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Online extended focused assessment with sonography for trauma (EFAST) course enhanced knowledge and perceived confidence among medical trainees during the COVID-19 pandemic disaster

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Abstract

Background The COVID-19 pandemic disrupted medical education worldwide, prompting the need for innovative e-learning solutions. This study evaluated the effectiveness of an online extended Focused Assessment with Sonography in Trauma (EFAST) course, delivered via the International Emergency Medicine Education Project's platform, to improve participants' knowledge and perceived confidence in EFAST procedure.

Methods A prospective observational study was conducted between May 17, 2020, and December 20, 2023. Pre- and post-course quizzes and surveys were used to assess participants' knowledge and confidence. Participant demographics, quiz scores, and survey responses were collected. Quantitative data were analysed using the Wilcoxon Signed-Rank test and Cohen's d to evaluate knowledge improvement and confidence changes. Thematic analysis of qualitative feedback was performed with the assistance of large language model AI tools for emerging themes.

Results 1758 participants enrolled in the course. From 111 countries, 1515 started the course, and 1190 (78.6%) reached the final exam stage, with 96.1% achieving a passing score. 66.4% indicated they had never attended a prior ultrasound course. Most (81.1%) were medical students, interns, or residents. 36.5% of participants were from low- or lower-middle-income countries. 1175 (77.6%) participants completed both the pre- and post-course formative knowledge quizzes. The median (IQR) scores were 53.3 (40.0–66.7) pre-course and 86.7 (73.3–93.3) post-course ($p < 0.001$, effect size: -0.958). 771 participants completed both pre- and post-course surveys. Participants' median (IQR) confidence in EFAST increased from 5 (3–7) to 8 (7–10) ($p < 0.001$, effect size: -0.844). Qualitative feedback showed that participants found the course practical, well-structured, and effective. They suggested improving video quality and simplifying content for clarity and engagement.

Conclusion The online EFAST course enhanced participants' knowledge and perceived confidence, demonstrating the potential of online clinical education during global crises.

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Background

The Extended Focused Assessment with Sonography for Trauma (EFAST) is useful in emergency settings to quickly detect free fluid and air in the peritoneal and pleural cavities which is crucial for the rapid triage of hemodynamically unstable patients [1]. It is non-invasive, safe, and can be performed bedside during resuscitation [2]. The integration of ultrasound into medical curricula significantly enhances students' motivation, diagnostic capabilities, and competence preparing them for modern trauma patient care [3–5]. We have included EFAST training in Emergency Medicine Clerkship for final-year medical students since 2013 [6]. Although face to face classroom and hands-on activities effectively improve this skill, Platz et al. reported that computer-based lectures are not inferior to traditional classroom lectures for those without prior ultrasound education [7].

The COVID-19 pandemic was the most severe global crisis faced by humanity since World War II [8]. Its effects extended to medical education, where preparedness, mitigation, response, and recovery phases must be followed to manage the pandemic's adverse effects on education [9]. Unfortunately, healthcare education was initially unprepared for the pandemic. However, the mitigation and response phases were effectively utilized to reduce the negative impact of the pandemic. With restrictions preventing hands-on sessions due to social distancing guidelines, virtual lectures were used to continue distant education. Online and hybrid programs were effectively used to teach practical ultrasound skills. An online digital sonography course for trainees achieved comparable results to those using traditional methods [10]. Similarly, web-based ultrasound training improved students' knowledge [11–12]. Despite lack of practical experience which hinders image interpretation, confidence levels in recognizing POCUS applications have improved among interns [13].

During the pandemic, online ultrasound training has emerged as a feasible alternative to traditional in-person training. The International Emergency Medicine Education Project [14] launched its course platform as a social responsibility initiative to meet emerging training needs, focusing on the mitigation and response phases of disaster medicine [15]. EFAST was one of the five courses offered on the platform, with the goal of achieving the required basic theoretical and practical knowledge in preparation for more practical, hands-on training in real-life during the post-COVID-19 recovery period. This study aims to evaluate the impact of online EFAST training on trainees' knowledge and perceived confidence in performing EFAST, and to demonstrate whether an online course can be a valuable supplement to practical ultrasound training during challenging times.

