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Open-access RUSH protocol course improves knowledge and perceived confidence among healthcare learners

Arif Alper Cevik[1*] and Fikri M. Abu-Zidan[2]

Abstract

Background The Rapid Ultrasound in Shock (RUSH) protocol is an effective point-of-care ultrasound (POCUS) tool for diagnosing shock, yet access to training is limited by high costs, instructor shortages, and global disruptions like COVID-19. This study evaluates the impact of an open-access RUSH course on enhancing knowledge and perceived confidence among healthcare learners, focusing on those from Low- and lower-middle-income countries (LIC and LMICs) and with varying levels of prior ultrasound experience.

Methods The online RUSH protocol course offered by the International Emergency Medicine (iEM) Education Project via iem-course.org. Participants completed pre- and post-course surveys that gathered demographic information and assessed their confidence using a 0-to-10 Likert scale. Pre- and post-course quizzes were included to measure knowledge gain. Quantitative and qualitative analyses were done as appropriate.

Results Of 1,008 participants, 982 completed the pre-course survey; 46.0% reported no formal ultrasound training at their institutions, and 40.2% had never attended an ultrasound course. Participants were from 100 countries, with 67.3% from Asia and 40.5% from LIC and LMICs. Knowledge scores significantly improved from 60.0 (46.7–73.3) to 86.7 (80.0–93.3) ($p < 0.001$), and perceived confidence also increased ($p < 0.001$). No differences were found in score improvements between income groups, though those without prior experience showed greater knowledge gains than those with experience (26.7 vs. 20, $p = 0.003$). Additionally, 20.5% of participants provided feedback, noting high satisfaction and suggesting scenario-based videos, more challenging quizzes, and offline resources to enhance the course.

Conclusion Online education proved to be successful in teaching an advanced ultrasound course by significantly improving knowledge and perceived confidence about the RUSH protocol. The course was attended by a large number of participants globally and was successful for those from LIC and LMICs, and those without prior ultrasound training experience. The online course can be considered as a preparatory phase which saves time for more advanced hands-on practice.

Keywords RUSH protocol, Online course training, Knowledge and confidence improvement, Low- and lower-middle-income countries

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Background

Rapid Ultrasound in Shock patients (RUSH) protocol is a systematic Point-Of-Care Ultrasound (POCUS) approach which is used to quickly diagnose the etiology of undifferentiated shock. It involves evaluating the "pump" (heart), "tank" (inferior vena cava, thoracic and abdominal cavities), and "pipes" (large arteries and veins) to identify potential causes of shock [1]. The method allows clinicians to differentiate between hypovolemic, obstructive, cardiogenic, and distributive forms of shock [2]. The RUSH results demonstrated a strong correlation with the final diagnosis, achieving a high correlation coefficient of 0.84. This method has 88% sensitivity and 96% specificity, showing its reliability and effectiveness in clinical settings [3]. Therefore, it can assist the clinical decision-making of physicians in critical situations.

There is great demand for ultrasound training among healthcare providers, yet access to formal ultrasound training remains limited in many institutions. This gap is primarily due to barriers including cost, access to ultrasound hands-on courses, lack of qualified instructors or ultrasound machines, lack of ultrasound training in the medical curricula [4–6]. The World Health Organization has recognized ultrasound as a sustainable technology for developing nations, yet the need for trained personnel remains unmet due to the high cost of traditional training methods [7]. In addition, traditional POCUS education, which relies heavily on hands-on, bedside learning, faced disruptions due to the COVID-19 Pandemic, urging educators to explore alternative methods such as virtual platforms and tele-ultrasound to effectively continue ultrasound training [8]. To support the education of trainees which was impacted by the Pandemic, the International Emergency Medicine (iEM) Education Project launched a course platform (iem-course.org) that offers massive open online courses (MOOC) for healthcare trainees worldwide as part of its social responsibility initiative [9]– [10]. The online RUSH course was one of the five courses on the platform. Its aim was to provide free, flexible education opportunities for participants from different geographical locations and economic levels and improve participants' knowledge and confidence in the RUSH protocol.

Recent institutional and regional studies reported that participants gained knowledge and were comfortable using ultrasound in clinical practice after online, virtual ultrasound courses. This led to high satisfaction by trainees and educators [11]– [12]. While the studies indicate potential positive outcomes from online virtual ultrasound courses, several potential drawbacks to consider include: the need for hands-on experience to master ultrasound techniques, participants might be less confident in their skills compared to face-to-face courses, and some learners may struggle with low self-motivation and lack of deep engagement with the teaching material compared with traditional classroom settings [13]– [14]. Although MOOCs have hindrances, they can be quite helpful in utilizing the time for face-to-face activities when in-person interactions are limited [15]. We think that MOOCs, which provide participants with a flexible learning opportunity in terms of time and location, are suitable for a flipped classroom model of training, where core didactic content is delivered asynchronously before class, allowing in-person sessions to focus on active learning, discussion, and practical application of skills. Low- and lower-middle-income countries (LIC and LMIC) may have fewer opportunities for exposure to effective ultrasound courses [16], a challenge likely exacerbated by the COVID-19 pandemic. Therefore, MOOCs could provide a valuable opportunity to acquire essential knowledge on ultrasound protocols, particularly in resource limited settings [11].

A single-day face-to-face training on the RUSH protocol has been found effective for medical students [17]. However, its complexity makes it more challenging to teach compared to the Extended Focused Assessment with Sonography for Trauma (EFAST) during hands-on training sessions [18]. Therefore, prior ultrasound course experience may be necessary and could impact the benefits gained from the course. However, it remains unclear what relationship prior ultrasound training has on knowledge acquisition specific to the RUSH exam, as this has not been well defined in the existing literature.

This study aims to evaluate the impact of an open-access RUSH Protocol course on improving knowledge and perceived confidence among healthcare learners, with a focus on those from LIC-LMICs and those with and without prior ultrasound course experience.

Methods

Study design and setting

This prospective observational study assessed the participants' knowledge and perceived confidence on the RUSH protocol prior to and following the completion of the RUSH course. The instructional content was disseminated via the course platform of the iEM Education Project (iem-course.org).

Course platform, content and implementation

The iEM Education Project is a non-profit project developed for medical students and interns that offers free educational resources globally [9]. It is supported by the United Arab Emirates (UAE) University and endorsed by the International Federation for Emergency Medicine. In May 2020, the project's course platform was opened in order to support education of students and interns who were affected by the COVID-19 pandemic [10].

The platform provided five courses, including the online RUSH course.

