier. The anonymized identifier was self-generated by the students. Some records could not be linked due to the absence or discrepancy of the identifier entered between measurements. To avoid unpaired comparisons, the main analysis was restricted to the 22 students with a linkable identifier in both assessments. Five pre-intervention and seven post-intervention records had no linkable match and were excluded from the main matched analysis, although the available post-intervention data were used for the descriptive survey analyses.

3.2 Pre/post intervention performance

In the 22 students with paired assessment, the mean pre-intervention score was 7.45/10 (SD 1.63; median 8; range 4–10). The mean post-intervention score was 8.82/10 (SD 1.05; median 9; range 6–10). The mean difference was 1.36 points out of 10 (SD 1.68; 95% CI: 0.62–2.11), equivalent to an approximate relative improvement of 18.3% from baseline. The Wilcoxon test showed a statistically significant improvement after the intervention ($p = 0.0019$). The effect size estimated using Cohen's d_z was 0.81. Thirteen students improved their score, eight showed no change, and one showed a one-point reduction.

3.3 Adherence and self-informed use

The main performance analysis included 22 students with linkable pre- and post-intervention assessments. The post-intervention survey included 29 responses, 22 of which were from students matched in the main analysis, while seven were analyzed descriptively only because they lacked a linkable pre-intervention assessment. In the post-intervention survey, 28 of 29 students (96.6%) reported having completed the required course materials. All surveyed students reported having participated in more than five hands-on ultrasound sessions.

Regarding the time spent on online content, 15 students (53.6% of comparable responses; 51.7% of total post-intervention responses) reported spending more than 120 minutes, 11 (37.9%) between 61 and 120 minutes, one (3.4%) between 31 and 60 minutes, one (3.4%) between 0 and 30 minutes, and one response was not comparable.

The approximate number of POCUS scans was quantifiable in 25 of the 29 responses. The mean was 8.68 scans and the median was 7. The most frequent categories were 6–10 scans (37.9%) and more than 10 scans (24.1%).

The contexts in which students considered what they learned to be most applicable were hospital ward (69.0%), Emergency Department (65.5%), other environments (clinical rotations, non-regulated simulation activities, supervised autonomous learning; 62.1%), consultation (58.6%), simulation (41.4%) and ICU (24.1%) (table 1).

Table 1. Self-reported usage and adherence indicators.

Indicator	Category	n	Valid N	%
Mandatory materials completed	Yeah	28	29	96.6
Mandatory materials completed	No / Partial	1	29	3.4
Practical sessions with ultrasound machine	>5 sessions	29	29	100.0
Time spent online	>120 min	15	28	53.6
Time spent online	61–120 min	11	28	39.3
Time spent online	31–60 min	1	28	3.6
Time spent online	0–30 min	1	28	3.6
Time spent online	Not comparable answer	1	29	3.4
Program continuity	Yeah	22	29	75.9
Program continuity	Yes, conditional / partial	5	29	17.2
Program continuity	No response	2	29	6.9

“n” indicates the observed frequency in each category. “Valid N” indicates the number of responses used to calculate the corresponding percentage. In the case of “time spent online,” one response was considered non-comparable and is presented separately; therefore, the percentages for the comparable online time categories were calculated based on 28 valid responses.

3.4 Perceived Self-Efficacy

The overall mean self-efficacy score was 4.31/5. The perceived ability to obtain an adequate ultrasound window averaged 4.38/5, with 100% positive responses. The perceived ability to recognize the main findings of the course averaged 4.24/5, with 89.7% positive responses.

