SYSTEMATIC REVIEW

From concepts to evaluation: mapping approaches to POCUS training assessment in low- and middle-income countries – a systematic scoping review

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ABSTRACT

Background: Point-of-care ultrasound (POCUS) training programs are increasingly implemented in low- and middle-income countries (LMICs) to strengthen diagnostic capacity. Qualitative and sustainable implementation of POCUS capacity requires evaluation of training concepts and programs. In this review we collate approaches of how POCUS training programs and trainee competencies are evaluated in LMICs using Donabedian's structure–process–outcome model and Miller/De Biasio's framework of clinical competence.
Methods: This review presents a secondary analysis of data from a previous systematic scoping review that included 53 original studies on POCUS training in LMICs, identified through July 2023. Reported evaluation methods for POCUS training were extracted and categorized according to the Donabedian (structure-process-outcomes) and Miller/De Biasio ("Knows", "Knows How", "Shows How", "Does") frameworks. Data synthesis focused on the type, timing, and scope of evaluation across structural, procedural, and outcome domains.
Results: POCUS training evaluation approaches were highly heterogeneous, with most studies using multiple methods. Pre- and post-course assessments predominated, focusing mainly on knowledge and technical skills. Competence evaluations covered all levels of the Miller/De Biasio framework, though most targeted lower-order levels ("Knows," "Knows How"), while workplace-based ("Does") assessments were infrequent. When mapped

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to Donabedian's model, outcome evaluations dominated, whereas structural and process assessments were inconsistently reported. Few studies demonstrated contextual adaptation, validity testing, or long-term evaluation of training outcomes.

Conclusions: POCUS training evaluation in LMICs remains inconsistent and focuses primarily on short-term outcomes and basic competency levels. Applying Donabedian's and Miller/De Biasio's frameworks reveals critical evaluation deficiencies across system and learner dimensions and establishes a conceptual basis for more comprehensive and sustainable POCUS evaluation strategies.

Key words: Point of care ultrasound, POCUS, training, training evaluation, medical education

Introduction

In low-resource settings, point-of-care ultrasound (POCUS) has increasingly been recognized as a valuable diagnostic modality across clinical disciplines (1-7). Its portability, affordability, and diagnostic yield make it particularly suited for use in low- and middle-income countries (LMICs), where conventional imaging is often unavailable (8-10). Beyond its technical utility, POCUS also holds promise for task redistribution within overstretched health systems (6). However, successful integration depends on the availability of context-specific training strategies, adaptable to local constraints and tailored to diverse user backgrounds (6, 9, 11, 12). Existing POCUS training initiatives in LMICs remain highly heterogeneous in terms of target groups, content, structure, and delivery models (13).

Ensuring that POCUS training reliably translates into both diagnostic competence and long-term clinical application is essential, not only to support safe patient care but also to inform sustainable investment in ultrasound programs (14). Training evaluation is therefore a critical step in both quality assurance and program development.

In medical education, numerous conceptual frameworks have been developed to guide the evaluation of training programs. Most of these emphasize the assessment of learners' competence following training (15), among them Miller's pyramid of clinical competence (16) and Moore's expanded outcomes framework (17). Other approaches, such as Kirkpatrick's model, additionally focus on learner satisfaction (18, 19). The Donabedian structure–process–outcome model, originally devised for quality assurance in industry and later adapted to healthcare evaluation, has been applied to assess structural and contextual aspects of educational programs (20-23). Together, these frameworks provide a structured basis for evaluating training design, implementation processes, and outcomes, ranging from individual competence to changes in clinical performance and patient care.

While such models are well-established in educational literature, their application to POCUS training programs in LMICs remains inconsistent. A recent adaptation of Miller's framework by De Biasio et al. specifically contextualizes the levels of clinical competence for POCUS, offering a structured approach to assess POCUS-related knowledge, skills, and performance (24). Nonetheless, a wide range of evaluation strategies continues to be employed, ranging from written knowledge tests and image interpretation to clinical performance assessments and follow-up surveys (14, 24-30). However, there is no consensus on how best to evaluate the quality and sustainability of POCUS training in low-resource settings.

This scoping review collates concepts and methods used to evaluate POCUS training in LMICs and provides a descriptive conceptual mapping of applied tools, intended to guide comprehensive and standardized development of program evaluation strategies.

Methods

This systematic scoping review followed the PRISMA Extension for Scoping Reviews (PRISMA-ScR) guidelines (31), the JBI Manual for Evidence Synthesis (32), and updated methodological guidance for scoping reviews (33). The protocol was registered on the Open Science Framework (OSF) (DOI: 10.17605/OSF.IO/8FQJW). A previous publication from this literature review described training concepts for POCUS in LMICs (13). The present analysis focuses on how these training programs were evaluated, examining methods used to assess outcomes, quality, sustainability, and scalability.

Detailed methodology, including database search, eligibility criteria, and study appraisal, has been reported elsewhere (13). Briefly, a systematic search of Medline, Embase, Cochrane, and Google Scholar was conducted on December 8, 2022, and updated on July 6, 2023, using terms related to POCUS, training, and LMICs (based on the 2022 World Bank classification (34)). Studies were included if they reported original data on evaluation of POCUS training in LMICs. Screening was performed independently by two reviewers, with disagreements resolved through discussion with two additional reviewers. In the original scoping review, data extraction already explicitly included information on training evaluation approaches and challenges, which was verified by a second reviewer, and summarized descriptively in Microsoft Excel (Supplement Figure S1 Prisma Flowchart). Although these evaluation data were collected during the initial review, they were intentionally not analysed or reported in the first publication to avoid overextension of scope. These data were then systematically mapped to Donabedian's structure–process–outcome framework and, for outcome-related assessments, to the levels of Miller's/De Biasio's competence framework. Where additional clarification or contextual detail was required (e.g. needs assessment or ambiguous reporting), targeted verification and supplementary extraction were undertaken by revisiting the original full texts to ensure accuracy. Categorization followed predefined operational definitions (Supplement Table S2) and was reviewed within the author team to ensure conceptual consistency and agreement on framework alignment.

Methodological quality was appraised using a five-item tool developed for this review and based on previously published instruments (13, 35, 36).

Because this study analyzed publicly available literature, ethical approval was not required.

Conceptual frameworks for mapping evaluation methods

To address the complex context of POCUS training in LMICs and to enable a structured categorization of the heterogeneous evaluation methods reported, we applied the Donabedian (20-22) and the Miller (16) framework, two established approaches in medical education previously adapted by Gullick et al. (23) and De Biasio et al. (24), respectively. These models were selected for their complementary perspectives: Donabedian provides a systems-level view of training quality, whereas Miller/De Biasio allow structured classification of outcome assessments by competence level.

Donabedian's structure–process–outcome model, originally developed to evaluate healthcare quality, distinguishes between structural conditions, procedural activities, and resulting outcomes (20-22). Following its adaptation to medical education by Gullick et al. (23) this framework was used to organize the evaluation of POCUS training programs. In this context structure referred to training prerequisites and resources, including infrastructure, course organization, local clinical needs, and trainees' prior skills. Process encompassed the conduct of training, such as instructional methods, attendance, and trainer–trainee interaction. Outcome described the effects of training, including acquired POCUS competence, integration into clinical practice, and user confidence (Figure 1a).

To further differentiate the outcome domain, we applied Miller's framework of clinical competence (16), as adapted for POCUS by De Biasio et al. (24). This model conceptualizes outcome evaluation as progressive levels of competence development, from foundational knowledge to independent clinical performance. Level 1 ("Knows") and Level 2 ("Knows How") assess theoretical and applied understanding through written or image-based tests. Level 3 ("Shows How") evaluates technical skills in simulated settings,