The online RUSH course structure was developed by the iEM project director, an emergency medicine academician with over 25 years of experience in undergraduate and postgraduate education. Course content was curated from peer-reviewed chapters of the 2018 Clerkship Book, available at iem-student.org. Pre- and post-course surveys (Appendix 1) were developed to gather demographic information and evaluate participants' perceived confidence in RUSH protocol. A formative assessment on the course content was conducted before and after the course. Participants were required to pass a final examination to complete the course. Figure 1 illustrates the course structure and implementation process. The RUSH course was offered free of charge to all participants. All instructional materials (surveys, texts, images, videos, formative assessments, and the final examination) were integrated into a learning management system (LMS). LearnDash LMS [19] is used for WordPress websites [20], where the project's course is located. The course was conducted from May 24, 2020, until December 17, 2023.

The RUSH course was designed to equip learners with essential knowledge and practical skills of the RUSH protocol. Through structured instruction, participants first learn and describe the basics of ultrasound, including the use of relevant terminology, knobology, image acquisition processes, and the identification of common artifacts. The course also addresses the clinical indications for using the RUSH protocol, along with guidelines for preparing both the patient and the ultrasound machine. Learners engage in targeted training to interpret various ultrasound examination views, recognize normal anatomical structures, and detect abnormal findings. The key outcomes of this course are improving the knowledge and fostering learner confidence to apply the skill in practice.

Ethical considerations

The course evaluation study was exempt from ethical review according to UAE University guidelines, due to the absence of sensitive or identifiable data (ERS_2020_6130). Participants were informed that pre- and post-course surveys was voluntary, with reminders provided prior to the course and before each survey.

Participants

The course was open to participants globally. Although the iEM Education Project primarily targets medical students and interns, enrolment was available to all levels of medical providers, given the course's relevance to learners at various stages, from medical students to residents. Participants voluntarily enrolled in the RUSH course through the iEM Education Project course platform (iem-course.org). No active recruitment was performed.

Quantitative data collection and analysis

Enrolment and completion data, formative and final (summative) exam results, and pre- and post-course survey responses were gathered through the LMS in WordPress. Access to this data was restricted to the project director, website administrator, and Primary Investigator of the study. The pre- and post-course formative quizzes contained 15 multiple-choice questions with various formats such as fill-in-the-blanks, single-best-answer, multiple-correct-answer selection, ordering, and matching. The final course exam consisted of 20 multiple-choice questions, including true/false items and single-best-answer questions with four options, as well as ordering. A minimum score of 70% was required to pass the course, and participants who met this threshold received a certificate of completion.

Participants had 12 days to complete the course. To be eligible for the final exam, they had to complete all required steps shown in Fig. 1, except for the optional pre- and post-course surveys. The surveys collected demographic data, such as gender, training level, region, and country. Participants also rated their confidence in

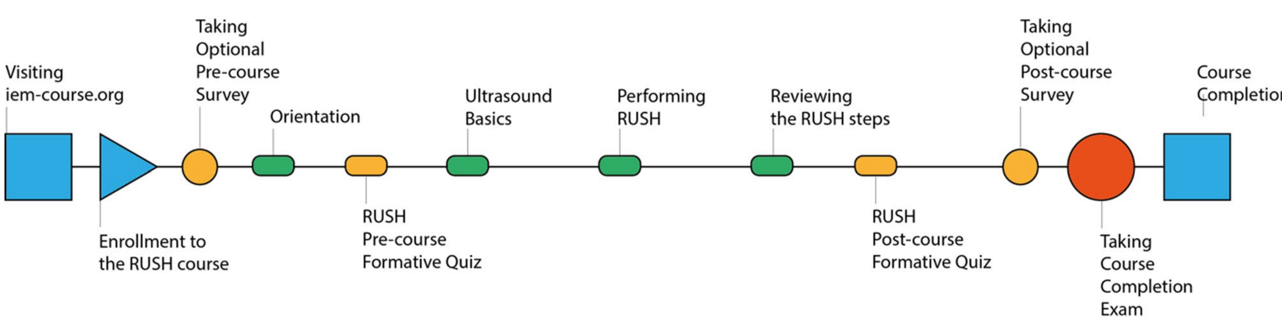

Fig. 1 After enrolment, participants may complete an optional pre-course survey at the start of the orientation session, then progress through the sessions step by step. After completion of all sessions and formative quizzes, they may complete a post-course survey before taking the final course exam. A score of 70% or higher on the exam qualifies them to receive a course completion certificate. The course is titled RUSH: Rapid Ultrasound in Shock patients

areas related to the course content. The post-course survey included open-ended questions for feedback and how likely they were to recommend the course. The confidence ratings used a 0-to-10 Likert scale.

Enrolment, completion, quiz, final exam, and survey data were exported from the WordPress database as comma-separated values (CSV) files. The only identifier included was a nine-digit user ID, used solely to match entry and exit quizzes with pre- and post-course survey responses for each participant. After matching, the user IDs were removed from the final CSV to maintain participant anonymity while retaining the data needed for descriptive and comparative analysis.

Statistical analysis was conducted using SPSS (version 29.0). Nominal variables were reported as frequencies and percentages, while continuous variables were presented as medians with interquartile ranges (IQR, 25th–75th percentile). The Fisher exact, Mann-Whitney U and Kruskal-Wallis tests were applied as appropriate. The Wilcoxon Signed-Rank test was compared pre- and post-course quiz and survey results. A p-value below 0.05 indicated statistical significance. Cohen's d effect sizes were also calculated, with 0.8 or higher representing a large effect.

Qualitative data collection and analysis

Qualitative data were collected through a post-course survey. Before initiating the qualitative analysis, the dataset was extracted, cleaned, and anonymized to ensure participant confidentiality. Course engagement data, retrieved from WordPress and LearnDash, were exported as comma-separated values (CSV) files, preserving only a unique 9-digit user identifier to maintain anonymity. For the qualitative analysis, we employed ChatGPT (OpenAI) and NoteBookLM (Google), leveraging their functionalities for inductive thematic analysis and data triangulation [21, 22]. The CSV files were uploaded to ChatGPT-4o and converted into text format, which was subsequently exported as a portable document format (PDF) file to facilitate accuracy checks. Thematic analysis was then conducted in accordance with Braun and Clarke's six-phase framework, ensuring a rigorous and systematic approach to data interpretation [23].

To support consistency and automation in the analytic process, we developed a dedicated Custom-GPT for qualitative analysis [24]. This involved defining analytic objectives, integrating the steps of Braun and Clarke's thematic approach, and evaluating the reliability of the model outputs. The verified PDF files were subsequently uploaded to both Custom-GPT and NoteBookLM to aid in theme identification and exploration. Triangulation was achieved by comparing insights from manual human coding, Custom-GPT outputs, and NoteBookLM analyses [24–26]. This methodological approach enhanced analytic efficiency, improved interpretive accuracy, and yielded structured qualitative insights. The validation of this process was informed by our prior use of large language models (LLMs) in smaller-scale qualitative studies [27]. Ethical considerations were rigorously addressed; no sensitive personal identifiers were collected or processed, and all qualitative data were anonymized before being introduced into LLM environments [24, 28]. Throughout the analysis, human oversight was maintained to ensure interpretive integrity and ethical compliance [24].

