ORIGINAL RESEARCH PAPERS

Point-of-care ultrasound training using near-peer training and remote supervision: A pilot randomized controlled trial

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ABSTRACT

Background and objective: Traditional point-of-care ultrasound (PoCUS) teaching that relies on hands-on practice faces challenges of limited scale and infection-control constraints during pandemics. We designed a low-contact curriculum integrating near-peer teaching (NPT) with faculty remote supervision (RS) and evaluated its effectiveness versus on-site faculty-led teaching.

Methods: In this randomized controlled pilot trial, 69 senior medical students were assigned to NPT+RS (n=34) or faculty-led control group (n=35). Both groups received identical didactic and hands-on training, with the NPT+RS group incorporating multi-camara telemedicine supervision by the faculty to support NPT. The primary outcome was the Entrustable Professional Activity (EPA)–based Objective Structured Clinical Examination (OSCE) score with four major domains measured 1 month after training. The secondary outcomes included the technology acceptance model (TAM) survey and the OSCE feedback.

Results: Total OSCE scores (74.9 vs 76.8; p=0.614) and the Indication-Acquisition-Interpretation-Medical decision domain scores did not differ between two groups. For single items, only a lower interpretation performance at the posterolateral alveolar/pleural syndrome in NPT+RS group (4.6 vs 6.5; p=0.013) was found. The NPT+RS group reported higher perceived usefulness (efficiency, usefulness, performance, productivity; all p<0.05), with no

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between-group difference in perceived ease-of-use. The OSCE was more often perceived by the NPT+RS group as revealing weaknesses (p=0.002) and meriting routine post-training implementation (p=0.034).
Conclusions: A low-contact PoCUS curriculum integrating NPT with RS achieved overall EPA-based OSCE performance comparable to traditional faculty-led instruction while enhancing perceived usefulness and assessment acceptance. Implementation of this model allows for greater training capacity and decreased contact. The capacity of NPT for image-interpretation skills warrants investigation (ClinicalTrials.gov number, NCT06777641.).

Key words: Point-of-care ultrasound; near-peer training; remote supervision; entrustable professional activities; technology acceptance.

Introduction

Point-of-care ultrasound (PoCUS) has transformed ultrasound from a centralized, time-consuming diagnostic test into a rapid, problem-oriented bedside assessment that augments history and physical examination (1–4). By enabling integrated, organ-spanning evaluation in minutes, PoCUS improves diagnostic efficiency and supports critical decisions across acute care contexts; classic applications include thoracic trauma, pleural and lung diseases (5–7), acute respiratory failure (2, 8). As point-of-care devices proliferate and curricula migrate toward earlier clinical exposure, PoCUS is increasingly recognized as a feasible competency for undergraduate medical education (1, 3).

Teaching PoCUS, however, faces three persistent challenges. First, a long-standing shortage of instructing faculty relative to the number of trainees has impeded the widespread dissemination of PoCUS skills to frontline practitioners. (9) Second, the COVID-19 pandemic exposed the fragility of close-contact, hands-on pedagogies that rely on prolonged physical proximity between faculty and learners (10, 11). Although virtual formats can deliver knowledge and image-interpretation exercises, skill acquisition in probe handling and image optimization remains difficult to replicate without some form of supervised practice (11). This has sharpened the need for "low-contact" instructional designs that preserve learning quality while reducing contact time and density during training. Third, beyond epidemiologic constraints, PoCUS instruction must bridge the "experience gap" between experts and novices. Near-peer/peer-assisted learning leverages cognitive and social congruence—senior students or early postgraduate trainees teach juniors using level-appropriate language, pacing, and exemplars (12). Systematic reviews and controlled studies across health-professional education show that near-pear teaching (NPT) can achieve learning outcomes comparable to faculty-led instruction while enhancing approachability, confidence, and teaching capacity among peer tutors (13–16). In ultrasound specifically, randomized and observational work suggests that NPT can match faculty performance in knowledge and skills, with some evidence of durable gains, though program designs and assessment frameworks vary (17, 18).

While NPT can partially offset the experience gap between experts and novices, it does not eliminate the need for timely expert oversight, especially for safety-critical procedures. Remote supervision (RS) offers a complementary strategy that extends expert guidance asynchronously or in real time without requiring co-location. In clinical education, tele-supervision can mitigate geographic maldistribution of faculty, embed teaching within routine workflows and reduce professional isolation (19, 20). In emergency PoCUS, commercially available low-cost tele-ultrasound solutions have been shown to be feasible and acceptable for real-time guidance and feedback (20). RS can be operationalized through multi-camera views that simultaneously display the ultrasound screen, probe–hand interactions (21), and probe–patient contact, enabling faculty to monitor fidelity and intervene when necessary while remaining remote.

Therefore, we directly addressed these deficiencies by developing a low-contact PoCUS curriculum and proposed a randomized evaluation that compares a near-peer teaching model with faculty remote supervision against traditional faculty-led, on-site instruction. Building on existing theoretical and practical considerations, this study aims to determine if an NPT+RS PoCUS curriculum is non-inferior to traditional faculty-led, on-site instruction, and to investigate the potential benefits of this new teaching model.

Methods

Study design and setting

We conducted a two-arm, parallel-group, randomized controlled educational trial at National Taiwan University Hospital and College of Medicine. The target population are senior medical students with no previous exposure to PoCUS training.

Participants

The study population included senior medical students in their fifth and sixth years of a six-year medical program in Taiwan. Students were excluded if they declined to take part or had previously attended the institution's bedside ultrasound course. Enrollment was entirely voluntary through open announcements and posters within the medical school, and did not influence academic grades or formal evaluations.

Implementation details from curriculum before trial

We standardized NPT instruction preparation before the study. The near-peer instructors were postgraduate year residents who had previously completed formal PoCUS training and volunteered for the role. Near-peer instructors participated in a 2-hour training and rehearsal sessions under faculty observation with structured feedback to standardize their readiness. The faculty instructors in both groups were hospitalist physicians with over 6 years of experience in POCUS education and authorship of national POCUS textbooks. We optimized the multi-camera RS setup to guarantee the two critical views during hands-on sessions. The remote supervision setup utilized commercially available handheld ultrasound devices (LeSONO, Leltek Inc.) connected to standard tablets and transmitted via video conferencing software (SynDr, Chunghwa Telcom Inc,, Taiwan) representing a low-cost solution compared to large specialized telemedicine workstations. These infrastructures were funded by the National Science and Technology Council (Taiwan).

Randomization and masking

After consent, students were randomized (1:1) to experimental or control arms, and they were masked to comparative hypotheses. Participants in the experimental arm completed a curriculum that combined lectures with small-group hands-on scanning guided by trained near-peer instructors. A PoCUS faculty member joined remotely through real-time two-way videoconferencing to observe performance and give feedback. During remote supervision, two cameras were used to show (1) the live ultrasound image, (2) hand and probe movements, and the probe–patient contact point (Figure S1 in supplement 1). Participants in the control arm completed a curriculum with the same content as the experimental group, but followed a traditional faculty-led model, receiving lectures followed by in-person hands-on training directly supervised on site by a faculty instructor.

Contents and duration of curriculum

Both groups received identical educational content covering the focused lung PoCUS, including the four anterior four lung points postero-lateral points, and deep vein thrombosis which were used in the Bedside Lung Ultrasound in Emergency (BLUE) protocol. The workshop-like curriculum comprised approximately one hour in total, consisting of a 20-minutes didactic lecture and a 40-minute hands-on practice session. Hands-on practice sessions were conducted using healthy volunteers as models. In both groups, an instructor-to-student ratio of 1:4 was maintained, and hands-on practice was provided flexibly until competency goals were met.