Methods

Study design and setting

This prospective observational study evaluated participants' perceived knowledge and confidence in EFAST before and after completing the course. The course was delivered through the online platform of the International Emergency Medicine Education Project (iem-course.org).

Course platform, content and implementation

The International Emergency Medicine Education Project is a non-profit initiative that provides free educational resources for medical students and interns worldwide [14]. It is supported by the United Arab Emirates University, College of Medicine and Health Sciences and endorsed by the International Federation for Emergency Medicine. In May 2020, the project launched its course platform (iem-course.org) to help students and interns whose training was disrupted by the COVID-19 pandemic [15]. During the pandemic, the platform offered five courses, including the online *EFAST* course.

The project director outlined the content of the online EFAST course. It was built using text chapters and visuals (images and videos) from the project's main website (iem-student.org). Pre- and post-course surveys were also created to collect demographic data and assess participants' perceived confidence in EFAST. A formative knowledge test on the course content was administered before and after the course. To complete the course, participants had to pass a final exam.

All course materials, including surveys, text, images, videos, formative tests, and the final exam, were uploaded to a learning management system (LMS). The platform uses LearnDash LMS [16], designed for WordPress-based sites [17], where the project's course platform is hosted. The course ran from May 17, 2020, to December 20, 2023.

The course aimed to teach the basics of ultrasound, including terminology, knobology, image acquisition, common artifacts, indications for EFAST, how to properly prepare both the patient and the machine, identify ultrasound windows and recognize normal anatomical structures, as well as abnormal findings such as pericardial effusion, intraperitoneal or pelvic free fluid, IVC collapse, and pneumothorax and hemothorax. By the end of the course, participants were expected to feel confident joining any practical EFAST sessions in their institutions.

Figure 1 illustrates the course structure and implementation process. Like other courses on the iem-course.org platform, this course was offered free of charge to all participants.

The content is organized into three main sections: Ultrasound Basics, Performing EFAST, and Hints and Pitfalls.

The **Ultrasound Basics** section covers key concepts essential for understanding and operating ultrasound machines. It introduces ultrasound physics, explaining how piezoelectric crystals in the transducer convert electrical signals into sound waves to generate images. Various ultrasound modes are described, including B-mode (for 2D imaging), M-mode (for motion tracking), and Doppler mode (for continuous wave emission). The section also explains acoustic impedance, highlighting how different tissues—such as fluids, bones, and soft tissues—affect ultrasound images based on their density. Participants learn about different transducers, such as curvilinear, linear, and sector types, and their clinical uses. Imaging planes (e.g., sagittal, transverse) and common artifacts, such as acoustic shadows and mirror artifacts, are also discussed. Finally, the section reviews essential ultrasound machine controls, including gain, depth, and mode selection, to help participants perform effective ultrasound examinations.

The **Performing EFAST** section covered the following topics: indications of EFAST, equipment and patient preparation, EFAST protocol steps, transducer orientation, and imaging the heart for pericardial effusion and tamponade. It also included scanning the abdomen for free intraperitoneal fluid, the pelvis for free fluid, the thorax for both free fluid and pneumothorax, and the IVC to assess volume status.

The **Hints and Pitfalls** section highlights key recommendations for performing EFAST effectively. It emphasizes the need to repeat the exam if clinical concerns persist or the patient's condition changes. The section offers tips such as distinguishing fat from clots and optimizing patient positioning. Post-procedure steps are also discussed, including clear communication with the trauma team, ensuring equipment hygiene, and maintaining proper documentation. Additionally, the section highlights the risks of incorrect performance or interpretation and reminds participants that EFAST should not delay critical interventions. Special considerations are provided for pediatric, geriatric, and pregnant patients.