Results

Quantitative results

1,008 participants enrolled and started the course. 982 (97.4%) completed the entry survey. The majority (77.6%) of the participants were medical trainees. Nearly half (46.0%) reported that their institutions lacked formal ultrasound training, and 40.2% stated they had never attended a prior ultrasound course. Participants represented 100 countries, with 67.3% coming from Asia. The UAE had the largest participation (22.7%), followed by India (14.0%). Based on the World Bank's 2023 income classification, 40.5% of participants were from low- or lower-middle-income countries [29].

However, attendance at prior ultrasound courses was 37.5% for participants from LIC and LMIC, compared to 62.1% for participants from upper-middle-income countries (UMIC) and high-income- countries (HIC) (p-value = 0.002, Fisher's exact test). Similarly, participants indicating that their institutions offered formal ultrasound training were 35.3% in LIC and LMIC, compared to 64.7% in HIC and UMIC, $p < 0.001$ (Fisher's Exact Test). Demographic data of participants are presented in Table 1.

Comparative analyses of participants' knowledge and perceived confidence

Formative knowledge quizzes

Of the 1,008 participants, 679 (67.4%) completed both the pre- and post-course formative quizzes. The results demonstrated a statistically significant improvement in knowledge, with median (IQR) scores increasing from 60.0 (46.7–73.3) in the pre-course quiz to 86.7 (80.0–93.3) in the post-course quiz ($p < 0.001$, effect size: −0.949). This substantial increase indicates that the course effectively enhanced participants' understanding of the RUSH protocol.

As illustrated in Fig. 2, the box-and-whisker plot visually represents this shift, showing a marked narrowing of the IQR in post-course quiz scores, with most participants scoring above 80%. The whiskers also demonstrate a reduction in score variability, suggesting a more uniform improvement across learners. The statistical significance of these findings ($p < 0.001$) further supports the

Table 1 Participants' demographics according to pre-course survey results

	N **= 982 (%)**
Gender	
Female	463 (47.1)
Male	511 (52.0)
Not answered	8 (0.8)
Current level of training	
Medical student	402 (40.9)
Intern	113 (11.5)
Resident	247 (25.2)
Educator	76 (7.7)
Other	144 (14.7)
Formal ultrasound training in their institution/college	
No	452 (46.0)
Yes	471 (48.0)
Do not know	59 (6.0)
Previous ultrasound course attendance	
No	395 (40.2)
Yes	587 (59.8)
Region	
Africa	130 (13.2)
Asia	661 (67.3)
Australasia/Oceania	15 (1.5)
Central America	22 (2.2)
Europe	66 (6.7)
North America	51 (5.2)
South America	37 (3.8)
Income Levels	
LIC	55 (5.6)
LMIC	343 (34.9)
UMIC	187 (19.0)
HIC	397 (40.4)

effectiveness of the course in achieving its educational objectives.

Formative quiz and country income category

There was no difference in pre-course quiz scores and post-course quiz scores between participants from different income levels. The pre-course median (IQR) score was 60 (40-73.3) in LIC and LMIC participants and 60 (46.7–73.3) in HIC and UMIC participants (p-value = 0.123, Mann-Whitney U). The post-course median (IQR) score was 86.7 (80-93.3) in LIC and LMIC participants and 86.7 (80–100) in HIC and UMIC participants ($p = 0.434$, Mann-Whitney U).

The median (IQR) post-course quiz scores of both participant groups, LIC - LMIC and HIC - UMIC, improved significantly ($p < 0.001$, Wilcoxon Rank test, effect size: −0.971 and − 0.957, respectively). While there was no statistically significant difference, the post-course quiz median (IQR) scores of participants from LIC-LMIC improved more than those from HIC-UMIC, with scores of 26.7 (6.7–40) and 20 (13.3–33.3), respectively ($p = 0.274$, Mann-Whitney U).

Formative quiz and prior ultrasound course experience

Participants without prior experience in ultrasound courses demonstrated significantly lower median (IQR) scores in the pre-course quiz compared to those with prior experience, $p < 0.001$ (Mann-Whitney U test): 53.3 (40-66.7) versus 66.7 (48.3–80). Additionally, in the post-course quiz, those without previous experience again scored lower, $p = 0.002$ (Mann-Whitney U test): 86.7 (73.3–93.3) compared with 93.3 (80–100) for those with prior experience. The median (IQR) pre- and post-course quiz scores of both participant groups improved significantly ($p < 0.001$, Wilcoxon Rank test, effect size: −0.960 and − 0.970, respectively). Participants without prior course experience showed a greater improvement in their median (IQR) scores, with an increase of 26.7 (13.3–40) points compared to 20 (6.7–33.3) points in participants with prior course experience ($p = 0.003$, Mann-Whitney U).

Perceived confidence

Participants' overall perceived confidence in the RUSH protocol significantly improved after completing the course. The median (IQR) confidence score increased from 6 (3–8) pre-course to 9 (8–10) post-course ($p < 0.001$, effect size: −0.842), indicating a substantial gain in self-reported confidence. Improvements were consistent across all measured components, including ultrasound physics, recognition of pericardial effusion, and identification of abnormal cardiac contractility, suggesting that the course provided a well-rounded confidence boost. Table 2 provides a comparison of participants' perceived confidence levels from the pre- and post-course surveys.

As illustrated in Fig. 3, the box-and-whisker plot visually displays this overall confidence shift, demonstrating that pre-course confidence levels were widely distributed, whereas post-course confidence levels were concentrated at higher values. The narrowing of the IQR in the post-course group suggests greater uniformity in confidence gains, reinforcing that the course was effective across diverse learners. The statistical significance ($p < 0.001$) further supports that this observed increase is unlikely due to chance, highlighting the course's impact on learners' perceived competence.