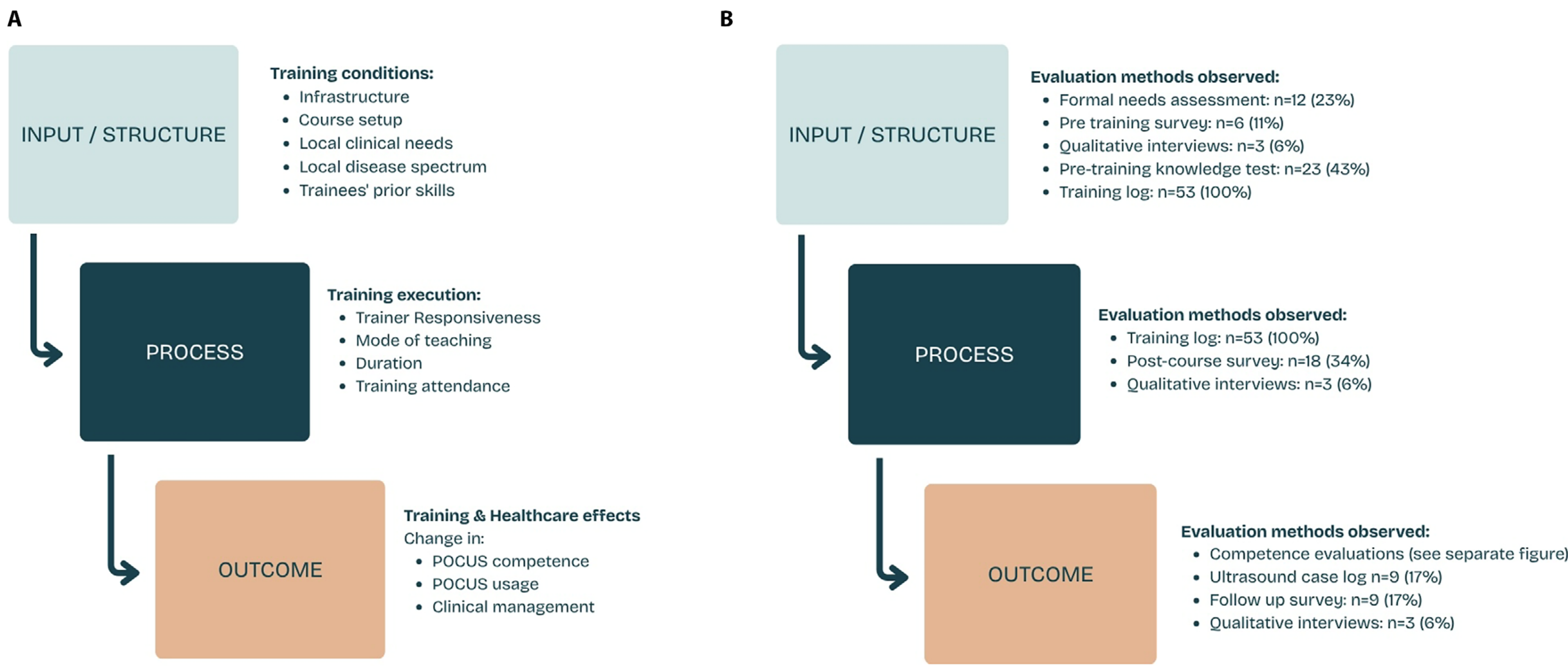

Figure 1. A) Donabedian's structure-process-outcome model applied to POCUS training evaluation (adapted conceptually from Gullick et al.). This figure illustrates the conceptual application of Donabedian's structure–process–outcome model to the evaluation of point-of-care ultrasound (POCUS) training in low- and middle-income countries. The framework organizes evaluation domains across three sequential components: Input/structure, srocess, and outcome. Arrows between domains indicate the directional relationship from structural conditions through implementation processes to resulting outcomes. B) Evaluation methods mapped to Donabedian's structure-process-outcome framework: This figure illustrates evaluation methods observed across 53 studies on POCUS training in low- and middle-income countries, organized according to Donabedian's structure–process–outcome framework as suggested in 1A. Arrows between domains indicate the sequential relationship from training structure through implementation processes to resulting outcomes.

such as hands-on or Objective Structured Clinical Examination (OSCE)-style assessments, while Level 4 ("Does") reflects integration of POCUS into clinical practice, evaluated through workplace-based assessments. In addition, we included an "other competence assessments" category to capture broader training effects or contextual factors (such as learners' confidence, perceived utility, or frequency of POCUS use) that were not represented within the original Miller/De Biasio framework (Figure 2a).

This review provides a descriptive inventory and conceptual mapping of evaluation and assessment approaches applied in LMIC POCUS training programmes. Owing to substantial heterogeneity, no comparative effectiveness or inferential analyses were undertaken.

Results

As previously described in our earlier scoping review on POCUS training in LMICs (13), the database search identified 357 unique records, of which 174 underwent full-text review and 53 met inclusion criteria for the present analysis (37-89) (Supplement Figure S1 Prisma Flowchart). Details on the search strategy, inclusion criteria, and methodological quality of included studies have been reported elsewhere (13).

Training evaluation

Across the 53 included publications, we identified a total of 232 individual training assessments. A wide range of methods was used to evaluate POCUS training, with most studies employing multiple tools in combination (Table 1). The median number of assessment methods per study was four with a range from two to nine assessments per publication. Pre- and post-course evaluations were commonly applied to capture changes in knowledge, skills, and clinical performance. Competence assessments were reported across all levels of Miller and De Biasio's framework. We subsequently mapped the identified evaluation methods to the Donabedian framework (22) to distinguish structure, process, and outcome assessments (Figure 1b, Table 2).

Input/Structure evaluations

Across the included studies, structural factors were most often evaluated through pre-training knowledge tests, surveys, and documentation of training conditions. Nearly half of the studies used pre-training knowledge tests (n=23, 43%) (41, 44, 45, 47, 50, 59-62, 65-68, 75-77, 81, 82, 84-87, 89), while a smaller proportion conducted formal needs assessments (n=12, 23%) (41, 44, 50, 52, 55, 60, 79, 80, 82, 83, 86, 88) or surveys (n=6, 11%) (45, 63, 67, 79, 80, 83) to capture trainees' prior ultrasound experience, expectations and local clinical needs. Qualitative interviews were rarely applied (n=3, 6%) (74, 83, 84) but provided additional insights into training conditions and infrastructure. All studies included at least minimal descriptions of training conditions and contextual factors. We conceptualized these collectively as training logs; however, these were not standardized evaluation tools but largely narrative or program-specific records documenting local clinical context and available resources, participation and implementation conditions and highlight the heterogeneity of settings in which POCUS training was delivered. An overview of the applied methods, frequencies, and corresponding studies is presented in Table 1.

Process evaluation

Across the included studies, process factors were mainly assessed through training logs, post-course surveys, and qualitative interviews. Post-course surveys were used in approximately one-third of studies (n=18, 34%) (39, 44, 45, 52, 55, 57, 58, 61-63, 67, 71, 75, 76, 80, 83, 85, 86) to obtain feedback on training delivery and teaching quality, whereas qualitative interviews were less common (n=3, 6%) (74, 83, 84). Training logs were reported by all studies in variable detail, including information on course duration, attendance, and curriculum adjustments, reflecting diverse approaches to process evaluation. Details on applied methods and their frequencies are summarized in Figure 1b and Table 2.

Outcome evaluation

Outcome evaluations primarily focused on assessing training effects and subsequent healthcare impacts,

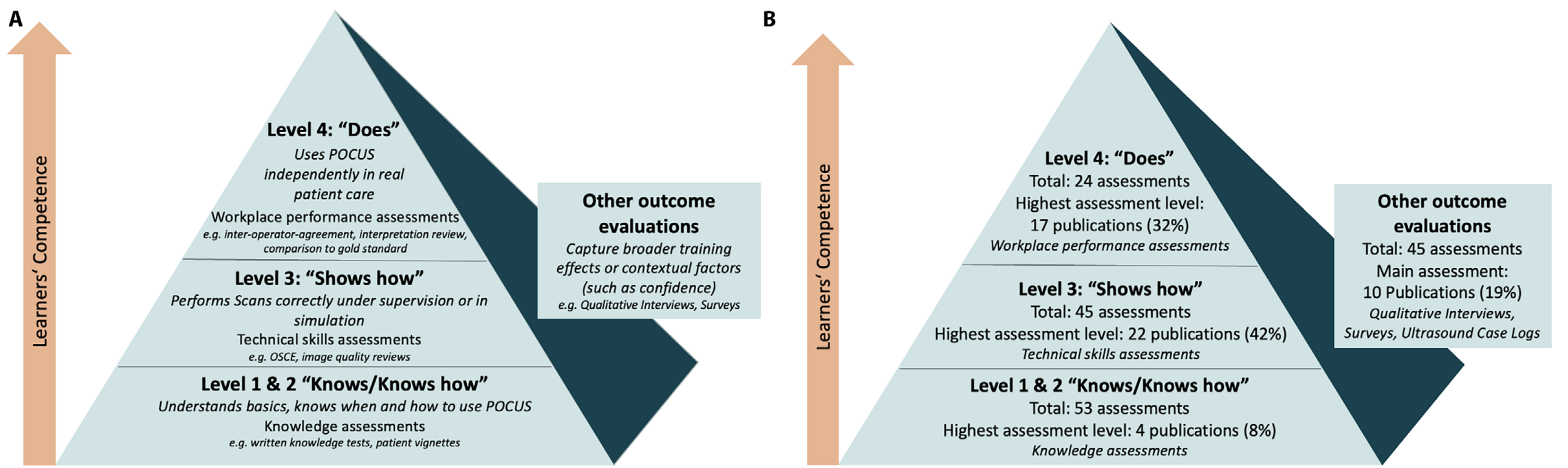

Figure 2. A) This figure illustrates the application of Miller's framework of clinical competence, as adapted by De Biasio et al., to the evaluation of point-of-care ultrasound (POCUS) training in low-resource settings. The upward arrow to the left indicates an increase in learners' competence across progressive levels of the pyramid. The base level (Level 1 & 2: "Knows/Knows How") represents foundational knowledge, the middle level (Level 3: "Shows How") reflects demonstration of technical skills under supervision or in simulation, the top level (Level 4: "Does") denotes independent use of POCUS in clinical care. The lateral side panel labeled "Other outcome evaluations" represents broader training effects or contextual dimensions captured through qualitative interviews or post-training surveys. B) This figure presents the distribution of evaluation methods observed across 53 studies on POCUS training in low- and middle-income countries, organized according to Miller's framework of clinical competence as adapted by De Biasio et al. Each pyramid level represents the corresponding competence domain and indicates both the total number of assessments reported and the number of publications in which this represented the highest assessment level applied within the study. Differences between total and highest assessment counts reflect studies applying multiple assessment types across different competence levels.