3.5 Satisfaction

The mean composite satisfaction score, calculated from the satisfaction items included in the survey, was 4.78/5 (SD 0.27) (Table 2; Figure 2). Specific overall satisfaction with EcoEduca was 4.93/5 based on 28 valid responses, with 100% of these responses being favorable. One record did not include a valid response for this item. Relevance to clinical practice was rated at a mean of 4.97/5, as was the desire to maintain or extend the format. The quality of the materials received a mean of 4.83/5, and the logistical organization at 4.69/5. The item with the lowest relative score was the usefulness of the feedback received, with a mean of 4.31/5, although it maintained a favorable response rate of 82.8%. Twenty-seven students (93.1%) expressed that the format should be maintained, extended, or maintained with some modifications.

Table 2. Self-efficacy and post-intervention satisfaction.

Item	Valid N	Average	OF	% favorable 4-5
Obtain a suitable window	29	4.38	0.49	100.0
Recognize key findings	29	4.24	0.64	89.7
Clinical relevance	29	4.97	0.19	100.0
Organization	29	4.69	0.54	96.6
Quality of materials	29	4.83	0.38	100.0
Feedback	29	4.31	0.76	82.8
Maintain/extend format	29	4.97	0.19	100.0
Overall satisfaction	28	4.93	0.26	100.0

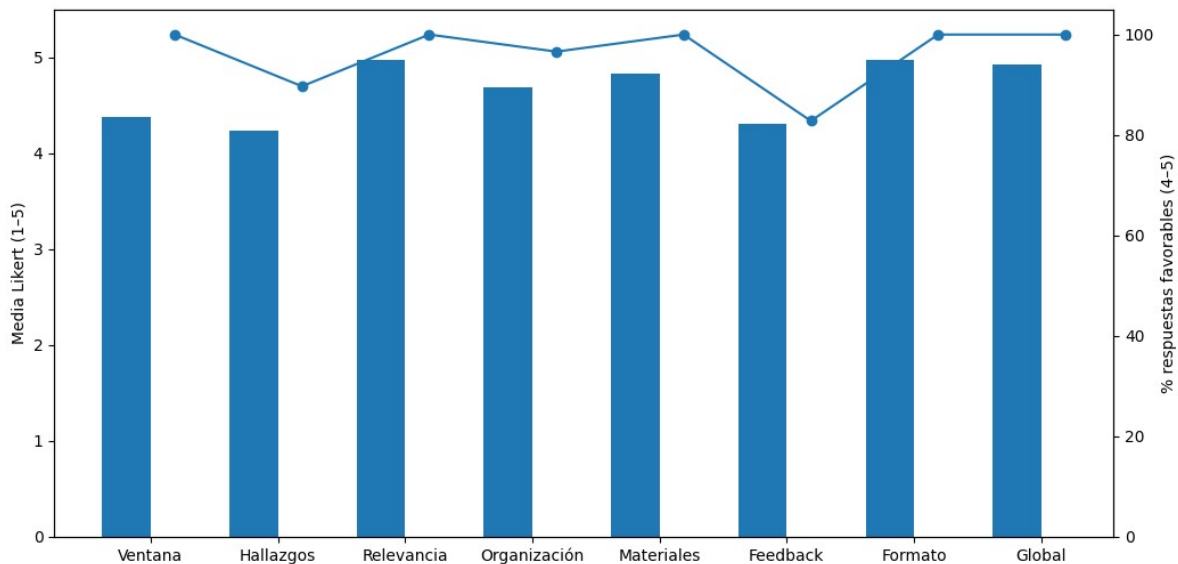


Figura 2. Satisfaction and self-efficacy. Bar graph with the mean of every Likert item and the percentage of answers 4-5.

4. Discussion

In this study, a hybrid educational intervention based on clinical ultrasound was associated with a significant improvement in performance on a pre/post-intervention assessment of ultrasound interpretation and with high levels of satisfaction and perceived self-efficacy. The mean improvement of 1.36 out of 10 points, along with a moderate-to-large effect size, suggests that structured teaching supported by existing institutional resources was associated with an objective improvement in ultrasound interpretation performance, although the design does not allow for definitive causality to be attributed.