Ethical considerations

This education evaluation study was exempt from ethical review under the UAE University Research and Graduate Studies Ethics Guidelines, as it did not involve sensitive or identifiable data (ERS_2020_6130). Participants were told that the pre- and post-surveys were optional before starting the course and before each survey.

Participants

The course was open to participants worldwide. The International Emergency Medicine Education Project mainly targets medical students and interns, most visitors to the platform are from this group. However, due to the course's relevance to various trainee levels (from medical students to residents) enrolment was open to all.

Quantitative data collection and analysis

Enrolment and completion data, formative and final (summative) exam results, and pre- and post-course survey responses were collected and stored in the WordPress database. Access to this data was restricted to AAC, the Project Director, Website Administrator, and Primary Investigator of the study.

Enrolment and completion data were collected through LMS, without any involvement from the research team. The pre- and post-course formative quizzes consisted of 15 multiple-choice questions, including true/false (1 question) and single-best-answer (14 questions) formats. The course completion exam included 20 multiple-choice

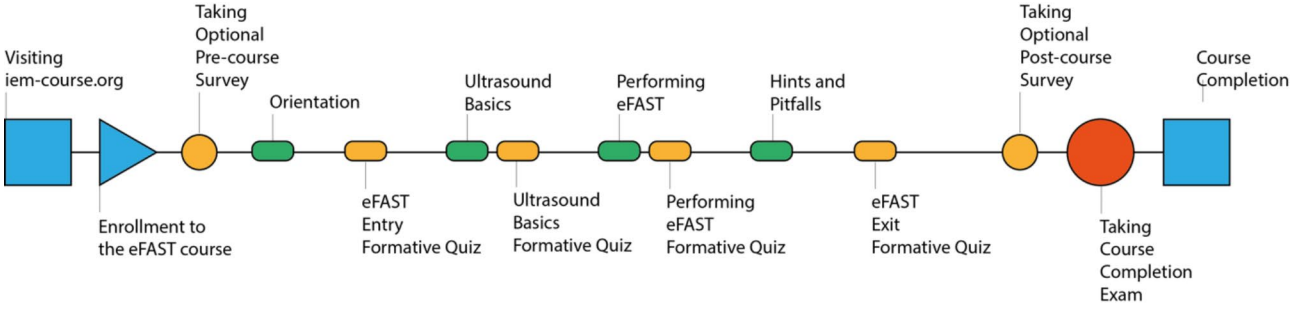

Fig. 1 Participants access the course website and enrol. Upon enrolment, they can take an optional pre-course survey. The course starts with an orientation session, and participants proceed through each session in sequence. After completing all sessions and quizzes, they can take an optional post-course survey before attempting the final (course completion) exam. Those who score 70% or higher on the exam receive a course completion certificate. EFAST: extended focused assessment with sonography for trauma

questions (four options, single best answer), with a minimum score of 70% required to pass the course.

Participants had 12 days to complete the course. To qualify for the course completion exam, they needed to complete all steps outlined in Fig. 1, except for the optional pre- and post-course surveys. These surveys were offered at the beginning and end of the course.

The surveys gathered demographic information, including gender, training level, geographic region, and country. Participants were also asked to rate their confidence in specific areas of the course content. The post-course survey included additional open-ended questions to gather feedback and assess how likely participants were to recommend the course to others. Demographic questions were presented as multiple-choice options, while confidence ratings used a Likert scale from 0 to 10.

Enrolment, completion, quiz, final (course completion) 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 exclusively to match entry and exit quizzes and pre- and post-course survey responses for each participant. Once the matching was complete, the user IDs were removed from the final CSV file to ensure participant anonymity while preserving the data required for descriptive and comparative analysis.

The statistical analysis was performed using SPSS software (version 29.0). Nominal variables were presented as frequencies and percentages, while continuous variables were reported as medians with 25th–75th percentile interquartile ranges (IQR). The Wilcoxon Signed-Rank test was used to compare pre- and post-course formative quiz and survey outcomes. Statistical significance was defined as a p-value of less than 0.05. Cohen's d effect sizes were calculated, with values of 0.8 or higher indicating a large effect.