Table 1. Overview of included publications.

First Author	Year of publ.	Course description	Needs assessment	Outcome assessments	Outcome types
Barsky et al. (43)	2015	Short focused abdominal sonography in echinococcosis (FASE) course (≤1 week) for six students in Tanzania, with ongoing mentoring.	no	Post training inter-operator agreement (trainee-experts)	Patient characteristics; concordance between trainee and expert (incl. sensitivity and specificity)
Dreyfuss et al. (37)	2020	Comprehensive POCUS short course (≤1 month) in Peru for three physicians covering multiple modalities (CUS, LUS, FAST, ABD, MSC, REN/BL, IVC, OCU) with ongoing mentoring and repeat sessions.	n.a.	Ultrasound case log	No. and type of US studies uploaded to database; common procedural applications; instruction time
Bell et al. (44)	2016	Basic obstetric and eFAST POCUS short course (≤1 week) in Kenya for 81 participants (MDs, nurses, clinical officers) with repeat sessions.	yes	Post course survey, pre course (written) test, post training OSCE	No. of trainees over time; written score results over time, practical exam (OSCE) scores over time; survey: frequency of POCUS use, influence on patient care, common POCUS applications
Vanderburg et al. (51)	2023	Lung ultrasound short course (≤1 week) in Sri Lanka for five physicians with ongoing mentoring.	no	Post training inter-operator agreement (trainee-experts), examination time, proctored ultrasound studies	No. of trainees and instruction time; average examination time; LUS score (audited examinations), score difference trainee-expert over time
Shumbusho et al. (65)	2020	One-day focused lung ultrasound short course for 15 physicians in Rwanda.	no	Pre course (written) test, post course (written) test, post training inter-operator agreement (trainee-experts), comparison of POCUS results to results of other imaging modality	Sensitivity and specificity of trainee LUS for diagnosing pneumothorax (compared to expert LUS and to Chest X-Ray); time to result (LUS vs Chest X-ray)
Hall et al. (50)	2019	Comprehensive basic and advanced obstetric POCUS short course (≤1 year) in Tanzania for 13 participants (MDs, midwives, clinical officers) with ongoing mentoring.	yes	Pre course (written) test, post course (written) test, mid training OSCE(s), post training OSCE, proctored ultrasound studies	No. of ultrasound examinations performed; comparison pre/post test results; no. of trainees who completed whole training; OSCE exam scores; OSCE scores compared to no. of trainee ultrasound scans

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First Author	Year of publ.	Course description	Needs assessment	Outcome assessments	Outcome types
Wanjikua et al. (53)	2018	Basic obstetric, cardiac, and FAST POCUS short course in Kenya for 33 participants (MDs, nurses, clinical officers) with repeat sessions; training duration not reported.	no	Follow up survey, follow up (written) test, follow up OSCE(s)	Exam pass rates; comparison of pre/post exam scores; comparison last training session and exam results; report of image quality scores, correlation between frequency of scanning and exam rates and image quality scores
Shokoohi et al. (54)	2019	Short course for 63 participants (MDs and midwives) in Malawi, Tanzania, and Uganda, covering basic and advanced obstetric, cardiac, lung, abdominal, musculoskeletal, renal/bladder, ocular, and vascular sonography, with repeat sessions; training duration not reported.	no	Follow up survey	Self-reported frequency of POCUS use; POCUS indications; barriers to POCUS application
Reynolds et al. (86)	2016	POCUS short course (≤1 month) in Tanzania and Mexico for 23 physicians covering obstetric, cardiac, lung, abdominal, renal/bladder, and IVC applications.	yes	Post course survey, pre course (written) test, post training OSCE	Exam pass rates; trainee satisfaction: perceived most useful training sessions, exams able to perform with greatest confidence, balance between didactic and hands on sessions
Vinayak et al. (82)	2018	Obstetric POCUS short course (≤1 month) in Kenya for nine midwives with ongoing mentoring.	yes	Pre course (written) test, mid course (written) test(s), post training OSCE, image quality review, POCUS interpretation review, examination time	Exam pass rate, reduction in scanning time, technical feasibility of teleradiology (image transmission times, clarity of transmitted images, technological functioning), post-delivery accuracy rate
Ienghong et al. (59)	2021	Emergency POCUS short course (≤ 1 month) in Thailand for eight physicians covering cardiac, lung, shock and trauma applications.	n.a.	Pre course (written) test, post course (written) test, post training patient vignette (case presentation + video clips) exam	Pre/post exam results and their difference
Ienghong et al. (58)	2021	Short emergency POCUS course (≤1 month) for 18 physicians in Thailand, covering cardiac, lung, shock, and trauma applications.	n.a.	Post course survey	Survey: usefulness of teaching activities and learning tools, frequency and type of pocus examinations; barriers to learning POCUS
Azizi et al. (66)	2020	One-day eFAST short course for 31 physicians in Pakistan.	no	Pre course (written) test, post course (written) test, post training patient vignette (case presentation + video clips) exam	Barriers to POCUS uptake; self-reported confidence after training; comparison of test results pre/post-test and between simulator and control group

Shah et al. (83)	2020	Basic and advanced obstetric POCUS short course (≤1 month) for 25 physicians, midwives, and nurses in Uganda, with ongoing mentoring.	yes	Pre course survey, post course survey, follow up survey, image quality review, interviews (with trainee/trainers)	Changes in provider confidence; OSCE results; image review results (accuracy, quality & measurement ability over time rated by 2 independent reviewers; common errors listing and rate over time); trainees' perceptions on POCUS training (qualitative)
Aspler et al. (41)	2022	Longitudinal POCUS training covering LUS, FAST, eFAST, and IVC for 17 physicians in Ethiopia.	yes	Pre course (written) test, post course (written) test, proctored ultrasound studies	Survey response rate; commonly requested POCUS modalities; report of training program modalities; training completion rate
Lee et al. (62)	2017	Short POCUS course (≤1 month) in Indonesia for 52 physicians covering obstetric, cardiac, lung, trauma, and FASH applications.	no	Post course survey, pre course (written) test, post course (written) test, post training OSCE	Pre/post exam results with comparison; OSCE results and pass rates; pre/post course confidence levels; course feedback (what was most useful, most useful and intended POCUS modalities in the clinical setting)
Dornhofer et al. (67)	2020	Short POCUS course (≤1 month) in Indonesia for 55 physicians, midwives, and nurses covering obstetric, cardiac, lung, abdominal, trauma, and FASH applications.	no	Pre course survey, post course survey, pre course (written) test, post course (written) test, post training OSCE	Pre/post exam results with comparison, divided by provider profession; OSCE pass rates, mean comfort levels after course completion
Shaffer et al. (75)	2017	Short POCUS course (≤1 week) in Tanzania for eight physicians covering cardiac, lung, and FAST applications.	no	Post course survey, pre course (written) test, post course (written) test, post training OSCE	Pre/post exam results with comparison; confidence levels
Bentley et al. (45)	2015	Short basic and advanced obstetric POCUS course (≤1 week) for 31 midwives in Liberia.	no	Pre course survey, post course survey, follow up survey, pre course (written) test, post course (written) test, follow up (written) test, post training OSCE, follow up OSCE(s)	Pre/post/follow up exam results; provider confidence over time; OSCE scores over time
Shresta et al. (84)	2020	Short POCUS course (≤1 week) for 50 physicians in Nepal, covering obstetric, cardiac, lung, shock, trauma, abdominal, and musculoskeletal applications.	no	Follow up survey, pre course (written) test, post course (written) test, interviews (with trainee/trainers)	Pre/post test scores (stratified by experience/profession); confidence levels; self-reported clinical use, barriers to POCUS use
Attiah et al. (77)	2021	Short POCUS course (≤1 month) for 150 medical students in Tanzania, covering obstetric, cardiac, lung, trauma, and abdominal applications.	no	Pre course (written) test, mid-course (written) test(s), post course (written) test, post training OSCE	Pre/post exam results by instruction group (English vs Kiswaheli), confidence/comfort levels