These results are consistent with previous literature supporting the introduction of ultrasound in the early stages of medical training. International recommendations indicate that ultrasound can bridge the gap between basic and clinical sciences, facilitating the learning of anatomy, physiology, physical examination, and diagnostic reasoning (1, 2). In the European context, the integration of point-of-care studies (POCUS) into medical degrees remains limited and heterogeneous, reinforcing

the need for feasible curricular experiences adapted to local resources (7). In this regard, EcoEduca aligns with a conception of POCUS not limited to the technical acquisition of images, but integrated into an active and contextualized learning model. To facilitate the international interpretation of the results, the denominators of each analysis were detailed, and it was specified that the main analysis was intraindividual and paired, while the post-intervention survey was cross-sectional and descriptive.

The observed improvement is also consistent with studies that have used structured ultrasound assessment formats, such as mini-OSCE stations, to evaluate technical skills, anatomical recognition, image interpretation, and non-technical competencies (3). Although the assessment focused on the interpretation of 10 ultrasound cases and not a full practical station, it allowed for objective measurement of the change in performance.

A key aspect of the project is its feasibility. The intervention relied on digital materials, paired practice, existing institutional resources, and focused faculty involvement. This approach can be particularly useful in faculties with limited expert faculty or reduced curricular time. Recent studies have shown that hybrid and shared POCUS curricula can improve knowledge, attitudes, and skills, although their implementation requires planning, coordination, and ongoing evaluation (5). Similarly, peer learning and teach-the-teacher models have been proposed as strategies to improve the scalability of ultrasound training (4, 6).

Furthermore, the barrier related to creating teaching materials can be reduced through two complementary strategies. On the one hand, the local development of micro-content is relatively feasible when an ultrasound machine, structured teaching cases, and basic audiovisual support are available. On the other hand, when it is not possible to develop in-house resources from the outset, open educational resources for medical education (FOAMed) from scientific societies and institutional websites can be used. For example, the ultrasound section of the American College of Emergency Physicians compiles free ultrasound education resources, including guides, videos, cases, and online teaching materials (8). These resources can facilitate the initial implementation of similar programs, provided they are adapted to the student's skill level, the local curriculum context, and the specific teaching objectives.

Student satisfaction was very high, especially regarding items related to clinical relevance, quality of materials, and desire for continued participation. This finding is important because student acceptance can facilitate the curricular integration of new methodologies (9). However, the feedback item received the lowest relative rating, although it still maintained a favorable overall assessment. To improve the program, it is proposed to implement specific rubrics for image acquisition, interpretation, clinical integration, ergonomics, and communication; establish minimum feedback times per student; and record faculty and peer feedback in a structured manner.

Perceived self-efficacy was also high. However, this should be interpreted with caution, as self-confidence does not necessarily equate to autonomous clinical competence. Point-of-care ultrasound (POCUS) training requires progressive supervision, objective evaluation, and clear limits on clinical use by students. In this regard, safety protocols, data protection, and procedures for handling incidental findings are essential elements of any educational program involving ultrasound examination of volunteers or peers (10).

The transferability of EcoEduca depends on local conditions, including the availability of ultrasound machines, teaching spaces, trained faculty, institutional support, academic policies, and protected curriculum time. Furthermore, EcoEduca's hybrid component could promote retention through repeated exposure, deliberate practice, asynchronous review of materials, and progressive

feedback. However, this study did not assess medium- or long-term retention or compare the model to a purely theoretical strategy; therefore, this hypothesis should be explored in longitudinal studies.