Perceived confidence and country income category

Prior to the course, the overall median (IQR) perceived confidence in the RUSH protocol was 7 (4–8) among LIC-LMIC participants, compared with 5 (3–8) among HIC-UMIC participants. This difference was insignificant ($p = 0.285$, Mann-Whitney U). After completing the

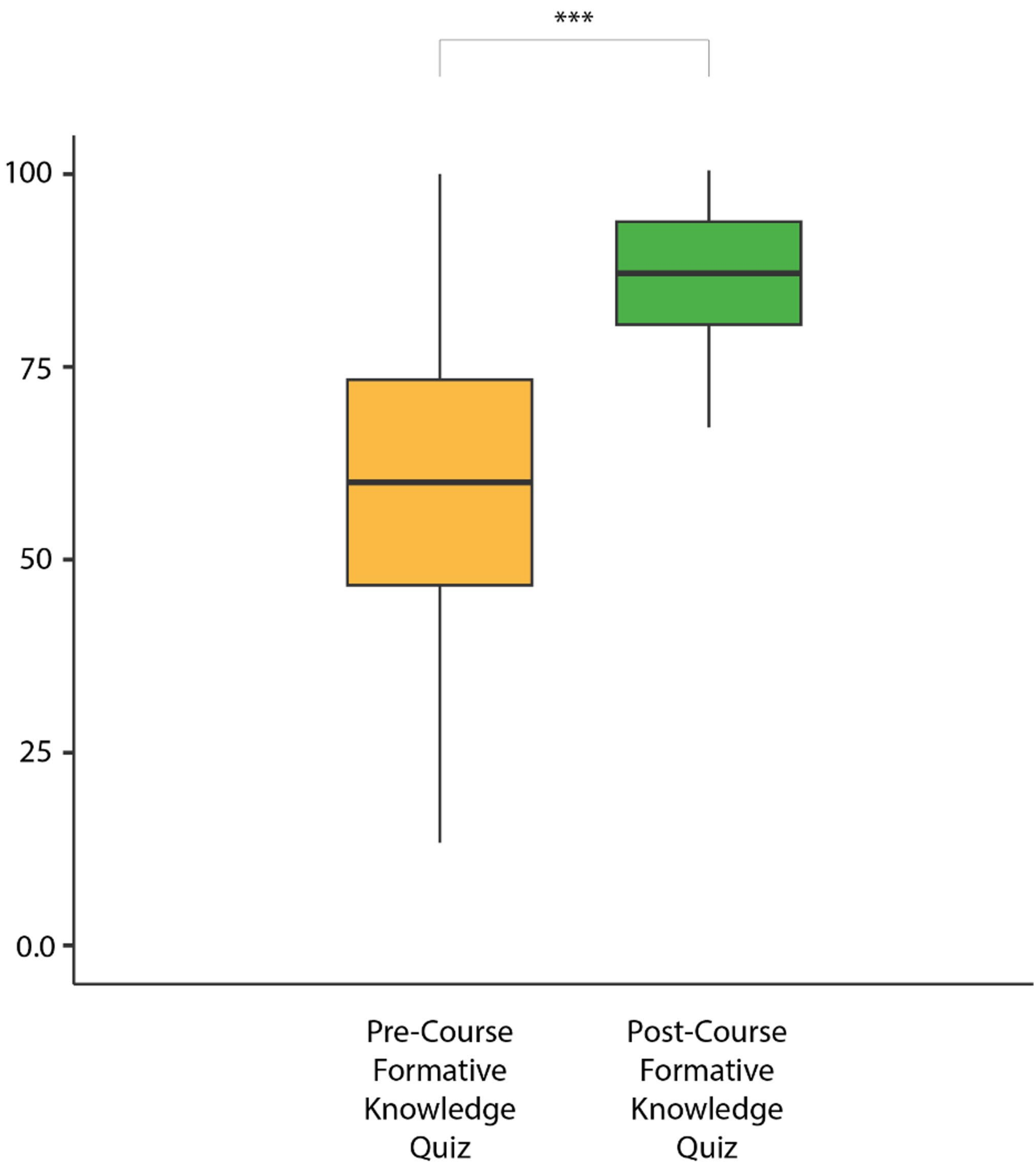

Fig. 2 A box-and-whisker plot of participants' formative quiz scores before and after the course is presented. The box represents the interquartile range (IQR) from the 25th to the 75th percentile, with the horizontal line inside indicating the median. The whiskers display the range of non-outlier values. Pre-course quiz results are shown in orange, post-course results in green, and *** indicates a p-value < 0.001

course, the median (IQR) perceived confidence for LIC-LMIC participants increased to 9 (8–10), while HIC-UMIC participants reported a median confidence of 9 (7–10). Again, this difference was not statistically significant ($p = 0.922$, Mann-Whitney U). Both participants groups, LIC-LMIC and HIC-UMIC, median (IQR) perceived overall confidence on RUSH protocol increased significantly, $p < 0.001$ (Wilcoxon-Rank test, effect size: −0.780 and −0.884, respectively). However, the median (IQR) score increase in both groups was 2 (0–5), with

Table 2 Comparative analyses of participants' perceived confidence (*N* = 439)

Questions	Pre-Course	Post-Course	*P* value	Effect Size
Expectation and Fulfilment of Expectation	9 (7–10)	9 (8–10)	< 0.001	−0.325
Current perceived overall confidence level about RUSH protocol	6 (3–8)	9 (8–10)	< 0.001	−0.842
Current perceived confidence on				
Ultrasound physics and knobology	6 (4–8)	9 (8–10)	< 0.001	−0.852
Recognizing pericardial effusion	7 (5–9)	9 (8–10)	< 0.001	−0.812
Recognizing abnormal cardiac contractility	6 (3–8)	9 (8–10)	< 0.001	−0.926
Recognizing abnormal RV size	5 (3–7)	9 (8–10)	< 0.001	−0.953
Recognizing IVC collapse	6 (4–8)	9 (8–10)	< 0.001	−0.915
Recognizing intraperitoneal free fluid	7 (5–9)	9 (8–10)	< 0.001	−0.840
Recognizing pelvic free fluid	7 (5–9)	9 (8–10)	< 0.001	−0.847
Recognizing pleural free fluid	7 (5–9)	9 (8–10)	< 0.001	−0.857
Recognizing pneumothorax	7 (5–9)	9 (8–10)	< 0.001	−0.837
Recognizing pulmonary congestion	5 (3–8)	9 (7–10)	< 0.001	−0.938
Recognizing aortic dissection	5 (2–7)	9 (7–10)	< 0.001	−0.932
Recognizing abdominal aortic aneurism	5 (2–7)	9 (7–10)	< 0.001	−0.959
Recognizing femoral DVT	5 (2–7)	8 (7–10)	< 0.001	−0.925
Recognizing popliteal DVT	5 (1–7)	8 (7–10)	< 0.001	−0.939

RV Right Ventricle, *IVC* Inferior Vena Cava, *DVT* Deep Venous Thrombosis

no significant difference between the groups ($p = 0.478$, Mann-Whitney U).