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First Author	Year of publ.	Course description	Needs assessment	Outcome assessments	Outcome types
Jones et al. (63)	2020	Short POCUS course (≤1 week) for 41 physicians in Kenya, covering obstetric, cardiac, lung, shock, abdominal, FASH, and deep venous thrombosis/peripheral vascular sonography applications.	no	Pre course survey, post course survey, follow up survey, post training OSCE	Self-reported POCUS use over time; confidence levels over time; self-reported skill scores over time; access to US machines; barriers to POCUS use
Kimambo et al. (68)	2021	Short cardiac ultrasound course (≤1 week) for eight physicians and clinical officers in Tanzania, with ongoing mentoring.	no	Pre course (written) test, post course (written) test, image quality review, post training inter-operator agreement (trainee-experts)	No. of POCUS examinations performed by trainees; median proportion of images with sufficient quality (quality of images obtained); kappa agreement between trainee and expert interpretation (image interpretation of key pathologies)
Wanjikua et al. (52)	2022	Longitudinal POCUS training for 14 participants (physicians, nurses, clinical officers, radiographers) in Kenya, covering basic obstetric and eFAST applications; training duration not reported.	yes	Post course survey	Feasibility, barriers to training, relevance of training program and cases; confidence rating; training costs
Nadimpalli et al. (38)	2019	Short lung ultrasound course (≤1 week) for six clinical officers in South Sudan, with ongoing mentoring.	n.a.	Image quality review, POCUS interpretation review	Demographic and clinical data of study population; image quality grading (ACEP Quality Assurance Grading Scale) by 2 reviewers; binary assessment of image adequacy and interpretation adequacy; inter-reviewer agreement rates; image review time requirements; case load description; trainee confidence; LUS sensitivity and specificity by clinical syndrome
Kimberley et al. (56)	2010	Comprehensive basic and advanced obstetric POCUS short course (≤1 year) for 21 midwives in Zambia, with mentoring and repeat sessions.	n.a.	Follow up survey, mid training OSCE(s), post training OSCE, image quality review, post training inter-operator agreement (trainee-experts), ultrasound case log, change in patient management	Mean no. of scans per trainee; trimester timing of scans; percentage of supervised scans; main US indications; common POCUS findings; OSCE pass rates over time; scan review results; changes in clinical management prompted by POCUS; follow up: self-reported uptake, confidence and barriers to POCUS use

Henwood et al. (80)	2016	Longitudinal POCUS training (≤1 year) for 17 physicians in Rwanda, covering cardiac, lung, trauma, abdominal, and IVC applications.	yes	Pre course survey, post course survey, post training OSCE, follow up OSCE(s)	Trainee characteristics; no. of scans (total and mean per trainee); change in image-based assessment scores; OSCE exam results and change over time; follow up survey: job satisfaction; frequently used POCUS applications
Gómez Betancourt et al. (73)	2016	One-day focused IVC ultrasound short course for eight physicians in Colombia.	no	Image quality review, examination time	Trainee characteristics; no. of scan repetitions needed to obtain minimum/maximum image quality score; mean time for adequate visualization (seconds)
House et al. (48)	2021	Short lung ultrasound course (≤1 week) for 21 physicians in Nepal, with ongoing mentoring.	no	Image quality review, POCUS interpretation review	Trainee characteristics; pass rate; no. of LUS scans performed; no. of scans/trainee; proportion of abnormal scans; no. of scans needed for proficiency; inter-operator agreement (expert-trainee), LUS diagnosis observed
Rao et al. (89)	2023	Short cardiac ultrasound course (≤1 week) for 15 physicians in Haiti.	no	Pre course (written) test, post course (written) test	No. of trainees and patients; pre/post test results
Ienghong et al. (57)	2022	Short POCUS course (≤1 month) for nine physicians in Thailand, covering cardiac, RUSH, and FAST applications.	n.a.	Post course survey	Survey response rate; learning experience rated on likert score; diagnostic findings on ultrasound video clips and images obtained during training
Vanichkulbodee et al. (39)	2021	FAST training for 234 medical students in Thailand; course structure and duration not reported.	n.a.	Post course survey	Trainee characteristics; survey: US machine availability, frequency of POCUS use, level of confidence, perceptions on course and suggestions for future courses
Kolbe et al. (69)	2014	Short course with mentoring and repeat sessions for four participants (MD and nurses) in Nicaragua, covering basic obstetric, cardiac, lung, abdominal, and vascular sonography applications; training duration not reported.	no	Change in patient management	Patient characteristics; change in diagnosis (n, CI), change in management (n, CI); image quality rating; performance over time
Ienghong et al. (60)	2021	Short course (≤1 month) for 18 physicians in Thailand; specific modalities not reported.	yes	Pre course (written) test, post course (written) test, post training OSCE	No. of trainees; median pre/post test exams by year; survey: feedback on online course

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First Author	Year of publ.	Course description	Needs assessment	Outcome assessments	Outcome types
Sabatino et al. (88)	2020	Short course (≤1 month) for two clinical officers in Sierra Leone, covering lung, abdominal, musculoskeletal, and vascular sonography applications, with mentoring and repeat sessions.	yes	Post training OSCE, image quality review, post training inter-operator agreement (trainee-experts), ultrasound case log	Patient numbers and characteristics/presentations; frequency and type of POCUS scans performed; rate of diagnostic and management change due to POCUS; exam: correct identification of POCUS views, agreement trainee-expert by POCUS view; comparison POCUS performance by clinical officers and physicians, inter-observer agreement
Stolz et al. (72)	2015	Longitudinal training (>1 year) for 13 nurses in Uganda, covering obstetric, cardiac, lung, trauma, abdominal, musculoskeletal, renal/bladder, and vascular sonography applications.	no	Ultrasound case log	No. of trainees, patients and scans; frequency of different POCUS applications; frequency of POCUS uptake over time
Henwood et al. (79)	2017	Short course (≤1 month) for physicians (no. of trainees not reported) in Rwanda, covering obstetric, cardiac, lung, abdominal, renal/bladder, and IVC applications, with mentoring and repeat sessions.	yes	Pre course survey, post training OSCE, follow up OSCE(s), image quality review, POCUS interpretation review, post training inter-operator agreement (trainee-experts), ultrasound case log	No. of scans; frequency of different POCUS applications; image quality review scores by application; test performance characteristics by application; frequency of change in clinical management and type of change
Silva et al. (64)	2016	Short course (≤1 week) for 53 physicians in Brazil, covering cardiac, lung, FAST, and musculoskeletal applications.	no	Post course (written) test, post training OSCE, post training patient vignette (case presentation + video clips) exam	Mean test scores (written + practical) by study cohort; trainee attendance
Terry et al. (42)	2019	Longitudinal training (≤1 month) for ten clinical officers and students in Uganda, covering FAST applications.	n.a.	Image quality review, POCUS interpretation review, post training inter-operator agreement (trainee-experts), ultrasound case log	Average no. of ultrasound scans per month over time; image quality scores over time; image interpretation scores over time; sensitivity / specificity for FAST scan over time
Haldeman et al. (55)	2022	Longitudinal training (≤1 year) for ten physicians in Zambia, covering obstetric, cardiac, lung, RUSH, abdominal, renal/bladder, IVC, and vascular sonography applications.	yes	Post course survey, post course (written) test, post training OSCE, ultrasound case log	Trainee characteristics; no. of trainees, patients, scans; scan type frequency; rate of POCUS scans assisting in diagnosis and changing clinical management

Osei-Ampofo et al. (74)	2018	Short course (≤1 month) for 20 physicians in Ghana, covering cardiac and lung applications.	no	Follow up OSCE(s), post training patient vignette (case presentation + video clips) exam, interviews (with trainee/trainers)	Exam (written and practical) pass rates; test scores; survey: relevance, frequency and difficulty of scan protocol components; frequency of POCUS use; recommendations for future trainings
Tafoya et al. (87)	2017	Short course (≤1 month) for 20 physicians in Ghana, covering cardiac and lung applications, with ongoing mentoring.	n.a.	Pre course (written) test, post course (written) test, post training OSCE	Mean pre/post test scores; OSCE pass rate
Dreizler et al. (71)	2019	Mentoring program (≤1 year) for six participants (physicians, nurses, clinical officers, radiographers) in Kenya, covering basic and advanced obstetric as well as eFAST applications.	n.a.	Post course survey	Survey response rate; trainee characteristics; relevance of training intervention; barriers to tele-mentoring
Nazari et al. (49)	2022	Short course (≤1 week) for seven physicians in Iran, covering cardiac ultrasound applications.	n.a.	Post training inter-operator agreement (trainee-experts), ultrasound case log	Agreement of echocardiography results between trainee-expert (repeated exam on similar patients within 1h)
Damgengkajornwong et al. (47)	2018	One-day short course for 74 physicians in Thailand, covering cardiac ultrasound applications.	n.a.	Pre course (written) test, post course (written) test, post training OSCE	Trainee characteristics; pre/post written test results; OSCE pass rates (overall and by POCUS view), median image acquisition time; factors associated with passing the training
Boniface et al. (70)	2018	Short course (≤1 week) for 63 physicians and midwives in Malawi, Tanzania, and Uganda, covering cardiac, lung, FAST, abdominal, FASH, and renal/bladder applications, with mentoring and repeat sessions.	no	Follow up survey	No. of trainees, geographical distribution of trainees; barriers to POCUS use; availability of alternative imaging modalities
Rominger et al. (40)	2018	Longitudinal training (>1 year) for eight physicians in Mexico, covering obstetric, lung, FAST, abdominal, musculoskeletal, renal/bladder, and ocular applications.	no	Image quality review, ultrasound case log	No. of ultrasound examinations performed (over time); distribution of POCUS modalities; change of diagnosis stratified by body region; change of clinical management stratified by type; overall rate of disagreement trainee-supervisor and overall rate of inadequate image quality

(*Continued*)