This study has several limitations. First, as it is a single-group quasi-experimental study without a concurrent control group, the observed changes do not allow for a definitive causal link to the intervention. Although Cohen's d_z suggests a moderate-to-high intraindividual change, this estimate should be interpreted as a measure of the change observed in the matched sample, not as a causal measure of effectiveness attributable solely to the intervention, and it could overestimate the true educational magnitude in single-group designs without a control, especially when there is a possibility of test familiarity. Second, the sample size was small, particularly in the matched analysis. As a conservative approach, the pre/post change was assessed only in matched records. Unmatched records were excluded from the main analysis to avoid independent comparisons that did not reflect intraindividual changes. However, this lack of matching may have introduced selection bias and reduced the statistical power of the main analysis. Third, demographic variables and structured information on prior ultrasound experience were not collected, which limits the characterization of the sample and the assessment of its homogeneity. Fourth, the secondary variables of adherence, satisfaction, and self-efficacy were collected anonymously and could not be individually linked to the pre/post change, so it was not possible to analyze their association with the improvement in performance.

Finally, the evaluation focused mainly on applied knowledge and image interpretation, so future versions should incorporate practical stations with rubrics for image acquisition, ergonomics, spatial orientation, communication, and professionalism.

Despite these limitations, the study provides real data on a seemingly feasible teaching intervention, supported by existing institutional resources and requiring limited additional funding, although a formal analysis of costs or teaching load was not conducted. Its results support the continuation of the program and justify a subsequent evaluation with a more robust design, a larger sample size, collection of common anonymized identifiers, objective practical evaluation, and longitudinal follow-up.

5. Conclusions

- EcoEduca was associated with a significant improvement in performance on a structured assessment of ultrasound interpretation, along with high self-reported adherence, high satisfaction, and good perceived self-efficacy. Taken together, these findings suggest that clinical ultrasound can be incorporated as an active learning tool in medical education through a potentially scalable hybrid model supported by existing institutional resources.
- However, since this was a single-group quasi-experimental study without a concurrent control group, the observed changes do not allow for a definitive causal link to the intervention. Therefore, future studies should confirm these results using larger samples, comparative designs, objective practical assessment, and longitudinal follow-up of skill acquisition and retention.

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

Authors' contributions: YTC participated in the project conception, design of the educational intervention, academic coordination, interpretation of results, and manuscript writing. MQD contributed to the design of the simulated practice, organization of the ultrasound classroom, and teacher training. RPP participated in the

academic integration and teacher supervision of the project. MAQS collaborated in the organization, supervision, and scheduling of the practical workshops. RMB and AMF participated in the technical review of the ultrasound content, image quality supervision, and design of evaluation criteria. All authors critically reviewed the manuscript and approved the final version.

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7. Supplementary Material 1.

ECOEDUCA training (asynchronous online content). The ECOEDUCA intervention included a structured library of online audiovisual resources designed to support self-directed learning before and after in-person clinical ultrasound practical sessions. The supplementary material was organized into thematic modules and included introductory content and clinical applications of abdominal, cardiac, pulmonary, and vascular ultrasound, guided procedures, and other complementary applications. The educational videos were available through specific playlists hosted on YouTube.

- Introduction: <https://www.youtube.com/playlist?list=PLbWdexAiw5RAI2C9HCzGgZmHN33LBg1PU>
- Abdomen: https://www.youtube.com/playlist?list=PLbWdexAiw5RBk5bytLDmcAWV_KUuWiRLj
- Cardiac: <https://www.youtube.com/playlist?list=PLbWdexAiw5RCDRtBGCmw2RVMP8UwcDIsd>
- Lung: <https://www.youtube.com/playlist?list=PLbWdexAiw5RCdY4wjCtSTVOWzz-ZnkRxa>
- Aorta and Venous System: https://www.youtube.com/playlist?list=PLbWdexAiw5RCzCe4T_t3i1ZKJAqP6y84u
- Gallbladder and urinary tract: <https://www.youtube.com/playlist?list=PLbWdexAiw5RA4NnyBPSTf5OIPf3onyzw>
- Procedures: https://www.youtube.com/playlist?list=PLbWdexAiw5RAWlmR_CPUx8pwsfjtTyqdu
- Miscellaneous: https://www.youtube.com/playlist?list=PLbWdexAiw5RC8x7RDmqOvd_JwzuxaGqUR