During hands-on sessions, the remote faculty supervisor maintained continuous visual access to both the live ultrasound image and probe–hand interactions through a dual-camera configuration (Figure S1 in supplement 1). Near-peer instructors provided immediate bedside coaching, while faculty focused on higher-level guidance and quality control. Faculty intervened only when image acquisition errors, probe positioning difficulties, or interpretive inaccuracies were observed and not corrected by on-site instructors.

Assessment framework and rater training

In PoCUS education, assessment is shifting from simple checklist-based ratings toward competency-based paradigms that align with real-world entrustment decisions. Entrustable Professional Activities (EPA) structures evaluation around whether learners can be trusted to perform clearly defined tasks under appropriate levels of supervision (22), and EPA-based Objective Structured Clinical Examinations (OSCEs) enable standardized, scenario-based judgments across indication, image acquisition, interpretation, and medical decision making—the I-A-I-M framework (22). These four major domains also constitute the fundamental skill sets in PoCUS training in previous literature (23–25). Because our NPT+RS model aims not only to preserve technical performance but also to foster sustainable uptake of PoCUS in future clinical practice, the present trial prospectively incorporates EPA constructs into OSCE outcomes and captures learner perceptions using the TAM, thereby jointly evaluating skill acquisition and perceived usefulness as key drivers of long-term adoption. OSCE stations and scoring follow an I-A-I-M structure previously developed and validated within a national project. In this study, checklist items were developed to reflect authentic clinical tasks and were piloted in this study. Only one investigator (NCH) completed the whole assessment framework training. The OSCE was therefore scored independently by a single investigator who was blinded to the randomized allocation of the students.

Procedures and timeline

Students completed the Technology Acceptance Model (TAM) questionnaire (26, 27) after the training course and before assessment (Table S1 in Supplement 1). Except for routine clinical duties during the rotation, participants had no access to ultrasound equipment or further faculty supervision between the training session and the assessment. Approximately one month after training completion, all students undertook an EPA-based OSCE (Table S2 in supplement 1) scored independently by an investigator (NCH) who was blinded to the randomized allocation. Each OSCE session included one student and one standardized patient. Immediately after the OSCE, a brief feedback survey on this test was collected (Table S3 in Supplement 1).

Outcomes

The primary outcome was total OSCE performance measured approximately one month after course completion by a single rater who scored each examination. Secondary outcomes included TAM questionnaire responses collected after the course and before the OSCE, as well as a post-OSCE feedback survey, both administered at approximately one month.

Sample size

We estimated the sample size for a two-arm, 1:1 randomized non-inferiority trial with a continuous primary outcome (score). We set the non-inferiority margin at 10 points (10% on a 0–100 scale) and assumed a common standard deviation of 15 points in both groups, with the expected true mean difference between groups of 0. Using a one-sided α of 0.025 and 80% power, we calculated the required sample size per group with the standard normal approximation for non-inferiority testing of a mean difference, which yielded 36 participants per group (72 total) after rounding up. Allowing for an anticipated 5% dropout, we increased the target to 38 participants per group, for a total planned sample size of 76 participants. The final registered anticipated sample size is 80 (40 in each parallel arm) in the ClinicalTrial.gov.

Statistical analysis

For the primary endpoint, we compared mean total OSCE scores between groups using independent-samples t tests. OSCE domain scores (Indication, Acquisition, Interpretation, Medical decision) and scoring items were analyzed similarly. When distributional assumptions were not met, we used nonparametric Wilcoxon rank-sum tests as sensitivity analyses. Secondary outcomes (TAM scale scores and OSCE feedback items) were summarized as means (standard deviations) and compared between groups using independent-samples t tests or Wilcoxon rank-sum tests, as appropriate. Categorical variables were summarized as counts (percentages) and compared using χ^2 tests or Fisher exact tests. Missing data for secondary outcomes were handled using complete-case analysis; All randomized participants for whom data were available were included in each analysis using an intention-to-treat approach. Subgroup analyses were performed to compare outcomes between fifth- and sixth-year students to assess if training level impacted the results. All statistical tests were 2-sided with α = 0.05, and no formal adjustment for multiple comparisons was performed. Analyses were conducted using SPSS (IBM Corp 27) and R (4.5.1).

Results

Of the 80 medical students screened from Jan 2025 to Sep 2025, 11 were excluded (10 not meeting inclusion criteria and 1 declining to participate), leaving 69 eligible students who consented and were randomized (Figure 1). All randomized students received the allocated intervention and completed the EPA-based OSCE. For secondary questionnaire outcomes, two participants in each group had missing data (incomplete questionnaire submissions after exams), resulting in slightly smaller sample sizes for some analyses (Figure 1).

PoCUS OSCE performance

There was no significant difference in total PoCUS OSCE scores between the NPT+RS group and the traditional group (74.94 ± 14.48 vs. 76.83 ± 16.39, p = 0.614; Table 1). Domain scores for indication (8.59 ± 1.42 vs. 8.34 ± 2.40, p = 0.608), image acquisition (29.06 ± 10.54 vs. 30.17 ± 10.27, p = 0.658), image interpretation (31.74 ± 6.82 vs. 33.57 ± 6.95, p = 0.272), and medical decision making (5.56 ± 3.09 vs. 4.74 ± 3.32, p = 0.294) were also comparable between groups.

At the checklist-item level, most individual tasks showed similar performance between groups (Figure S2 in supplement 1). The only significant difference was observed in interpretation of postero-lateral alveolar pleural syndrome (PLAPS), where the control group achieved higher scores than the NPT+RS group (6.54 ± 3.29 vs. 4.62 ± 2.96, p = 0.013; Table 1, Figure S2 in supplement 1). All remaining items, including lung, deep vein scans, and cardiac/IVC views, were not significantly different.

Technology Acceptance Model (TAM) outcomes

Post-training TAM results indicated high perceived usefulness of PoCUS in both groups, with significantly higher ratings in the NPT+RS group for several items (Table 2, Figure 2). Compared with controls, students in the NPT+RS group gave higher scores for "enhancing effectiveness in practice" (4.91 ± 0.30 vs. 4.59 ± 0.61, p = 0.009), "usefulness in practice" (4.94 ± 0.25 vs. 4.68 ± 0.59, p = 0.022), "improving practice performance" (4.84 ± 0.37 vs. 4.53 ± 0.71, p = 0.027), and "enhancing productivity" (4.75 ± 0.44 vs. 4.38 ± 0.65, p = 0.009). For the other perceived-usefulness items (Q1 and Q6) and all perceived ease-of-use items (Q7–Q12), mean scores were similar between groups (Figure 2). Stacked bar plots show that most students in both cohorts selected "agree" or "strongly agree" for usefulness items, whereas responses to ease-of-use items were more widely distributed with a higher proportion of neutral or disagree responses (Figure 2).