Perceived confidence and prior ultrasound course experience

Participants without prior ultrasound course experience reported similar median (IQR) confidence levels in the pre-course survey compared to those with previous experience, with scores of 6 (4–8) versus 6 (3–8), respectively ($p = 0.734$, Mann-Whitney U). In the post-course survey, however, participants without prior experience demonstrated a lower median (IQR) confidence compared to those with experience, scoring 8 (7–10) versus 9 (8–10) ($p = 0.013$, Mann-Whitney U). Both groups showed significant improvements in their median (IQR) confidence from pre- to post-course ($p < 0.001$, Wilcoxon Rank test; effect sizes: −0.754 and − 0.883, respectively). The increase in median (IQR) confidence was similar across groups, with both showing a gain of 2 (0–5) points ($p = 0.545$, Mann-Whitney U).

The level of expectation from the course

At the beginning of the course, participants expressed high expectations from the course, with a median (IQR) score of 8 (7–10). Participants with prior ultrasound course experience had significantly higher expectations from the course, with a median (IQR) of 9 (7–10) compared to 8 (6–10) for those without prior experience ($p = 0.014$, Mann-Whitney U). Similarly, participants whose institutions offered ultrasound courses had higher expectations from the course, with a median (IQR) of 9 (7–10) compared with 8 (7–10) among those from institutions without such courses ($p = 0.018$, Kruskal-Wallis). There were no differences in course expectation scores across country income levels. 512 of 1008 participants (50.8%) completed the exit survey. They indicated that the course met their expectations, with a median (IQR) score of 9 (8–10). The quality of the text content, videos, quizzes, and overall material was also rated at 9 (8–10). The likelihood of recommending the course received a median (IQR) score of 10 (8–10). A total of 439 participants (43.5%) completed both the pre- and post-course surveys (Table 2). The median (IQR) expectation score before the course was 9 (7–10). Upon completion, the median (IQR) score for how well the course met their expectations was 9 (8–10), with a p-value < 0.001 and an effect size of −0.325.

Final exam

726 participants (72.0%) reached the final exam stage, with 685 (94.4%) successfully passing the exam. 602 (87.8%) of them passed the final exam on their first attempt. The median passing score was 80, with an IQR of 75–90.

Qualitative results

Of the 512 participants who completed the post-course survey, 105 (20.5%) submitted written feedback.

In our evaluation, we manually assessed 30% of the participants' qualitative feedback, from which we extracted codes, themes, relevant quotes, and pertinent information. This manual coding process yielded 12 distinct codes and identified four overarching themes. We documented these findings for comparison with the results generated by Custom-GPT [24]. We continued our manual assessment of the complete qualitative dataset,

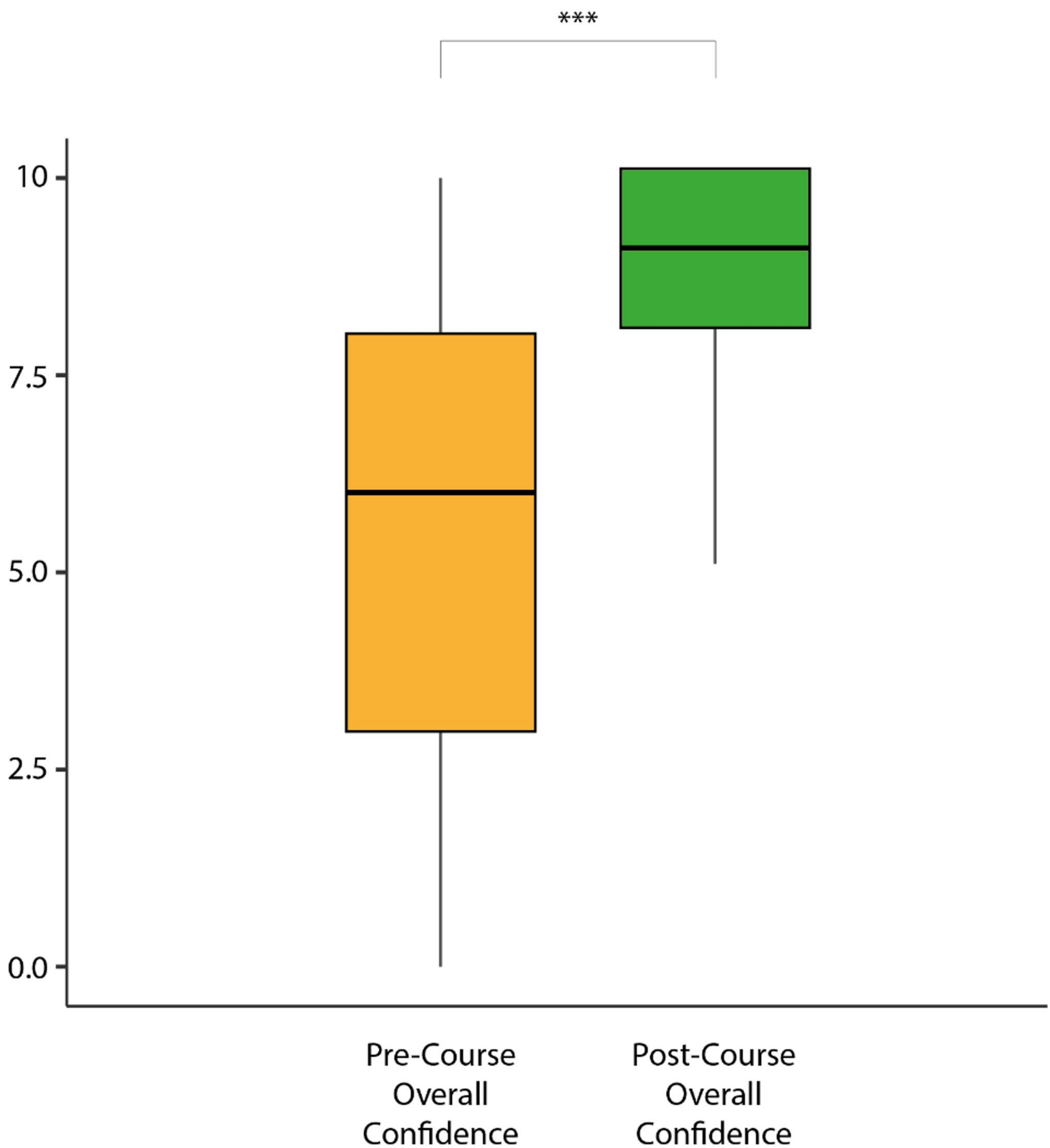

Fig. 3 A box-and-whisker plot of participants' perceived overall confidence for RUSH protocol before and after the course is presented. The box represents the interquartile range (IQR) from the 25th to the 75th percentile, with the horizontal line inside indicating the median. The whiskers display the range of non-outlier values. Pre-course overall confidence is shown in orange, post-course overall confidence in green, and *** indicates a p-value< 0.001

systematically extracting codes, themes, and relevant quotes and information [24].