First Author	Year of publ.	Course description	Needs assessment	Outcome assessments	Outcome types
Bhoi et al. (46)	2013	Short course (≤1 week) for five physicians in India, covering FAST applications, with ongoing mentoring.	no	Post training inter-operator agreement (trainee-experts)	Patient characteristics; no. of scans; scan results by non-radiologist (FAST pos/neg) vs. radiologists; comparative FAST observations between non-radiologists and radiologists incl. sensitivity, specificity, PPV, NPV; details of organ injury in patients with positive FAST; comparison of results with other international studies
Bui et al. (76)	2023	Short course with mentoring for 20 physicians in Guyana, covering renal/bladder applications; training duration not reported.	n.a.	Post course survey, pre course (written) test, post course (written) test, post training OSCE	No. of trainees; course completion rate; average written test score with details; OSCE pass rate; mean no. of scans per trainee; survey: trainee satisfaction (Likert scale), trainees' recommendations for future courses
Schmidt et al. (61)	2022	Short course with mentoring for 14 physicians and clinical officers in Uganda, covering cardiac and lung applications; training duration not reported.	n.a.	Post course survey, pre course (written) test, post course (written) test, post training OSCE, image quality review, POCUS interpretation review, post training inter-operator agreement (trainee-experts)	Pre/post test scores; image quality scores; image interpretation scores; survey: trainee satisfaction
Vinayak et al. (81)	2017	Short course (≤1 month) for three midwives in Kenya, covering basic obstetric applications, with ongoing mentoring.	n.a.	Pre course (written) test, post course (written) test, post training OSCE	Exam pass rate; no. of scans; image interpretation accuracy (compared to radiologist's report), post-delivery outcome comparison to POCUS report; turnaround time from POCUS scan to radiologist validation; patient satisfaction
Denny et al. (85)	2018	Short course (≤1 month) for 354 participants (physicians, nurses, clinical officers, and students) in Tanzania, covering obstetric, cardiac, lung, FAST, abdominal, and musculoskeletal applications.	no	Post course survey, pre course (written) test, post course (written) test, post training OSCE	Course participation by year; pre/post test scan result (absolute no., comparison, by trainee profession, stratified over time); survey: perceived usefulness of training components; general course feedback
Matiang'i et al. (78)	2022	Economic analysis of POCUS implementation and mentoring program for 45 midwives in Kenya, covering basic and advanced obstetric applications; training duration not reported.	n.a.	Follow up survey	No. of trainees implementing POCUS; economical calculation of feasibility of POCUS implementation (incl. scale up strategies, break even analysis, cash flow analysis)

Table 1. Overview of included publications: *Summary of studies evaluating POCUS training in low- and middle-income countries (LMICs). Columns present the first author and reference, year, training description, presence of formal needs assessment, and reported evaluation methods.* Needs-assessment: *Indicates whether a formal needs assessment was conducted prior to training (yes/no/not available (n.a.)).* Outcome assessments: *Type of evaluation approaches applied to assess POCUS training outcomes.* Outcome types: *Categories describing the domains in which outcomes were reported.*

Table 2. Assessment methods organized by Donabedian Categories.

Donabedian Category	What is evaluated	Evaluation method	Description	No (%) of publications	References
Input / Structure	Training conditions: *i.e. Infrastructure, course setup, local clinical needs and disease spectrum, trainees' prior skills*	• *Formal needs assessment*	*Varying in detail but commonly concentrating on evaluating clinical and training necessities as well as existing infrastructure prior to the training*	*12 (23%)*	(41, 44, 50, 52, 55, 60, 79, 80, 82, 83, 86, 88)
		• *Pre training survey*	*To assess trainees' prior ultrasound experience, usage, confidence and training expectations*	*6 (11%)*	(45, 63, 67, 79, 80, 83)
		• *Qualitative interviews*	*Exploring training experience regarding training infrastructure, appropriateness of curriculums*	*3 (6%)*	(74, 83, 84, 41, 45, 47, 50, 55, 59-62, 64-68, 75-77, 81, 84, 85, 87, 89)
		• *Pre-training knowledge test*	*Assessing and documenting trainees' prior existing knowledge*	*23 (43%)*	(41, 44, 45, 47, 50, 59-62, 65-68, 75-77, 81, 82, 84-87, 89)
		• *Training log*	*Documenting factors like no. of US machines, no. of trainers and trainees*	*53 (100%)*	
Process	Training execution *i.e. Trainer responsiveness, mode of teaching, duration, training attendance*	• *Training log*	*Documenting duration of trainings, attendance, changes in curriculum due to trainees' needs*	*53 (100%)*	
		• *Post-course survey*	*To collect feedback on the execution of the training*	*18 (34%)*	(39, 44, 45, 52, 55, 57, 58, 61-63, 67, 71, 75, 76, 80, 83, 85, 86)
		• *Qualitative interviews*	*Exploring trainees' experience regarding execution of the training, opinions on training and trainers*	*3 (6%)*	(74, 83, 84)
Outcome	Training & Healthcare effects *i.e. Change in POCUS competence & usage, change in clinical management*	• *Competence evaluations*	*Assessing trainees' clinical competence for POCUS after training*	See table no. 3	see table no. 3 (38, 42, 48, 61, 79, 82)
		• *Ultrasound case log*	*Recording no. of ultrasound examinations performed*	*9 (17%)*	(37, 40, 42, 49, 55, 56, 72, 79, 88)
		• *Follow up survey*	*Recording confidence and ultrasound use*	*9 (17%)*	(45, 53, 54, 56, 63, 70, 78, 83, 84)
		• *Qualitative interviews*	*To explore confidence in performing POCUS post-training*	*3 (6%)*	(74, 83, 84)

Table 2 Assessment methods organized by Donabedian Categories: *This table summarizes evaluation methods used to assess POCUS training, structured according to Donabedian's model of quality assessment. The first column indicates the domain:* ***Input***, ***Process***, *or* ***Outcome***. *The second column specifies what was evaluated within each domain: training conditions (e.g. infrastructure, course setup, local clinical needs, trainees' prior skills), training execution (e.g. trainer responsiveness, teaching mode, duration, attendance), or training and healthcare effects (e.g. changes in POCUS competence, usage, and clinical management). The third column lists the evaluation methods applied, while the fourth column provides a brief description of each method. The fifth column shows the number of publications reporting each method, with corresponding percentages. The final column provides respective references.*

including changes in POCUS competence, frequency of use, and influence on clinical management. Across the included studies, outcome measures were assessed through competence evaluations, ultrasound case logs, surveys, and qualitative interviews, with many studies combining multiple methods to capture a broader picture of training impact. Additional outcomes included assessment of post-training confidence, the number of ultrasound examinations performed, and self-reported practice integration. Long-term retention was evaluated in five studies (9.4%) using follow-up OSCEs alone (74, 79, 80) or in combination with written knowledge assessments (45, 53).

Competence assessments

We mapped competence assessments along Miller and De Biasio's framework, reflecting progressive levels of POCUS proficiency. We identified a total of 167 individual competence assessments across the included studies, representing a broad range of approaches from written knowledge tests to workplace-based performance evaluations.

Level 1/2 – "Knows / Knows How": We identified a total of 53 knowledge assessments, representing the highest evaluation level in 4 studies (8%) (59, 66, 84, 89). Written tests and case-based or image-based questions were used to evaluate theoretical and applied understanding.

Level 3 – "Shows How": These evaluations were conducted 46 times and constituted the highest level in 22 studies (42%) (40, 44, 45, 47, 53, 55, 60, 62-64, 67, 73-77, 80, 81, 83, 85-87). Assessments included OSCEs, expert image-quality reviews, and tracking of examination times to monitor proficiency gains.

Level 4 – "Does": Was reported 24 times and served as the highest level in 17 studies (32%) (38, 41-43, 46, 48-51, 56, 61, 65, 68, 69, 79, 82, 88). Methods comprised expert review of post-course POCUS interpretations, validation of ultrasound findings against clinical outcomes (e.g. post-delivery of newborn), inter-operator agreement testing, proctored scans, and documentation of management changes following POCUS use.

Other outcome measures were evaluated 45 times and represented the primary outcome in 10 studies (19%) (37, 39, 52, 54, 57, 58, 70-72, 78). These encompassed follow-up surveys, ultrasound case logs, qualitative interviews, and needs assessments addressing confidence, frequency of POCUS use, and broader contextual effects.

We present a summary of competence assessments and their frequencies across framework levels in Table 3 and Figure 2b.

Evaluation challenges

Challenges related to training evaluation were reported in 27 studies (51%). The most common issues concerned incomplete data such as trainee dropout, low survey return rates, and data loss, followed by technical difficulties (internet instability, power outages, equipment malfunction) and methodological limitations, including lack of baseline OSCEs, language barriers, and absence of gold-standard comparators. Nearly half of the studies (n=26, 49%) reported no evaluation challenges (37, 41, 46, 47, 49, 51, 54, 55, 59-62, 65-70, 72-74, 77, 82, 84, 86, 88) (Table 4).

Discussion

In this systematic scoping review, we provide a structured overview of how POCUS training has been evaluated in LMICs. As training programs expand, systematic evaluation becomes increasingly important to ensure that educational objectives translate into competence, clinical performance, and improved care. Despite the recognized value of POCUS in resource-limited settings, evaluation efforts have not kept pace with program growth.