OSCE feedback questionnaire

Both groups reported favorable experiences with the PoCUS OSCE, and several feedback items favored the NPT+RS model (Table 3, Figure 3). Students in the NPT+RS group more strongly endorsed that the OSCE helped reveal their weaknesses (4.97 ± 0.17 vs. 4.64 ± 0.55, p = 0.002) and increased appreciation of the problem-oriented nature of PoCUS (4.88 ± 0.33 vs. 4.45 ± 0.97, p = 0.021). Students in NPT+RS group were also more likely to agree that completing a PoCUS OSCE should become a regular

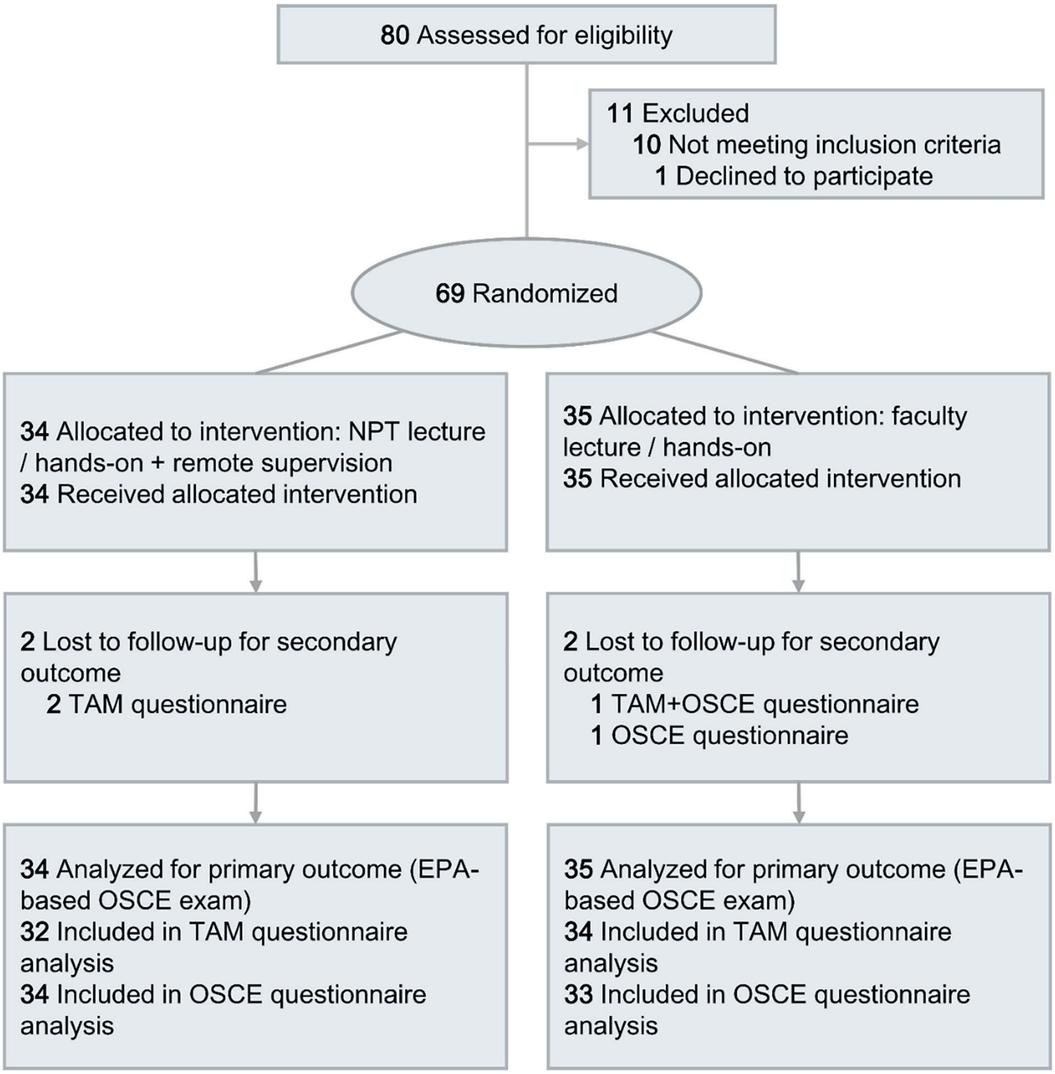

Figure 1. Flow of participants through the randomized controlled trial (OSCE, Objective Structured Clinical Examination; TAM, Technology Acceptance Model).

step after learning PoCUS (4.65 ± 0.60 vs. 4.24 ± 0.90, p = 0.034). The remaining feedback items (Q3–Q7) showed no significant between-group differences.

Response distributions again demonstrated that the majority of students in both groups agreed or strongly agreed with the positive statements about the OSCE (Figure 3).

Comparison between fifth- and sixth-year students

Subgroup analyses stratified by academic year (fifth- vs. sixth-year students) showed broadly similar patterns across outcomes. Within each instructional model, EPA-based OSCE domain scores, TAM ratings, and OSCE feedback responses were comparable between fifth- and sixth-year students, without a consistent trend favoring either year level (Figures S3 and S4 in Supplement 1). These findings suggest that the introduction of the new model were not confined to a specific year of training.

Discussion

The present randomized trial found that a PoCUS curriculum integrating near-peer teaching with remote

Table 1. Performance on the EPA-based PoCUS OSCE, comparing the NPT+RS (experimental) and traditional (control) groups. Each sub-item had a maximum score (shown).

OSCE I-A-I-M Scores	Experimental (n=34)	Control (n=35)	P value
Indication – Total (10)	8.59 (1.42)	8.34 (2.40)	0.608
Indication – BLUE symptoms (3)	3.00 (0.00)	2.74 (0.85)	0.083
Indication – Anatomical sites (5)	3.71 (1.36)	4.00 (1.53)	0.403
Indication – Presence/absence of explanation (2)	1.88 (0.48)	1.60 (0.81)	0.083
Acquisition – Total (40,+6) $^{\beta}$	29.06 (10.54)	30.17 (10.27)	0.658
Acquisition – Anterior chest 4 BLUE points (10)	7.59 (2.72)	7.60 (2.39)	0.985
Acquisition – Common femoral vein (10)	4.94 (4.86)	5.14 (5.07)	0.867
Acquisition – Popliteal vein (10)	6.82 (4.57)	6.74 (4.68)	0.942
Acquisition – PLAPS points (10)	6.41 (3.26)	7.60 (2.74)	0.105
Acquisition – Others: PLAX/A4C/ IVC (+6) $^{\beta}$	3.29 (1.77)	3.09 (2.29)	0.673
Interpretation – Total (40)	31.74 (6.82)	33.57 (6.95)	0.272
Interpretation – Anterior chest 4 BLUE points (10)	9.29 (2.46)	9.60 (1.80)	0.556
Interpretation – Common femoral vein (10)	8.76 (2.31)	8.80 (2.29)	0.949
Interpretation – Popliteal vein (10)	9.06 (1.72)	8.63 (2.69)	0.433
Interpretation – PLAPS points (10)	4.62 (2.96)	6.54 (3.29)	0.013
Medical decision – Total (10,-6) $^{\beta}$	5.56 (3.09)	4.74 (3.32)	0.294
Medical decision – Number of management items (10)	6.15 (3.15)	5.83 (2.99)	0.668
Medical decision – Hazard penalty points (diuretic / Intubation / Anticoagulation therapy / others) (-6) $^{\beta}$	-0.59 (0.92)	-1.09 (1.63)	0.124
Total scores (100)	74.94 (14.48)	76.83 (16.39)	0.614

α Scores are presented as mean (standard deviation); β The maximal bonus for additional answers is +6; γ The maximal minus for incorrect answers is -6

faculty supervision achieved EPA-based OSCE performance comparable to traditional faculty-led on-site instruction, while simultaneously strengthening learners' perceptions of PoCUS usefulness and the value of OSCE assessment.