Comparisons were made between the manually derived results from the initial 30% sample and the entire qualitative dataset and results produced by Custom-GPT. The content of these codes and themes exhibited a degree of similarity, allowing for their potential amalgamation. The manually derived codes and themes from the 30% sample were successfully captured by Custom-GPT, as were those extracted from the complete dataset.

NoteBookLM was used triangulating the results obtained from Custom-GPT and manual ones [24].

We successfully identifying the appropriate codes and information within the document. This analytical exercise concluded with a final determination of nine codes and five themes. The thematic outputs not only met our expectations but also accurately reflected the underlying data.

The feedback collected from participants reflects a mix of suggestions for improvement and positive reflections on the course. Five themes emerged from the qualitative data: Learner Satisfaction and Future Expansion, Engaging and Clear Content Delivery, Hands-on Learning Experience, Effective Assessment Strategies, and Access to Learning Resources.

Learner satisfaction and future expansion

While many participants provided constructive criticism, others expressed positive feedback and satisfaction with the course. A few even requested course expansion into related areas, such as ECG training.

> *"Everything was explained well in the videos, and it is easy to comprehend".*

(A participant from Philippines)

> *"Please make such wonderful course for ECG also. Thank you."*

(A participant from India)

Engaging and clear content delivery

Participants emphasized the need for more videos, better explanations, and scenario-based learning. Some participants expressed difficulty with unclear video content and access issues to some video resources provided in the course. They also suggested that video presentations should involve practical, scenario-based examples to enhance retention.

> *"Video possibly need a bit more descriptive for understanding. It could be scenario-based presentation rather [than] just a statement through video clip!!!"*

(A participant from Bangladesh)

> *"I would strongly like the end list videos more integrated with the text since they were the best."*

(A participant from Canada)

> *"More videos and examples - and more pictures with annotations."*

(A participant from Canada)

Hands-on learning experience

Many participants expressed a strong preference for practical, hands-on learning, suggesting that theoretical knowledge alone is insufficient. They emphasized that applying the content in practical settings enhances comprehension and retention.

> *"I suggest giving us more practical classes because we learn better when we apply the theoretical information in real life."*

(A participant from UAE)

> *"Need more videos for abnormal conditions."*

(A participant from India)

Effective assessment strategies

Several participants found the quizzes repetitive. They suggested improving quizzes by adding new questions and more varied content. The participants expect the assessments to be more dynamic and challenging to align with the course content.

> *"Expecting more difficult quizzes."*

(A participant from India)

Access to learning resources

Participants expressed the need for downloadable resources such as PDFs or notes to complement the online content. Some users reported access issues with videos, which negatively impacted their learning experience.

> *"Difficulty to access some of the videos as certain areas of work and living areas in remote sites no YouTube access".*

(A participant from South Africa)

> *"If you could create a downloadable version of the notes, it would be very helpful."*

(A participant from Egypt)

> *"The videos should have the caption below for foreign student like me."*

(A participant from Vietnam)

Each theme captures different aspects of the learning experience, highlighting both satisfaction and areas for improvement. Key recommendations based on these themes include enhancing video content with more scenario-based explanations while ensuring seamless access. Practical learning elements should be incorporated to complement theoretical instruction, and quiz structures revised to include more varied and challenging questions. Additionally, providing offline access to materials, such as PDFs and downloadable notes, would improve usability. Finally, the course could be expanded to cover related areas to further meet participants' professional development needs.

Discussion

Our study has shown that an online RUSH course was successful with a reach to 100 countries, and significantly improved participants' knowledge and perceived confidence. Participants highly rated the course for satisfaction, content quality, and for recommending it for others. A significant proportion of participants lacked prior ultrasound exposure or formal prior training; however, lack of prior ultrasound course experience and being from LIC or LMIC settings had no negative effect on participants' knowledge and confidence gains. These findings suggest that the course successfully addressed gaps in ultrasound education, particularly for participants from low-resource settings, which may enhance future ultrasound hands-on training.

The online RUSH course improved both knowledge and perceived confidence, aligning with findings in the literature on online ultrasound education. Ward et al. reported that participants in a virtual clinical course on FAST exam and vascular access, felt confident in all ultrasound skills covered during the course. They also indicated an increased likelihood of using ultrasound in their clinical practice [11]. Similarly, trainees who took a virtual ultrasound course designed to mitigate the negative effects of COVID-19 pandemic on educational activities showed satisfaction with the course and confidence in their ability to acquire and interpret ultrasound images [12]. In these studies, learners participated in virtual, real-time sessions where instructors presented ultrasound topics, allowing for interaction between the presenter and other participants. In contrast, our online RUSH course was self-driven and asynchronous, relying on reading materials, multimedia resources (such as videos and images), and quizzes to enhance retention. While the completion of the course by 72% of participants suggests a level of engagement with the asynchronous materials, it is also possible that those who found the asynchronous format challenging may have discontinued the course prior to the final exam. This limitation should be considered when interpreting the effectiveness of the asynchronous component. Similar patterns of selective dropout in online learning environments have been observed in other studies [30]. One factor contributing to dropouts is the self-paced nature of asynchronous online courses, which creates a "lack of pressure" that negatively affects successful completion [31].

Confidence and self-efficacy are essential in healthcare, as they influence trainees' ability to provide quality care and effectively handle professional challenges. More importantly, confidence aids in forming a strong professional identity, a crucial aspect of a healthcare professional's career development. Richmond et al., in their systematic review and meta-analysis, reported that there is no difference between the effectiveness of traditional and online teaching activities in improving healthcare trainees' confidence [32]. Our findings align with these findings and demonstrate a substantial increase in trainees' confidence. However, we must be skeptical when evaluating self-reported confidence in medical training, as self-assessment often fails to correlate with objective measures of knowledge or skill [33]. Therefore, its reliability as a sole outcome measure is questionable. Studies on medical trainees' evaluations have shown no relationship between their self-reported confidence and their formally assessed performance [34]. Thus, more robust measures should be implemented to accurately assess actual gains in confidence. However, in our course, the significant increase in knowledge observed from pre- to post-assessment suggests that real improvements in understanding likely accompanied the reported gains in confidence.