Across 53 studies, evaluation approaches were highly heterogeneous and largely outcome- and short time focused, with limited attention to the structural and procedural factors that influence training effectiveness. Most assessments targeted lower levels of Miller's framework, while evaluations of skill demonstration or workplace performance were far less common. This predominant focus on short-term outcomes reflects broader trends in POCUS education literature (14, 25, 27-29, 90, 91) but contrasts with established quality assurance frameworks such as Donabedian's,

Table 3. Competence Assessments Organized by Miller's Levels.

Miller's Level	Trainee's Competence	Evaluation method	Description	Time point	No. (%) of publications	References
Level 1-2 "Knows / Knows How "	***Knowledge:*** *Understands ultrasound principles, anatomy, and when and how to apply POCUS in specific clinical contexts.*	*Written knowledge test*	*Written test on basic physics, knobology, probe placement; often included printed ultrasound pictures for interpretation. Pre- and post-course test results commonly were compared to assess training success.*	Pre-course	23 (43%)	(41, 44, 45, 47, 50, 59-62, 65-68, 75-77, 81, 82, 84-87, 89)
				Mid-course	2 (4%)	(77, 82)
				Post-course	22 (42%)	(41, 45, 47, 50, 55, 59-62, 64-68, 75-77, 81, 84, 85, 87, 89)
				Follow-up	2 (4%)	(45, 53)
		Patient vignette	*Including case presentations and video clips challenging trainees to interpret and diagnose.*	Post-training	4 (8%)	(59, 64, 66, 74)
Level 3 "Shows How"	***Competence in non-clinical setting:*** *Demonstrates accurate image acquisition and interpretation in supervised or simulated settings.*	*Objective Structured Clinical Exams (OSCEs)*	*OSCEs are used to evaluate learners standardized and objectively in a clinical scenario. An OSCE typically requires the learner to independently perform a clinical task (like a POCUS exam). The observing examiner checks if certain relevant clinical steps are performed correctly.*	Mid-training	2 (4%)	(50, 56)
				Post-training	23 (43%)	(44, 45, 47, 50, 55, 56, 60-64, 67, 75-77, 79-82, 85-88)
				Follow-up	5 (9%)	(45, 53, 74, 79, 80)
		Image quality review	*Experts grading the clarity and accuracy of ultrasound images obtained by trainees. Often conducted remotely by trainers accommodating potential time differences, thereby increasing its feasibility, if image transfer capabilities are available.*	Post-training	12 (23%)	(38, 40, 42, 48, 56, 61, 68, 73, 79, 82, 83, 88)
		Examination times	*Tracking the duration of POCUS exams throughout the training period, demonstrating a trend towards reduced examination times as learners gain proficiency.*	Pre/post-training	3 (6%)	(51, 73, 82)

(*Continued*)

THE ULTRASOUND JOURNAL 2026; VOL. 18: 18295 DOI: 10.5826/TUJ.2026.18295

Miller's Level	Trainee's Competence	Evaluation method	Description	Time point	No. (%) of publications	References
Level 4 "Does"	***Independent performance in clinical settings:*** *Independently performs and integrates POCUS findings into real-time patient care.*	*POCUS interpretation review*	*Trainees' recorded images and their POCUS interpretation based on these images, are evaluated by a POCUS expert for accuracy. Typically combined with image quality review.*	Post-training	6 (11%)	(38, 42, 48, 61, 79, 82)
		Post-delivery validation of results	*Obstetric ultrasound reports were compared with clinical findings after delivery of the newborn.*	Post-training	1 (2%)	(82)
		Inter-operator agreement	*Inter-operator agreement assessments measure the consistency of POCUS examination results between trainees and POCUS experts, performed in immediate succession on the same patients.*	Post-training	11 (21%)	(42, 43, 46, 49, 51, 56, 61, 65, 68, 79, 88)
		Proctored ultrasound studies	*POCUS studies conducted by trainees in a clinical setting under the supervision of an experienced practitioner. These assessments enable the trainer to observe progress and pinpoint areas of improvement in real-world clinical scenarios.*	Mid/ post-training	3 (6%)	(41, 50, 51)
		Change in patient management	*Trainees document their initial diagnosis and planned treatment before and after conducting POCUS exams. A change in the original diagnosis and management strategy indicates a successful diagnosis facilitated by POCUS.*	Post-training	2 (4%)	(56, 69)
		Comparison to other imaging modality	*POCUS results compared to findings of another imaging modality (chest X-ray).*	Post-training	1 (2%)	(65)

Other outcome evaluations	*Capture broader training effects or contextual factors such as confidence in and opportunity to perform POCUS in clinical practice.*	*Ultrasound case log*	*Record details of ultrasound examinations performed in a clinical setting incl. indication, results, date of examination, occasionally patient management.*	Mid/ post-training	9 (17%)	(37, 40, 42, 49, 55, 56, 72, 79, 88)
		Survey	*Surveys are a common tool to explore prior ultrasound experiences, confidence with using POCUS, frequencies of POCUS usage, and furthermore input and process factors like previous ultrasound experiences, course evaluations, and training feedback.*	Pre-course	6 (11%)	(45, 63, 67, 79, 80, 83)
				Post-course	18 (34%)	(39, 44, 45, 52, 55, 57, 58, 61-63, 67, 71, 75, 76, 80, 83, 85, 86)
				Follow-up	9 (17%)	(45, 53, 54, 56, 63, 70, 78, 83, 84)
		Qualitative interviews	*To explore experiences during and after the training and opinions on training and trainers, as well as trainees' confidence in performing POCUS post-training.*	Post-training	3 (6%)	(74, 83, 84)

Table 3. Competence Assessments Organized by Miller's Levels: *This table presents the assessment methods used to evaluate POCUS competence in included studies, structured according to Miller's framework for clinical assessment. The first column indicates the Miller level: Level 1–2 ("Knows"/"Knows How") reflects knowledge acquisition; Level 3 ("Shows How") represents demonstration of competence in non-clinical settings; Level 4 ("Does") corresponds to independent performance in clinical practice. The second column describes the expected trainee competence at each level. The third column categorizes the types of evaluation methods used at each level. The fourth column provides a brief description of each method. The fifth column indicates the time point at which the assessment was conducted (e.g. immediately post-training, at follow-up). The sixth column reports the number of publications applying each method, including the percentage of total studies. The final column lists the relevant references.*

Table 4. Evaluation challenges.

Category	Challenge Detail	No (%) of publications	References	Additional details or commentary
Incomplete data	*Limited trainee attendance to evaluation*	4 (8%)	(45, 50, 64, 75)	
	Loss to follow up	2 (4%)	(45, 80)	
	Trainee dropout	5 (9%)	(40, 48, 50, 78, 79)	
	Low response rates (Survey)	5 (9%)	(56, 57, 63, 71, 80)	"50% return rate" (71)
	Delayed data transfer	1 (2%)	(83)	
	Delayed data collection	1 (2%)	(40)	It took 6 weeks after the initial session to get the ultra-sound logs to all the machines and have consistent recording of the examinations (40)
	Loss of data	7 (13%)	(38, 40, 42, 43, 53, 71, 79)	5 POCUS studies lost in transmission (38)
Technical challenges	*Internet connectivity* *Power outages*	4 (8%)	(50, 52, 81, 83)	Hampered proper conduct of evaluation
	Ultrasound machine breakdown	1 (2%)	(50)	
	High cost	3 (6%)	(52, 79, 83)	Related to machine maintenance, image archiving, as well as data transfer and internet
Methodological constraints	*Changes in evaluation methodology necessary due to high failure rate*	1 (2%)	(44)	Initially closed book pre-training test - 50% pass mark to high --> changed to open book pre-training with unlimited trials and pass mark 90%
	High failure rate	2 (4%)	(89) (44)	"3 trainees had worse results in the post training test compared to pre training" (89)
	No pre-course OSCE	2 (4%)	(76, 87)	No baseline; change not measurable
	Language barriers	4 (8%)	(40, 43, 50, 85)	
	Inadequate evaluation methods	3 (6%)	(39, 40, 58)	No OSCE/clinical competence evaluation planned
	Lack of gold standard diagnostics	2 (4%)	(38, 42)	E.g. no chest x-ray available
No challenge reported	*No evaluation challenge reported*	26 (49%)	(37, 41, 46, 47, 49, 51, 54, 55, 59-62, 65-70, 72-74, 77, 82, 84, 86, 88)	

Table 4 Evaluation challenges: *This table presents challenges related to the evaluation of POCUS training, as reported in the included publications. The first column indicates the overarching category of each challenge (e.g. incomplete data, technical challenges, methodological constraints, or no challenges reported). The second column lists the challenges as reported by the study authors. The third column shows the number of publications addressing each challenge, with corresponding percentages. The fourth column provides references. The final column offers additional details or commentary to further contextualize the reported challenges.*

which emphasize the interdependence of structure, process, and outcome in achieving sustainable training quality (22, 23).