These findings suggest that, when appropriately prepared, near-peer instructors (such as junior residents or senior students) can assume substantive responsibility for hands-on ultrasound teaching without compromising short-term skill outcomes. This responds directly to long-standing concerns about faculty shortages, the expert–novice gap, and the need for flexible formats under infection-control constraints (10, 11).

In line with prior work on near-peer/peer-assisted learning, our results support the view that instructional roles can safely extend beyond faculty when peer instructors receive structured training and supervision. Near-peer teaching has repeatedly been shown to yield knowledge and skills outcomes similar to faculty-led instruction, while enhancing approachability and confidence among learners (12–16). In ultrasound education specifically, randomized and observational studies have demonstrated comparable OSCE and written test performance between near-peer and faculty instructors (17, 18). However, concerns remained about the correctness and robustness of near-peer instruction, and the selected outcomes may have overlooked

Table 2. Post-training Technology Acceptance Model (TAM) results, comparing student ratings between the NPT+RS (experimental) group and the traditional (control) group. Items are scored from 1 (strongly disagree) to 5 (strongly agree).

TAM Questionnaire	Experimental (n=34)	Control (n=35)	P value
Perceived usefulness			
Q1. Using PoCUS in my practice will enable me to accomplish tasks more quickly.	4.53 (0.51)	4.29 (0.87)	0.185
Q2. Using PoCUS would enhance my effectiveness in my practice.	4.91 (0.30)	4.59 (0.61)	0.009
Q3. I found PoCUS useful in my practice.	4.94 (0.25)	4.68 (0.59)	0.022
Q4. Using PoCUS would improve my practice performance.	4.84 (0.37)	4.53 (0.71)	0.027
Q5. Using PoCUS in my practice would enhance my productivity.	4.75 (0.44)	4.38 (0.65)	0.009
Q6. Using PoCUS would make it easier to do my job.	4.72 (0.46)	4.59 (0.66)	0.35
Perceived ease-of-use			
Q7 Learning to operate PoCUS was easy for me.	3.41 (0.71)	3.03 (0.94)	0.072
Q8.I found it easy to get PoCUS to do what I want it to do.	2.41 (1.10)	2.50 (0.86)	0.701
Q9. My interaction with PoCUS has been clear and understandable.	3.41 (0.67)	3.26 (0.86)	0.46
Q10. I found PoCUS would be clear and understandable.	2.28 (0.85)	2.15 (0.86)	0.526
Q11. It was easy for me to become skillful at using PoCUS.	2.59 (0.76)	2.53 (0.79)	0.736
Q12. I found PoCUS easy to use.	2.81 (0.74)	2.65 (0.85)	0.402

αScores are presented as mean (standard deviation)

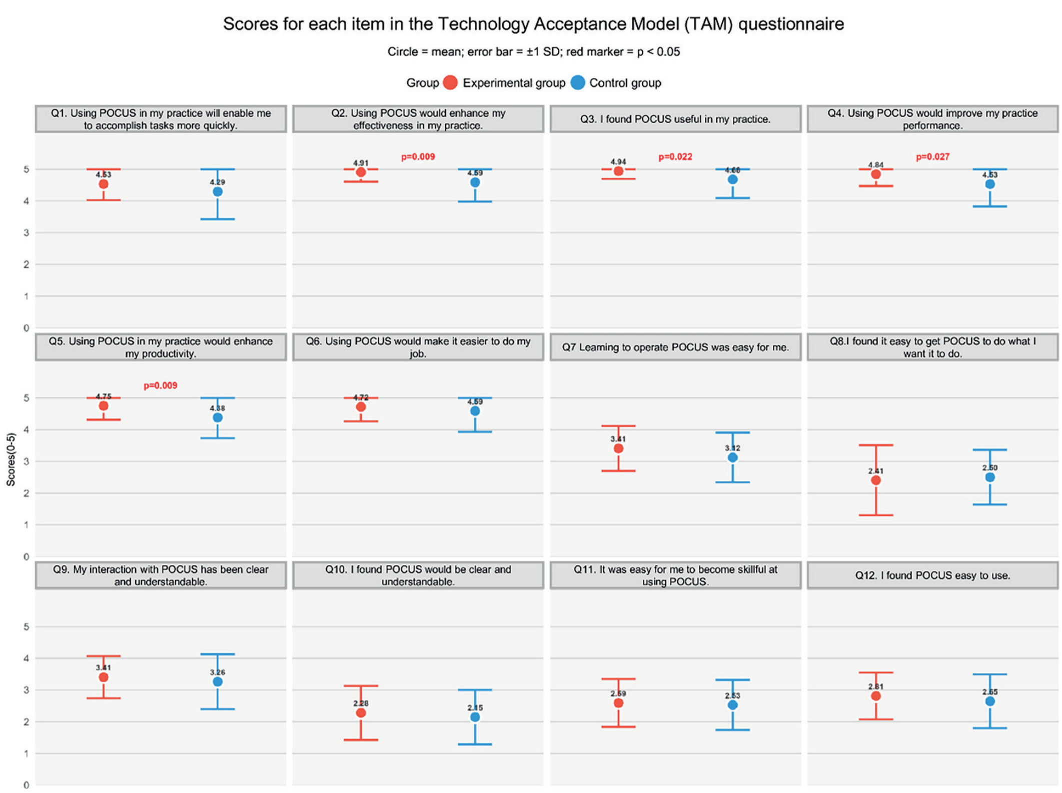

Figure 2. Each item on the Technology Acceptance Model (TAM) questionnaire compares the NPT+RS (experimental) group and the traditional (control) group. Red markers indicate items with significant between-group differences (p < 0.05).

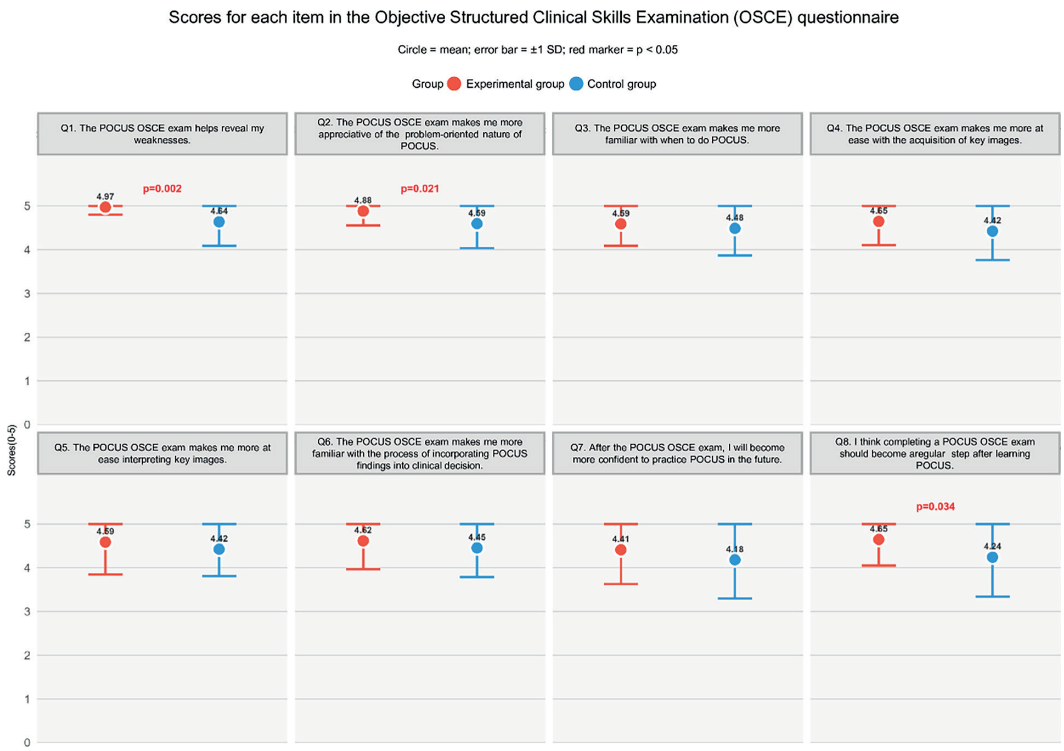

Figure 3. Each item on the PoCUS OSCE feedback questionnaire, compares the NPT+RS (experimental) group and the traditional (control) group. Red markers indicate items with significant between-group differences ($p < 0.05$).