Online ultrasound teaching offers numerous advantages [15]. It allows for large number of students to participate simultaneously, overcome geographical limitations, and makes ultrasound training accessible to learners in remote locations [35]. It is also more cost-effective than traditional methods, as it reduces the need for physical space, travel expenses, and dedicated equipment for each learner [36]. The platforms offer flexibility in terms of scheduling and pacing, accommodating different time zones and individual learning preferences [37]. While online ultrasound education offers these advantages, it is important to remember that it is not a complete replacement for hands-on experience. Trainees still require practical training to develop their scanning proficiency. Bakhribah et al. reported that an average of 11.23 scans is required to achieve competency in the FAST exam, which is a simpler protocol compared to RUSH [38]. They found that 66.1% of trainees reached proficiency within the first 10 scans, while 33.8% needed more than 10 scans to become proficient. Additionally, Situ-LaCasse et al. found that for ultrasound-naive medical students, engaging with online modules and participating in hands-on evaluations led to the development of basic ultrasound skills [39]. They indicated a positive correlation between performance in online modules and hands-on skills, suggesting that initial learning can be effectively enhanced through online resources. A hybrid approach, combining virtual instruction with in-person hands-on sessions, can be a valuable strategy to optimize ultrasound education [36]. The online component can be used as a preparation phase which saves time for more advanced hands-on practice.

Participants without prior experience in ultrasound courses had significantly lower scores compared with those who had ultrasound training both before and after the course. Nevertheless, both those with previous ultrasound experience and those without it significantly gained knowledge. This finding was encouraging showing that the course was useful for both those who had ultrasound training and those who did not. Participants without previous training gained more knowledge in the course, while confidence scores remained similar across groups. This suggests that the structured, self-paced MOOC format may be particularly effective for beginners, enabling them to acquire foundational ultrasound knowledge without the pressure of real-time instruction. We believe that introducing RUSH protocol education by starting with fundamental concepts and progressively building upon them in a structured, scaffolded manner effectively supports participants with no prior training. Scaffolding traditionally plays a critical role in helping novices transition through the stages of expertise by managing cognitive load, guiding the organization of knowledge, and fostering self-regulation [40, 41]. The learners with prior training might skip the fundamentals and focus on advanced steps, which could explain their lack of improvement in knowledge due to potentially bypassing a review of prior knowledge.

Future iterations of similar courses could consider adaptive learning pathways tailored to different experience levels. For instance, novice learners may benefit from additional foundational modules covering ultrasound basics before advancing to more complex RUSH protocol applications. Conversely, experienced learners could be provided with advanced case-based exercises or real-world clinical scenarios to reinforce their expertise. Instruction could be tailored to the learner's stage, starting with straightforward tasks and gradually increasing complexity [40]. This differentiated approach may optimize engagement and knowledge retention across diverse learner groups, further enhancing the effectiveness of online ultrasound education. Incorporating a hands-on component in future iterations could further solidify practical skills and bridge the gap between theoretical understanding and clinical application.

Access to ultrasound courses in LICs and LMICs is often restricted by costs, and even MOOCs may be limited by infrastructure challenges such as internet connectivity [16]. However, our open-access course attracted participants from 100 countries, with those from LICs and LMICs demonstrating significant gains in knowledge and confidence. This suggests that MOOCs can serve as a viable alternative to costly in-person training.

A key contribution of this study is its demonstration of how an open-access, structured online course can effectively bridge the ultrasound training gap in resource-limited settings, where in-person training opportunities remain scarce. The results suggest that MOOCs, when strategically structured with formative assessments and multimedia integration, can serve as an effective preparatory phase for hands-on ultrasound education. This aligns with the flipped classroom model, where foundational knowledge is acquired asynchronously, allowing in-person sessions to focus on skill application. Several studies have demonstrated the effectiveness of blended learning models in medical education, including ultrasound training [39, 42], highlighting their potential to enhance training efficiency when in-person resources become available. Another novel finding of this study is the demonstration that participants with no prior ultrasound course experience exhibited the most substantial knowledge gains. This suggests that structured online education can partially compensate for the absence of formal in-person ultrasound instruction, particularly in settings where limited access to qualified instructors and ultrasound machines poses a barrier to advanced skill acquisition. However, the long-term retention of skills acquired through such online formats remains uncertain, especially in the absence of opportunities for continued hands-on practice and expert feedback. An important consideration for the interpretation of our findings is the unknown trajectory of long-term knowledge retention and real-world application of the RUSH protocol. While our study demonstrated significant short-term gains in knowledge and confidence, it did not assess whether these gains are sustained over time or effectively translated into clinical practice. Given the complexity and procedural nature of point-of-care ultrasound, including RUSH, longitudinal reinforcement and supervised application are likely essential for true skill consolidation [43]. Future studies should explore retention rates, the impact of intermittent hands-on practice, and integration into clinical workflows to fully understand the durability and practical value of online ultrasound education.

Future directions based on the integration of quantitative and qualitative findings

Many participants expressed high levels of satisfaction with the course, describing it as well-structured, easy to follow, and comprehensive. The provision of high-quality instruction and the development of well-structured online courses are essential for fostering student satisfaction [44]. The implementation of effective teaching methodologies, the establishment of transparent grading criteria, and the accessibility of instructors play significant roles in enhancing positive learning experiences [11, 12, 44]. Several respondents also suggested expanding the course options to include additional related topics, such as ECG interpretation. These responses align with the high satisfaction ratings and strong likelihood of recommendation found in the quantitative data, verifying that the course effectively met participant expectations.

Participants emphasized the clarity and effectiveness of the instructional materials but suggested incorporating more scenario-based videos and interactive content to enhance retention. The effectiveness of these materials is supported by the significant improvement in knowledge scores. However, the request for more interactive videos indicates that while the existing content was beneficial, learners felt additional enhancements could further optimize engagement and retention. Recent research indicates that interactive videos can substantially enhance student engagement, with findings revealing a 45% increase in interaction rates and an extension of viewing times by 30% when compared to traditional video formats [45]. These results underscore the potential of interactive media as a pedagogical tool, suggesting that its integration into educational practices may lead to more effective learning experiences.

A recurring theme in the qualitative feedback was the desire for practical, hands-on training to complement the theoretical aspects of the course. While the quantitative data showed a substantial increase in confidence levels, the qualitative responses show that participants may still feel less prepared for real-world application due to the absence of practical training. While online courses have thrived in providing theoretical training, practical experience remains essential for mastering skills. The common critique of entirely virtual courses is their lack of hands-on practice [46]. This means that while our course was effective in building theoretical confidence, practical exposure remains a necessary next step for skill mastery.

Several participants found the quizzes helpful for reinforcing learning but suggested making them more challenging and diverse. The significant improvements in quiz performance justify their effectiveness, but some learners felt that greater variation in question formats could enhance their overall learning experience. This feedback highlights an opportunity to refine assessment strategies to better cater to different learning styles and levels of experience.

Some participants from resource-limited settings faced challenges related to internet access and requested downloadable materials for offline use. While the quantitative data demonstrated broad global participation, qualitative responses revealed potential barriers that could impact learning experiences, particularly for those in low-resource environments. In countries with limited resources, access to the internet may be inconsistent or completely unavailable, posing challenges for obtaining online educational resources [16]. Addressing these issues through offline accessibility options could improve the inclusivity and reach of future iterations of the course.