System-level evaluation gaps

From a systems perspective, structural and process evaluations were inconsistently reported. Most studies included basic details such as course duration, setting, and available equipment, but few performed formal needs assessments and systematically assessed structural readiness, including trainer availability, equipment maintenance, or alignment with local disease profiles. Likewise, process evaluation was rarely formalized: although all studies used some form of training log, only one-third incorporated post-course surveys or qualitative interviews. Consequently the majority of studies provided limited insight into teaching quality and implementation challenges. Programs that lack structured input and process data produce outcome findings that are difficult to interpret or replicate. Consistent documentation of context and delivery quality is therefore essential for meaningful comparison and adaptation across settings. Applying Donabedian's framework underscores that sustainable POCUS capacity building depends not only on producing competent trainees but also on ensuring adequate infrastructure, supportive training processes, and follow-up mechanisms that evaluate and maintain performance over time.

Competence evaluation and emerging practices

Mapping the reported assessments along Miller's framework, as adapted for POCUS by De Biasio et al. revealed a strong concentration at the lower competence levels. Most programs assessed theoretical knowledge and applied understanding (Levels 1 and 2: "Knows" / "Knows How") using written tests or patient vignettes, often in pre-/post-training design. While such assessments demonstrate measurable cognitive gain, they offer limited insight into procedural skill or clinical translation. Consistent with broader POCUS education literature (14, 28), this gap between knowledge acquisition and practical competence remains a key challenge in training evaluation. Several studies further highlighted language-related bias and limited contextual adaptation (40, 43, 50, 85), underscoring the need for culturally and linguistically appropriate assessment tools.

Evaluations at the "Shows How" level were less frequent but provide essential insight into hands-on and interpretive skills in non-clinical settings. These methods are recognized as key components of structured POCUS assessment frameworks (14, 24, 25, 27, 30) yet remain difficult to implement in low-resource contexts due to supervision constraints. Some innovative strategies, including remote image quality review often combined with timely tele-mentoring and structured interpretation feedback, represent feasible alternatives to strengthen skill verification and sustain learning even under resource limitations.

The "Does" level, reflecting autonomous performance in clinical practice, was reported in approximately 1/3 of studies (32%), and was primarily assessed through expert POCUS interpretation review, inter-operator agreement testing, or proctored ultrasound scans thereby indicating that real-world performance evaluation is increasingly feasible even in resource-limited settings. These workplace-based assessments best capture real-world performance and are increasingly emphasized in competency-based medical education (28-30, 91). At this level, several innovative approaches were identified that serve as pragmatic proxies for assessing clinical impact, including post-delivery validation of obstetric POCUS findings (82), documentation of POCUS-induced changes in clinical management (56, 69) and remote tele-mentoring.

An additional category, "Other outcome assessments," captured behavioral and contextual effects of training that extend beyond technical competence, such as learners' confidence, frequency of POCUS use, and perceived clinical utility. These measures complement competence evaluations by reflecting behavioral change and clinical integration. While a few recent tools developed in high-income settings have attempted to incorporate such elements (92), their applicability in LMIC contexts remains to be demonstrated.

Overall, competence assessments clustered at the lower tiers of Miller's pyramid, emphasizing short-term learning rather than long-term performance.

Consistent with recommendations by Damewood et al. (26) and Kumar et al. (28), most programs employed multiple complementary tools rather than a single assessment method suggesting that multimodal approaches may strengthen validity of training outcomes.

Integrating system- and learner-level perspectives

To align evaluation strategies with intended outcomes, evaluators should first define what is being assessed: training context, implementation processes, or learner outcomes. By combining Donabedian's and Miller's frameworks we were able to achieve a multilayered understanding of training quality by linking system-level prerequisites and educational delivery with learner competence and clinical application. Programs that assess both contextual and learner dimensions yield a more comprehensive view of training effectiveness and sustainability. This integrated logic can help guide the selection of appropriate evaluation methods and foster more coherent, theory-informed evaluation design. Conversely, when structural and process data are missing, outcome findings remain difficult to interpret or reproduce.

Evaluation challenges

Evaluation challenges were reported in roughly half of the included studies, most commonly related to incomplete or missing data, technical limitations, and methodological constraints. Low survey response rates, data loss, unstable internet connectivity, and participant dropout frequently affected evaluation quality. Strengthening methodological planning and use of streamlined digital tools could help mitigate these recurring barriers. Sparse data on long-term competence retention and workplace integration further highlight persistent challenges in evaluating sustained POCUS training outcomes in LMICs.

Limitations

This scoping review has several limitations that should be considered when interpreting its findings. The heterogeneity of study designs, reporting quality, and evaluation terminology inherently limits comparability and restricts the extent to which broader generalisations can be made. Moreover, the available evidence is unevenly distributed across settings and program types, which likely introduces contextual bias.

Most studies originated from tertiary or academic centers, which may limit generalizability to peripheral or primary care settings where POCUS could have the greatest impact. This contextual bias suggests that many programs operated within established institutional structures, while data from less-resourced environments, where systematic evaluation is even more challenging, remain scarce.

Framework-based mapping inherently involves interpretation. To minimize bias, evaluation methods were independently extracted by two reviewers, while categorization according to predefined operational definitions was conducted by one reviewer and reviewed within the author team for consistency. Although appropriate for a scoping review, heterogeneous terminology and inconsistent reporting limited comparability across studies.

In addition, a temporal limitation must be acknowledged. The literature search was completed in July 2023. Since then, POCUS education has continued to evolve, particularly with the emergence of AI-assisted guidance and automated feedback tools. While recent literature increasingly discusses these innovations as educational supports (93-95), we did not identify evidence that they are currently being used as structured, validated evaluation methods in LMIC POCUS training contexts. Nevertheless, early work – including evidence from other imaging domains and POCUS-related pilot studies – suggests that AI may be particularly promising for automated image quality review (96, 97). Coupled with survey data indicating openness to AI-assisted tools among obstetric providers (98), this suggests growing acceptance and future feasibility. Future work is needed to explore whether and how such technologies may be integrated into formal assessment frameworks.

Recognising these limitations is essential, as they reflect both the realities under which many LMIC POCUS programs operate and the urgent need for more standardised, transparent, and methodologically robust approaches to evaluation.

Implications for future POCUS training evaluation

Comprehensive evaluation of POCUS training should address three dimensions: (1) structured documentation of training prerequisites and context, (2) transparent monitoring of instructional processes, and (3) longitudinal outcome assessment extending beyond immediate post-course testing. The mapping presented here provides practical orientation for selecting appropriate methods within these domains but does not establish which approaches are most valid or feasible for each purpose. Further research is needed to determine which evaluation methods best capture training effectiveness, competence acquisition, and sustained clinical integration under varying LMIC conditions. Feasible approaches such as workplace-based evaluations, tele-supervision, and remote image review could enable higher-level competence assessment, provided that reliable mentorship and feedback systems are established. Ultimately, developing and validating context-adapted evaluation frameworks will be essential to enhance comparability across studies and to build an evidence base for sustainable, high-quality POCUS training programs in resource-limited healthcare systems.

Building on these implications and in response to the observed fragmentation and inconsistency of current evaluation practices, we propose a set of core reporting domains for POCUS training programs in LMICs. Derived from the combined findings of this scoping review and our previously published review on POCUS training concepts in LMICs (13) and informed by Donabedian's structure-process-outcome framework, these domains outline a small set of essential elements that should be assessed and reported at a minimum: (1) trainee characteristics; (2) training context; (3) curriculum and training design; (4) intended evaluation focus and target competence level; (5) documentation of implementation and process; and (6) timing and type of outcome assessment performed (Table 5).

Table 5. Proposed core reporting domains for POCUS training evaluation in LMICs.

Proposed reporting domain	Proposed key reporting items	Item description
Trainee characteristics *Determines starting competence level for interpretability of assessments*	*Number of trainees*	*Number of applicants and trainees enrolled in and starting the training program*
	Trainees' profession and experience	*Professional background of trainees (e.g. clinical officer, midwife, nurse, medical student, physician), preferably stratified by level of training or specialization, years of clinical practice and local clinical role*
	Baseline POCUS experience	*Prior exposure to POCUS, including previous training and clinical use*
Training context *Enables contextualization and assessment of appropriateness, feasibility and scalability*	*Local setting and needs:* a. *care setting* b. *clinical scope* c. *assessed needs*	a. *Clinical level and context in which the POCUS training is delivered (e.g. primary, secondary, tertiary care; urban or rural setting)* b. *Clinical domains and intended applications of POCUS relevant to the local practice setting* c. *Whether and how local needs, gaps, or baseline competencies were assessed to inform training design and content*
	Training capacity: a. *trainer qualification* b. *trainer-trainee ratio* c. *no. and type of devices* d. *training models*	a. *Professional background, clinical expertise, and POCUS-related training of instructors involved in the programme* b. *Number of trainees per instructor during training activities* c. *Availability and characteristics of ultrasound devices used for training (e.g. number, portability, functionality)* d. *Types of models used for training, such as simulators, healthy volunteers, or patients with relevant pathology*

(*Continued*)