Table 3. PoCUS OSCE questionnaire results, comparing student feedback and ratings between the NPT+RS (experimental) group and the traditional (control) group. Items are scored from 1 (strongly disagree) to 5 (strongly agree).

OSCE feedback	Experimental (n=34)	Control (n=35)	P value
Q1. PoCUS OSCE exam helps reveal my weaknesses.	4.97 (0.17)	4.64 (0.55)	0.002
Q2. PoCUS OSCE exam makes me more appreciative of the problem-oriented nature of PoCUS.	4.88 (0.33)	4.45 (0.97)	0.021
Q3. PoCUS OSCE exam makes me more familiar with when to do POCUS.	4.59 (0.50)	4.48 (0.62)	0.454
Q4. PoCUS OSCE exam makes me more at ease with the acquisition of key images.	4.65 (0.54)	4.42 (0.66)	0.137
Q5. PoCUS OSCE exam makes me more at ease interpreting key images.	4.59 (0.74)	4.42 (0.61)	0.329
Q6. PoCUS OSCE exam makes me more familiar with the process of incorporating PoCUS findings into clinical decision.	4.62 (0.65)	4.45 (0.67)	0.315
Q7. After the PoCUS OSCE exam, I will become more confident to practice PoCUS in the future.	4.41 (0.78)	4.18 (0.88)	0.263
Q8. I think completing a PoCUS OSCE exam should become a regular step after learning PoCUS.	4.65 (0.60)	4.24 (0.90)	0.034

αScores are presented as mean (standard deviation) certain underlying deficiencies. Our trial extends this literature by embedding near-peer instruction within a prospectively registered randomized design and by using an EPA-aligned OSCE that captures essential ultrasound skill domains—indication, acquisition, interpretation, and management decisions. It also explicitly operationalizes a low-contact instructional format suitable for pandemic-era education.

In this study, the only performance difference favoring the faculty-led control group was in interpretation of PLAPS findings, a relatively advanced task. This pattern is consistent with the notion that near-peers, while effective in teaching foundational scanning and common patterns, may have less experience with subtle or complex pathology. Furthermore, a remote supervising faculty member may also overlook subtle deficiencies when learners do not fully acquire this interpretation skill. Similar concerns about the depth of clinical reasoning available from peer instructors have been raised in prior reviews of near-peer teaching (13, 14). Our findings therefore underscore the importance of targeted faculty input for higher-level image interpretation and suggest that future iterations of the curriculum should prioritize cases with difficult pathologies in peer-instructor training and case libraries. PLAPS evaluation requires posterior probe positioning and integration of pleural and parenchymal findings, making it cognitively and technically more demanding than anterior lung windows. This finding suggests that comparable instructional reinforcement may be necessary for other technically complex views, such as advanced cardiac windows.

Beyond technical performance, the NPT+RS model was associated with higher ratings on perceived usefulness items in the Technology Acceptance Model, whereas perceived ease-of-use scores remained modest and similar across groups. It suggests that the intervention primarily shifted learners' beliefs about the value and impact of PoCUS rather than their sense of effort required. Near-peers, being closer in training stage, may have contextualized PoCUS within scenarios that felt immediately relevant to students' upcoming clerkships and internships, thereby enhancing perceived utility and professional alignment—factors known to support adoption of new technologies in clinical settings (28, 29). At the same time, both groups' lower ease-of-use scores reflect an appropriate recognition that PoCUS is a demanding skill, reinforcing that peer instructors did not trivialize the difficulty of mastery. Although ease of use is not a primary goal of PoCUS training for medical students, it underscores the need for continued opportunities to perform PoCUS after initial exposure.

Learners in the NPT+RS arm were also more likely to endorse the EPA-based OSCE as a meaningful assessment that revealed weaknesses, highlighted the problem-oriented nature of PoCUS, and should become a routine component of training. This aligns with calls in competency-based medical education to integrate assessment more tightly with learning, using workplace-relevant tasks and entrustment decisions rather than isolated checklists (30). The combination of near-peer–led practice and remote faculty presence may have created a psychologically safe environment in which assessment was experienced as part of a supportive learning continuum rather than an external judgment. This safer learning environment may make the subsequent formal assessment more impactful in revealing competency gaps.

Our results also resonate with emerging literature on tele-supervision and tele-ultrasound in education. Tele-supervision has been shown to extend specialist support to resource-limited or geographically distant settings when roles, cadence, and technical standards are clearly defined (19, 20). Although evidence is limited, findings from a small-scale telemedicine education study suggested improved teaching efficacy over the traditional model (31). During the COVID-19 pandemic, studies of tele-ultrasound and virtual PoCUS teaching reported that, when carefully designed, remote components can achieve knowledge and interpretation outcomes comparable to in-person courses (11). By combining multi-angle real-time camera (screen, hand–probe interface, and probe–patient contact) with near-peer facilitation, our NPT+RS model offers a concrete hybrid blueprint in which faculty can focus on high-level guidance and quality assurance while near-peers provide continuous on-site coaching.

This study has several strengths. The randomized, parallel-group design with blinded OSCE raters reduces selection and assessment bias. The EPA-based, I-A-I-M–structured OSCE allowed us to evaluate authentic clinical tasks rather than isolated technical maneuvers, and the inclusion of TAM and OSCE feedback produced a multidimensional view of educational impact that extends beyond test scores. Limitations of this study must be acknowledged. First, this was a single-institution pilot trial with a relatively small, volunteer sample and highly motivated near-peer instructors, which may limit generalizability. Second, the remote supervision model relied on stable audiovisual infrastructure and multi-camera setups that may not be readily available everywhere. Third, we did not assess long-term retention, transfer to clinical rotations, or objective written knowledge, and a novelty effect cannot be entirely excluded, particularly for the experimental format. Implementation fidelity, including the quality of peer-instructor preparation and the consistency of remote faculty engagement, may still affect outcomes despite the randomized design. Future research should address these limitations by examining longer-term outcomes such as PoCUS performance in clinical environments, sustained use of EPA frameworks, and eventual independent practice. Comparative studies of different configurations of remote supervision (e.g., varying faculty-to-group ratios, scheduled versus on-demand involvement, or asynchronous video review) may help optimize the balance between scalability and quality. Fourth, voluntary recruitment may have introduced self-selection bias favoring highly motivated students and contributing to elevated OSCE scores in both groups. Randomization was employed to reduce this bias. Fifth, RS teaching on real patients or within a hospital environment may be challenging, as the whole multi-camera system must also be portable and feasible at the point of care. Finally, adapting the NPT+RS framework to other hands-on skills—such as basic procedural ultrasound, vascular access, or simulation-based resuscitation training—could test its broader applicability as a model for scalable, competency-oriented medical education.