The qualitative findings provide deeper insight into the quantitative improvements in knowledge and confidence, reinforcing the effectiveness of the course while highlighting areas for improvement. Although the course structure effectively delivered content, enhancements in video interactivity, quiz difficulty, hands-on integration, and accessibility features could further optimize learning outcomes. These findings suggest that future versions of the course could incorporate hybrid learning models combining online instruction with practical workshops to bridge the gap between knowledge acquisition and real-world application [36]. In addition, feedback emphasized the need for hands-on practice and more case-based learning approaches. This aligns with prior studies indicating that scenario-based learning enhances ultrasound competency by reinforcing decision-making in clinical settings [47, 48]. A potential solution is to incorporate interactive case scenarios within the MOOC structure, allowing learners to apply theoretical knowledge before transitioning to in-person training.

Furthermore, the demand for offline learning resources underscores the accessibility challenges faced by learners in resource-limited settings. To address this, future course versions could provide downloadable PDFs summarizing key learning points, interactive offline quizzes, and structured self-assessment tools. Additionally, localized partnerships with institutions in LIC-LMICs could facilitate on-site hands-on training sessions, ensuring that learners transition from theoretical understanding to clinical proficiency.

Limitations

This study has several limitations that should be acknowledged. Participants voluntarily enrolled in the RUSH course, this non-randomized enrolment process introduces the potential for selection bias, as those who chose to participate may have had a pre-existing interest in ultrasound or access to stable internet resources, which could impact the generalizability of findings. To mitigate this concern, we analysed outcomes across different subgroups, including prior ultrasound experience and country income level. Additionally, the absence of a control group limits our ability to establish a direct causal relationship between the course and the observed knowledge and confidence gains. Future studies should consider a randomized controlled trial design, comparing learners who complete the online RUSH course to those receiving traditional in-person instruction or no intervention. Another alternative would be a matched cohort study, comparing participants who voluntarily take the course with those who do not, to better assess its relative effectiveness. As participants who enrolled in the course likely had a pre-existing interest in the topic, potentially enhancing their motivation and engagement. While increases in confidence and knowledge were observed, it remains unclear whether these translate into improved clinical performance. Future studies should incorporate well-validated and reliable instruments designed to assess changes in actual clinical practice, to more accurately determine the real-world impact of the course.

The reliance on self-reported confidence levels introduces the potential for subjective bias, as participants may overestimate or underestimate their abilities. The course's online nature limits hands-on ultrasound practice, which is crucial for mastering the RUSH protocol, potentially affecting the practical applicability of the knowledge gained. Due to technical constraints in the learning management system, we were only able to extract overall exam scores and could not analyze performance by individual questions or topic areas. This limited our ability to assess knowledge gains in specific content domains and precluded more granular insights into participants learning.

Due to the global nature of the course and representation from over 100 countries, subgroup analysis was limited to income level classifications to preserve analytical clarity and relevance to international equity considerations. Further stratification by learner training level was not pursued in this study but could be explored in future analyses. Internet access and technical challenges, such as restricted video access in some regions, may have impacted participants' learning experiences, especially for those in remote or low-resource settings. Although this study included a diverse international cohort, the overrepresentation of participants from specific regions, such as Asia and the UAE, may limit the broader applicability of the results. This geographic imbalance could influence the findings due to variations in prior ultrasound exposure, medical education systems, and access to technology. Future studies should explore targeted recruitment strategies to ensure a more representative distribution of participants across different regions and healthcare settings. While we categorized participants based on their country's income level using World Bank classifications, this does not directly reflect individual socioeconomic status, financial resources, or access to educational opportunities, which may have potential influence on educational outcomes.

Language barriers and technology limitations can pose challenges to virtual ultrasound training, particularly in international settings [11]. The variations in prior ultrasound exposure and English proficiency as a first or second language could have affected how participants interpreted and responded to the survey questions. Additionally, this study did not evaluate long-term knowledge retention or the real-world clinical application of the RUSH protocol. While immediate post-course improvements in knowledge and confidence were significant, it remains unclear how well participants retain this information over time and whether they successfully implement these skills in clinical practice. This limitation is not unique to our course, but rather reflects a broader challenge inherent in online ultrasound education, where the translation of virtual learning into durable skills and clinical performance is often difficult to assess. Future studies should incorporate longitudinal assessments, such as follow-up quizzes or practical skill evaluations at 3-, 6-, and 12-months post-course, to determine the durability of learning. Lastly, research exploring the clinical impact of RUSH training on patient outcomes, such as accuracy in diagnosing shock, decision-making efficiency, and patient care improvements, would provide valuable insights into the practical utility of this training approach.

Conclusions

Online, open-access education proved to be successful in teaching an advanced ultrasound course by significantly improving knowledge and perceived confidence about the RUSH protocol. Participants were highly satisfied with the course and were enthusiastic to recommend it for others. The success of this MOOC in reaching a diverse, global audience, particularly participants from LIC-LMICs, demonstrates its potential as a scalable, cost-effective solution to the educational gap in critical care ultrasound. By serving as a preparatory phase, such structured online courses can complement traditional hands-on training, ultimately enhancing ultrasound competency in resource-limited healthcare settings.

Abbreviations

AAC	Arif Alper Cevik
COVID-19	Coronavirus disease 2019
CSV	Comma-separated values
HIC	High-income Countries
iEM	International Emergency Medicine
LIC	Low-income Countries
LLM	Large Language Model
LMS	Learning Management System
LMIC	Lower-middle-income Countries
MOOC	Massive Open Online Courses
PDF	Portable Document Format
POCUS	Point-of-care Ultrasound
RUSH	Rapid Ultrasound in Shock
UAE	United Arab Emirates
UMIC	Upper-middle-income Countries

Supplementary Information

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Supplementary Material 1.

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Authors' contributions

AAC launched the project's course platform and administered the instructional design, content upload to the learning management system, and platform testing. AAC collected the data, which was jointly analyzed by AAC and FAZ. AAC prepared the figures. AAC and FAZ drafted the manuscript. All authors have reviewed and approved the final version of the manuscript. AAC accepts full responsibility for the content of the manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

This course evaluation study was exempt from ethical review according to United Arab Emirates University The Social Sciences Research Ethical Committee guidelines (Exemption criteria: Research involving the use of non-sensitive, completely anonymous educational tests, survey and interview procedures when the participants are not defined as "vulnerable" and participation will not induce undue psychological stress or anxiety), due to the absence of sensitive or identifiable data (ERS_2020_6130). Participants were informed that their participation in the surveys was optional through the following statement included at the beginning of each survey: *"This is an anonymous survey aiming to improve the student experience, course delivery, and educational research. Continuing the survey is optional."*, with reminders provided prior to the course and before each survey.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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