Proposed reporting domain	Proposed key reporting items	Item description
Curriculum and training design *Core determinant of learning exposure and competence development*	*Content scope*	*Range of POCUS topics, protocols, and applications covered by the training program*
	Instructional approach	*Teaching methods used and share of practical hands-on training versus didactic instruction*
	Training duration	*Total instructional time allocated to the training program, preferably stratified by instructional components (e.g. didactic sessions, hands-on practice)*
	Training format	*Overall structure of the training program, distinguishing between single-session courses and longitudinal training formats*
Intended evaluation focus & target competence level *Clarifies evaluation intent and alignment between training goals and assessment*	*Purpose of evaluation*	*Primary focus of the evaluation (e.g. POCUS protocols, training approach, trainee satisfaction, or trainee competence)*
	Intended trainee competence level post training (according to Miller/De Biasio (24))	*Target level of competence the training program aims to achieve according to the Miller/De Biasio framework*
Implementation & process *Distinguishes monitoring of implementation from descriptive context reporting*	*Delivery fidelity*	*Extent to which the training was delivered as originally planned*
	Trainee attendance	*Overall attendance, dropout rates, relevant lack of attendance including reasons*
	Deviations from planned training delivery	*Documented changes to the planned curriculum, timing, instructional methods, or evaluation approach during implementation*
	Trainee & trainer responsiveness	*Level of engagement and participation during training, including trainer accessibility and adaptation to learners' needs*
	Process documentation tools	*Type of tools used to document training delivery and implementation processes (standardised instruments vs. narrative "training logs")*
Timing & type of outcome assessment performed *Differentiates intended from measured competence and addresses retention and transfer*	*Assessment methods applied*	*Types of assessment instruments used (Table 2, Table 3)*
	Competence levels assessed	*Levels of competence evaluated according to the Miller/De Biasio framework (24) (Figure 2, Table 3)*
	Timing of assessment	*Time points at which assessments were conducted (immediate post-training vs. longitudinal follow-up)*
	Evaluation attendance	*Proportion or number of trainees who participated in the evaluation activities*
	Evaluation results	*Summary of reported evaluation outcomes, including pass/fail decisions and deltas between pre-/post-course levels*

Table 5 Proposed core reporting domains for POCUS training evaluation in LMICs: *This table presents proposed reporting domains for the evaluation of point-of-care ultrasound (POCUS) training programmes in low- and middle-income countries (LMICs). The table lists reporting domains, corresponding key reporting items, and brief item descriptions derived from synthesis of two scoping reviews. Domains are organized into six reporting areas and ordered to reflect a structure–process–outcome logic informed by Donabedian's framework. The proposed domains are intended to support transparent description and interpretation of training context, implementation, evaluation focus, and assessment practices, rather than to define prescriptive reporting standards or consensus-based guidelines.*

These domains represent an evidence-informed, non-prescriptive starting point and will require further validation through consensus-based approaches, ideally involving LMIC stakeholders and relevant organisations.

Conclusion

POCUS training evaluation in LMICs remains fragmented and dominated by short-term, lower-level outcomes. Mapping current practices revealed key methodological gaps - limited structural and process evaluation, short-term outcome focus, and inconsistent use of validated tools - and underscored the need for structured, theory-informed approaches. Building on insights from this and our prior review, we propose a preliminary, evidence-informed Set of Core Reporting Domains for POCUS training programs in LMICs as a pragmatic starting point to improve transparency and comparability across future studies. Further consensus-based work will be required to refine and validate such approaches and to strengthen the evidence base for sustainable POCUS training and its contribution to improved patient care.

Abbreviations

POCUS: point of care ultrasound
LMICs: Low- and middle-income countries
OSF: Open Science Framework
OSCE: Objective Structured Clinical Examination

Ethics Approval and Consent to Participate: As published and publicly available literature forms the basis of the review, ethical approval was not required for this investigation.

Consent for Publication: Not applicable

Availability of Data and Materials: The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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Supplementary files

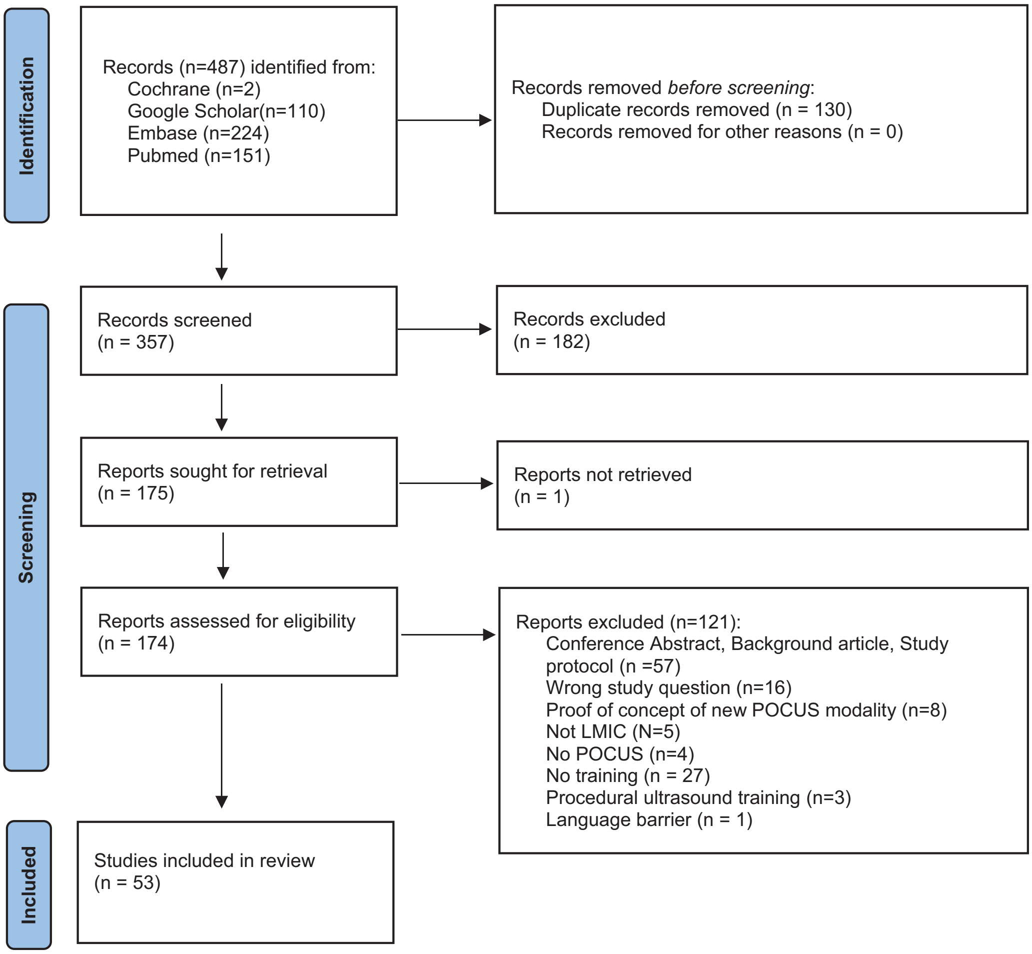

Figure S1. PRISMA flow diagram literature search and review (primary literature search on December 8, 2022, search update on July 6, 2023) from the original scoping review (13), summarizing study selection and inclusion process for the dataset used in this secondary analysis.

Table S2. Coding Framework.

Framework	Category	What is evaluated?	Operational definition	Example assessment methods
Donabedian	Structure	**Training conditions:** *i.e. Infrastructure, course setup, local clinical needs and disease spectrum, trainees' prior skills*	*Conditions and inputs before training*	Needs assessment
Donabedian	Process	**Training execution** *i.e. Trainer responsiveness, mode of teaching, duration, training attendance*	*Implementation aspects of training*	Training log
Donabedian	Outcome	**Training & Healthcare effects** *i.e. Change in POCUS competence & usage, change in clinical management*	*Post-training results or effects*	Competence evaluations Ultrasound case log
Miller	Level 1-2 ("Knows/ Knows How")	**Knowledge:** *Understands ultrasound principles, anatomy, and when and how to apply POCUS in specific clinical contexts.* *Excl: practical exams*	*Theoretical understanding*	Written knowledge texts
Miller	Level 3 ("Shows How")	**Competence in non-clinical setting:** *Demonstrates accurate image acquisition and interpretation in supervised or simulated settings.* *Excl: independent clinical performance*	*Skill demonstration*	OSCE Image quality review
Miller	Level 4 "Does"	**Independent performance in clinical settings:** *Independently performs and integrates POCUS findings into real-time patient care.*	*Workplace performance*	Image interpretation review Comparison to radiological gold standard
Other outcome assessments	Other outcome evaluations	**Broader training effects or contextual factors:** *such as confidence in and opportunity to and frequency of performing POCUS in clinical practice*	*Confidence, frequency of use*	Surveys Qualitative interviews

Table S2. Coding Framework: *The figure illustrates the analytical framework used to categorize observed evaluation methods according to Donabedian's model (structure, process, outcome) and Miller's pyramid of clinical competence ("knows", "knows how", "shows how", "does"). Each category defines what aspect of training was evaluated and how it was operationalized in the included studies. "Other outcome assessments" capture broader behavioral and contextual effects, such as learners' confidence, frequency of POCUS use, and perceived clinical utility.*