Overall, our findings indicate that a near-peer teaching model supported by structured remote faculty supervision can deliver PoCUS training outcomes that are indistinguishable from traditional faculty-led instruction, while enhancing perceived usefulness and acceptance of competency-based assessment. In an era marked by fluctuating infection-control demands, constrained faculty time, and expanding curricular expectations, NPT+RS model offers a promising strategy to scale high-quality, learner-centered ultrasound education without sacrificing educational rigor.

Conclusions

In this randomized trial, a low-contact PoCUS curriculum integrating near-peer teaching with remote faculty supervision achieved EPA-based OSCE performance that was non-inferior to traditional faculty-led on-site instruction, while also yielding higher perceived usefulness of PoCUS and stronger endorsement of OSCE-based assessment, with only one advanced interpretation item favoring the traditional model. These findings suggest that, when peer instructors are appropriately selected and prepared, NPT+RS can maintain technical competence and assessment quality even under constraints on faculty time or physical co-location.

The NPT+RS model may offer a practical strategy for expanding PoCUS (and other hands-on skills) training capacity, supporting small-group, skills-focused education in settings affected by infection-control requirements, geographic dispersion, or growing class sizes. By systematically incorporating junior trainees into teaching roles under structured remote supervision, this approach may benefit both learners and peer instructors and aligns with contemporary moves toward collaborative, technology-enabled, and competency-based medical education. With suitable infrastructure and faculty development, NPT+RS can help institutions scale high-quality skills training in a sustainable and learner-centered way.

List of abbreviations

A4C: Apical 4-chamber view
BLUE: Bedside Lung Ultrasound in Emergency
EPA: Entrustable Professional Activity
I-A-I-M: Indication, Acquisition, Interpretation, and Medical decision making
IVC: Inferior vena cava
NPT: Near-peer training / Near-peer teaching
OSCE: Objective Structured Clinical Examination
PLAPS: Posterolateral alveolar/pleural syndrome
PLAX: Parasternal long axis view

PoCUS: Point-of-care ultrasound
RS: Remote supervision
SD: Standard deviation
TAM: Technology Acceptance Model

Ethics Approval and Consent to Participate: The study was approved by the National Taiwan University Hospital Research Ethics Committee E (approval No. 202410061RINE). Written informed consent was obtained from all participants. The trial was registered at ClinicalTrials.gov (NCT06777641).

Consent for Publication: Not applicable.

Availability of Data and Materials: Data is available for sharing for researchers whose proposed use of the data has been approved by the corresponding author.

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Authors' Contributions: NCH proposed the conceptual framework, collected, and analyzed the data, and also wrote the preliminary manuscript. CWY, HBT and YFL participated in curriculum and assessment design and data collection. CL assisted in data interpretation and revised the manuscript. CJY and CCH supervised the work and did literature comparison and discussion. All authors read and approved the final manuscript.

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Declaration on the Use of AI: none.

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Appendix – Supplementary files

Supplement 1

Table S1. Technology Acceptance Model (TAM) questionnaire for PoCUS.

TAM Questionnaire	Level of Agreement (1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree)				
Q1對於POCUS，我認為它會提高我的工作效率。 Using PoCUS in my practice will enable me to accomplish tasks more quickly.	□1	□2	□3	□4	□5
Q2對於POCUS，我認為它對我的工作是重要的。 Using PoCUS would enhance my effectiveness in my practice.	□1	□2	□3	□4	□5
Q3我認為POCUS是有用的。 I found PoCUS useful in my practice.	□1	□2	□3	□4	□5
Q4我覺得POCUS對提升我的工作表現是有益的。 Using PoCUS would improve my practice performance.	□1	□2	□3	□4	□5
Q5使用POCUS可以增加我的工作生產力。 Using PoCUS in my practice would enhance my productivity.	□1	□2	□3	□4	□5
Q6對於POCUS，我覺得它對我是有價值的。 Using PoCUS would make it easier to do my job.	□1	□2	□3	□4	□5
Q7學習如何使用POCUS對我來說是容易的。 Learning to operate PoCUS was easy for me.	□1	□2	□3	□4	□5
Q8在使用POCUS上需要花很少努力。 I found it easy to get PoCUS to do what I want it to do.	□1	□2	□3	□4	□5
Q9我發現POCUS容易使用。 My interaction with PoCUS has been clear and understandable.	□1	□2	□3	□4	□5
Q10在使用POCUS時，我不需要學習太多。 I found PoCUS would be clear and understandable.	□1	□2	□3	□4	□5
Q11使用POCUS很簡單。 It was easy for me to become skillful at using PoCUS.	□1	□2	□3	□4	□5
Q12對我來說，使用POCUS是一個容易的任務。 I found PoCUS easy to use.	□1	□2	□3	□4	□5

Table S2. I-AIM–Based Objective Structured Clinical Examination (OSCE) Scoring Rubric for PoCUS.

Item	**Assessment description**	**Performance criteria**	**Points**
Indication 10 分	向病人說明超音波檢查 BLUE 符合適應症： (1) 呼吸窘迫 (2) 極度缺氧 (3) 將近呼吸衰竭 **The examinee explains to the patient that bedside lung ultrasound following the BLUE protocol is indicated because of:** (1) Respiratory distress (2) Severe hypoxemia (3) Impending respiratory failure	□ 3 個適應症中提到 1 項以上 Identifies one or more of the three clinical indications	3
		□ 3 個適應症都未提到 Fails to identify any of the three clinical indications	
	向病人說明超音波檢查之部位： (1) 肺部 (2) 下肢靜脈 (3) 心臟 **The examinee explains to the patient the ultrasound examination sites, including:** (1) The lungs (2) The lower extremity veins (3) The heart	□ 3 個部位中至少提到 2 項 Identifies two or more of the three ultrasound examination sites	5
		□ 3 個部位中提到 1 項 Identifies one of the three ultrasound examination sites	3
		□ 3 個部位都未提到 Fails to identify any of the three ultrasound examination sites	0
	向病人說明超音波檢查之幫助（例：鑑別診斷、快速、無侵入性、協助選擇下一步檢查等） The examinee explains to the patient the clinical benefits of ultrasound examination, such as facilitating differential diagnosis, providing rapid bedside assessment, being noninvasive, and guiding subsequent diagnostic testing.	□ 有說明 Explains the clinical benefits of the ultrasound examination	2
		□ 未說明 Fails to explain the clinical benefits of the ultrasound examination	0

Acquisition 40 分	前胸 4 BLUE points 【操作 1】 Anterior chest: four BLUE points 【Performance 1】	□ 位置正確且影像清楚 Correct probe positioning with clear image acquisition	10
		□ 位置正確但影像不夠清楚 Correct probe positioning but suboptimal image quality	7
		□ 位置大致正確但非採用標準方式 Approximate correct positioning but not performed using a standard technique	4
		□ 位置不正確 Incorrect probe positioning	0
	下肢 Common femoral vein（直接口述） **Lower extremity veins: common femoral vein** *(verbalized)*	□ 位置正確 Correct anatomical location identified	10
		□ 位置大致正確 Approximate correct anatomical location identified	6
		□ 位置不正確或未檢查此部位 Incorrect anatomical location identified or the site was not examined	0
	下肢 Popliteal vein （直接口述） **Lower extremity veins: popliteal vein** *(verbalized)*	□ 位置正確 Correct anatomical location identified	10
		□ 位置大致正確 Approximate correct anatomical location identified	6
		□ 位置不正確或未檢查此部位 Incorrect anatomical location identified or the site was not examined	0
	側胸 2 PLAPS points 【操作 1】 **Lateral chest: two PLAPS points** 【Performance 1】	□ 位置正確且影像清楚 Correct probe positioning with clear image acquisition	10
		□ 位置正確但影像不夠清楚 Correct probe positioning but suboptimal image quality	6
		□ 位置不正確 Incorrect probe positioning	0
	其他部位 （例：心臟、PLAX、A4C、IVC，直接口述） **Other regions** *(e.g., cardiac ultrasound including PLAX, A4C, and IVC; verbalized)*	□ 用 PLAX 確認 LV systolic function Assesses left ventricular systolic function using the parasternal long-axis (PLAX) view □ 用 A4C 確認 RV dilatation Assesses right ventricular dilatation using the apical four-chamber (A4C) view □ 用 IVC 確認 volume status Assesses volume status using inferior vena cava (IVC) evaluation	每項加2分 Each item is awarded 2 points.

Table S2. I-AIM–Based Objective Structured Clinical Examination (OSCE) Scoring Rubric for PoCUS (*continued*)

Item	Assessment description	Performance criteria	Points
Interpretation 40 分	前胸 4 BLUE points 【B1】 **Anterior chest: four BLUE points 【B1】**	□ 能正確判斷為 A profile Correctly identifies an A-profile	10
		□ 1 個點判斷錯誤 Misclassifies one BLUE point	6
		□ 2 個點以上判斷錯誤 Misclassifies two or more BLUE points	0
	下肢 Common femoral vein【B2】 **Lower extremity: common femoral vein 【B2】**	□ 能正確依據 compression test 判斷兩側為 no thrombus Correctly interprets bilateral compression testing as no thrombus	10
		□ 有一側判斷錯誤（懷疑 thrombus）或無法判斷 **Incorrectly interprets one side as suspicious for thrombus, or is unable to determine**	6
		□ 兩側皆判斷錯誤或無法判斷 Incorrectly interprets both sides, or is unable to determine on both sides	0
	下肢 Popliteal vein 【B3】 **Lower extremity: popliteal vein 【B3】**	□ 能正確依據 compression test 判斷兩側為 no thrombus Correctly interprets bilateral compression testing as no thrombus	10
		□ 一側判斷錯誤或無法判斷 Incorrectly interprets one side, or is unable to determine	6
		□ 兩側皆判斷錯誤或無法判斷 Incorrectly interprets both sides, or is unable to determine on both sides	0
	側胸 2 PLAPS points 【B4】 **Lateral chest: two PLAPS points 【B4】**	□ 能正確判斷右側 PLAPS(+)、左側 PLAPS(-)，並明確說明利用 continuous spine sign 判斷 Correctly identifies right-sided PLAPS positive and left-sided PLAPS negative, and explicitly states that the continuous spine sign was used to support the interpretation	10
		□ 能正確判斷右側 PLAPS(+)、左側 PLAPS(-) Correctly identifies right-sided PLAPS positive and left-sided PLAPS negative	7
		□ 一側 PLAPS 判斷錯誤 Incorrect PLAPS interpretation on one side	4
		□ 兩側 PLAPS 皆判斷錯誤 Incorrect PLAPS interpretation on both sides	0

Medical decision 10 分	提到以下 5 項處置： (1) CXR (2) 抽血（血液、生化、培養） (3) 抽血（blood gas 或 D-dimer） (4) 給予抗生素治療 (5) 考慮插管或非侵襲性呼吸器或 HFNC **Mentions the following five management steps:** (1)Chest radiography (CXR) (2) Blood sampling for laboratory tests, including hematology, biochemistry, and cultures (3)Blood sampling for arterial blood gas analysis or D-dimer testing (4)Initiation of antibiotic therapy (5)Consideration of endotracheal intubation, noninvasive ventilation, or high-flow nasal cannula (HFNC)	□ 能正確提出 3 項以上 Correctly proposes three or more appropriate management items	10
		□ 能正確提出 2 項 Correctly proposes two appropriate management items	7
		□ 能正確提出 1 項 Correctly proposes one appropriate management item	4
		□ 無法提出(1)-(5)任一項處置 Fails to propose any of the management items listed in (1)–(5)	0
	扣分項目：處置錯誤可能造成危害 **Deduction applied for management decisions that may result in patient harm**	□ 給予利尿劑 Administration of diuretics □ 給予胸管插入或細針減壓於氣胸 Chest tube insertion or needle decompression for pneumothorax □ 給予抗凝血劑治療血栓 Initiation of anticoagulant therapy for thrombosis	每項扣2分 Each item is awarded 2 points.

Table S3. OSCE feedback questionnaire for PoCUS**.**

OSCE feedback	**Level of Agreement (1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree)**				
Q1接受POCUS教學，能反映我的不足。 PoCUS OSCE exam helps reveal my weaknesses.	□1	□2	□3	□4	□5
Q2我認為POCUS教學能讓我更理解POCUS問題導向的特性。 PoCUS OSCE exam makes me more appreciative of the problem-oriented nature of PoCUS.	□1	□2	□3	□4	□5
Q3我認為POCUS教學能讓我更熟悉何時要執行POCUS。 PoCUS OSCE exam makes me more familiar with when to do POCUS.	□1	□2	□3	□4	□5
Q4我認為POCUS教學能讓我更熟悉如何取得關鍵影像。 PoCUS OSCE exam makes me more at ease with the acquisition of key images.	□1	□2	□3	□4	□5
Q5我認為POCUS教學能讓我更熟悉如何判讀關鍵影像。 PoCUS OSCE exam makes me more at ease interpreting key images.	□1	□2	□3	□4	□5
Q6我認為POCUS教學能讓我更熟悉如何將POCUS結果納入臨床決策。 PoCUS OSCE exam makes me more familiar with the process of incorporating PoCUS findings into clinical decision.	□1	□2	□3	□4	□5
Q7我認為POCUS教學後，能增加我未來執行POCUS的自信。 After the PoCUS OSCE exam, I will become more confident to practice PoCUS in the future.	□1	□2	□3	□4	□5
Q8我認為學完POCUS後，應接受POCUS OSCE測驗。 I think completing a PoCUS OSCE exam should become a regular step after learning PoCUS.	□1	□2	□3	□4	□5

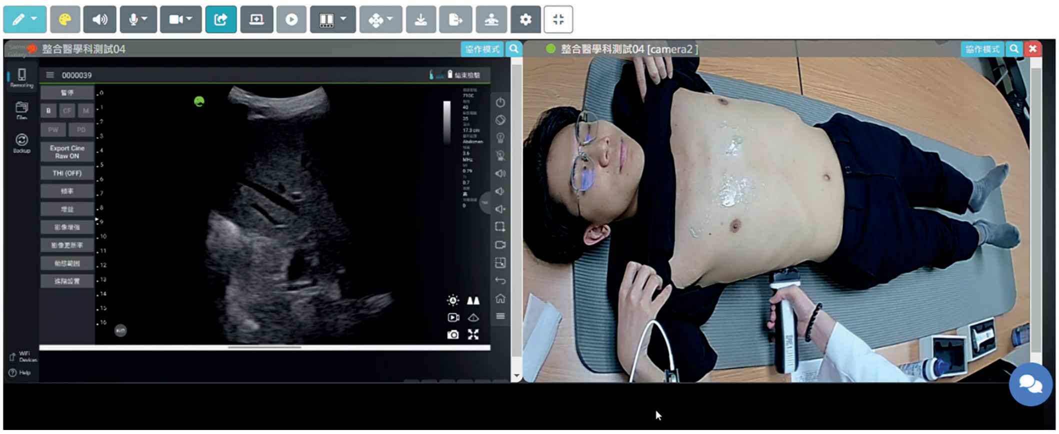

Figure S1. Remote supervision uses two cameras to show the live ultrasound image, hand and probe movements, and the probe–patient contact point.

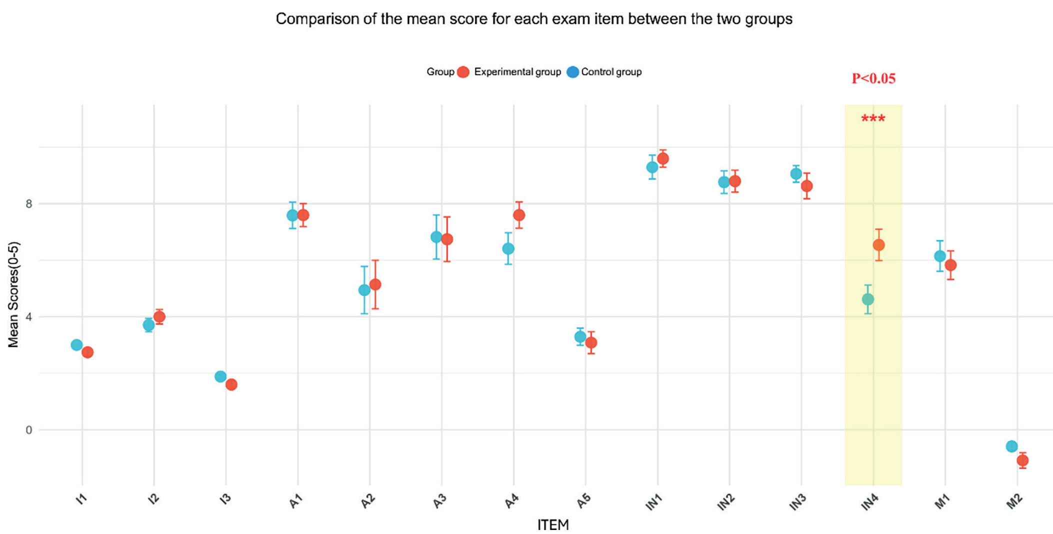

Figure S2. Comparison of mean EPA-based PoCUS OSCE item scores (±1 SD) between the NPT+RS (experimental) group and the traditional (control) group. Items are grouped by domains of indication (I1-I3), acquisition (A1-A5), interpretation (IN1-IN4), and medical decision making (M1-M2). The PLAPS point interpretation item (IN4), which showed a significant between-group difference is highlighted.

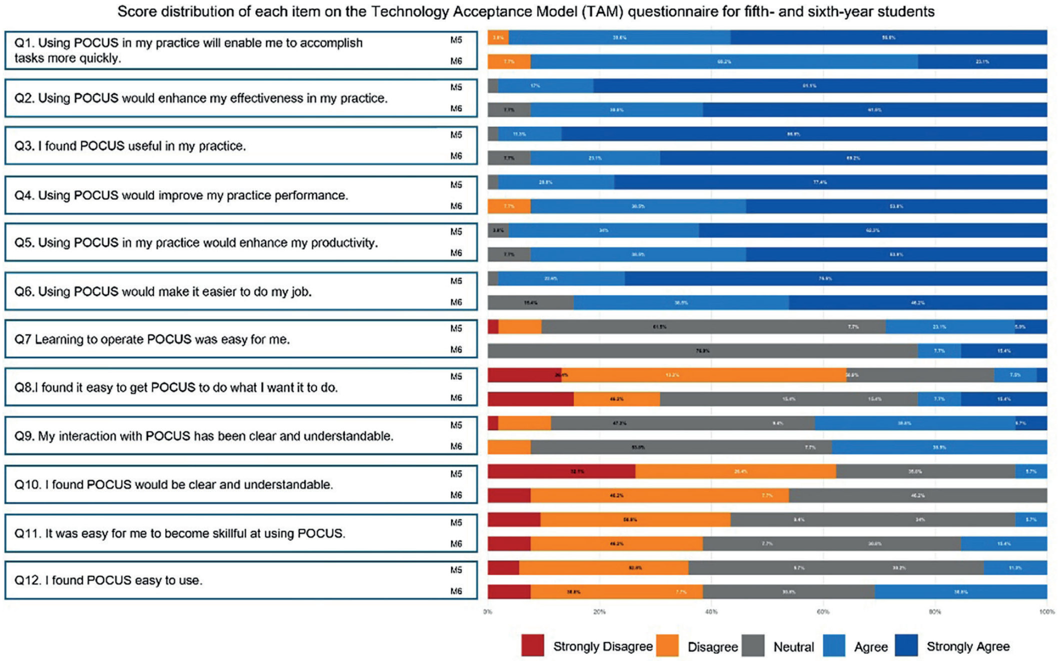

Figure S3. Score distribution of each item on the Technology Acceptance Model (TAM) questionnaire for fifth- and sixth-year students, by grade level (M5, M6). Bars show the proportion of respondents selecting each Likert category from "strongly disagree" to "strongly agree."

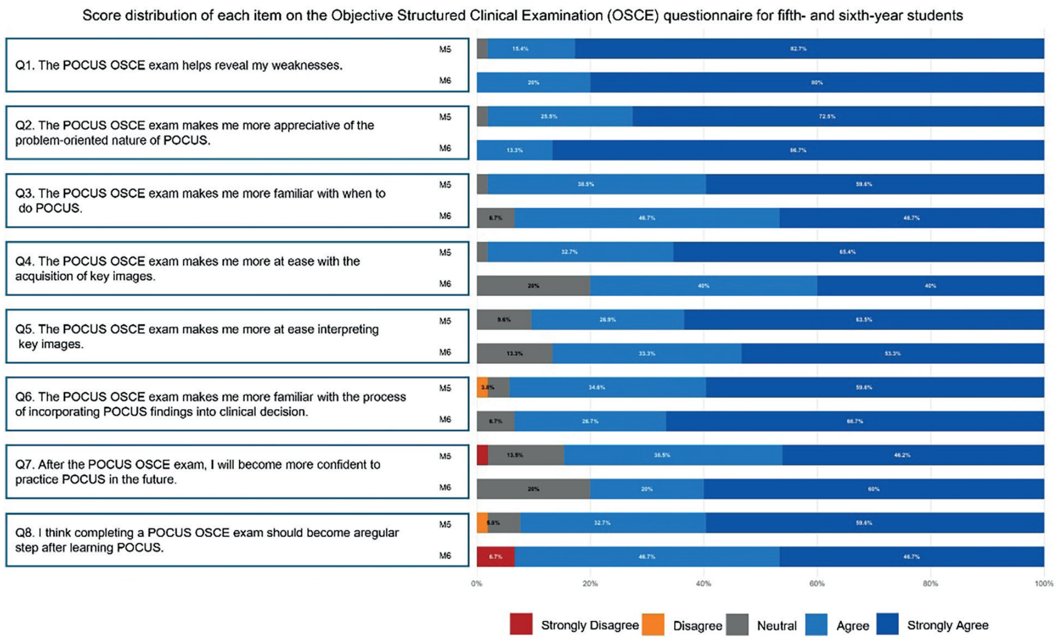

Figure S4. Score distribution of each item on the Objective Structured Clinical Examination (OSCE) feedback questionnaire for fifth- and sixth-year students, by grade level (M5, M6). Bars show the proportion of respondents selecting each Likert category from "strongly disagree" to "strongly agree."