Qualitative data collection and analysis

Qualitative data was gathered through the post-course survey. Prior to performing qualitative data analysis, the data was extracted, cleaned, and anonymized to protect privacy. Course activity data obtained from WordPress and LearnDash was formatted into comma-separated values (CSV), maintaining only a distinct 9-digit user ID. For the qualitative analysis, we utilized ChatGPT (OpenAI) and NoteBookLM (Google), taking advantage of their capabilities in inductive thematic analysis and data triangulation [18–19]. The data, initially in CSV format, was uploaded to ChatGPT-4o and converted into text format. This text was then downloaded as a portable document format (PDF) file for accuracy verification. Thematic analysis was conducted following Braun and Clarke's six-step process, ensuring a methodical approach to interpreting the data [20]. Furthermore, we created a specialized GPT (Custom-GPT) designed for qualitative analysis to enhance the consistency and automation of responses. Developing Custom-GPT required establishing objectives, configuring Braun and Clarke's thematic analysis steps, and assessing output reliability. The PDF was later uploaded to both Custom-GPT and NoteBookLM to aid in discovering and examining emerging themes. The triangulation involved a comparison among human manual input, Custom-GPT, and NoteBookLM. This methodological strategy enhanced data processing efficiency, increased analytical accuracy, and provided structured qualitative insights.

Results

Quantitative results

During the active course period, 1758 participants enrolled. Among them, 1515 (86.2%) completed the entry survey and began the course stages. Male participants accounted for 52.6% of the total. The majority (81.1%) were medical students, interns, or residents. More than half (51.3%) reported the absence of formal ultrasound training at their institutions. 111 countries were recorded in entry survey. Participants from Asia constituted 64.6% of the cohort. The United Arab Emirates had the highest representation, comprising 22.8% of participants. According to the World Bank's 2023 income classification [21], 63.5% of participants were from upper-middle- or high-income countries, while 36.5% were from low- or lower-middle-income countries. Additionally, 66.4% indicated they had never attended a prior ultrasound course. Participants expressed high expectations for the course, with a median (IQR) score of 8 (6–10). Demographic data are presented in Table 1.

A total of 938 participants (61.9%) completed the course exit survey. Participants reported that the course met their expectations, with a median (IQR) score of 10 (8–10). They rated the quality of the text information, videos, quizzes, and overall content coverage with a median (IQR) score of 9 (8–10). The likelihood of recommending the course received a median (IQR) score of 10 (8–10).

Comparative analyses of participants' knowledge and perceived confidence

Knowledge

Of the 1515 participants, 1175 (77.6%) participants completed both the pre- and post-course formative quizzes. There was a significant improvement in participants' knowledge. The median (IQR) scores out of 100 were 53.3 (40.0–66.7) for the pre-course quiz and 86.7 (73.3–93.3) for the post-course quiz, respectively ($p < 0.001$, effect size: -0.958). Box-and-whiskers plot of participants' quiz scores before and after the course are presented in Fig. 2.

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

	N **= 1515 (%)**
Gender	
Female	715 (47.2)
Male	797 (52.6)
Not answered	3 (0.2)
Current level of training	
Medical student	699 (46.1)
Intern	185 (12.2)
Resident	346 (22.8)
Educator	80 (5.3)
Other	205 (13.5)
Formal ultrasound training in their institution/college	
No	777 (51.3)
Yes	578 (38.1)
Unknown	160 (10.6)
Previous ultrasound course attendance	
No	960 (66.4)
Yes	485 (33.6)
Region	
Africa	235 (15.5)
Asia	978 (64.6)
Australasia/Oceania	37 (2.4)
Central America	25 (1.7)
Europe	105 (6.9)
North America	86 (5.7)
South America	49 (3.2)
Income Levels	
LIC	124 (8.2)
LMIC	429 (28.3)
UMIC	318 (21.0)
HIC	644 (42.5)

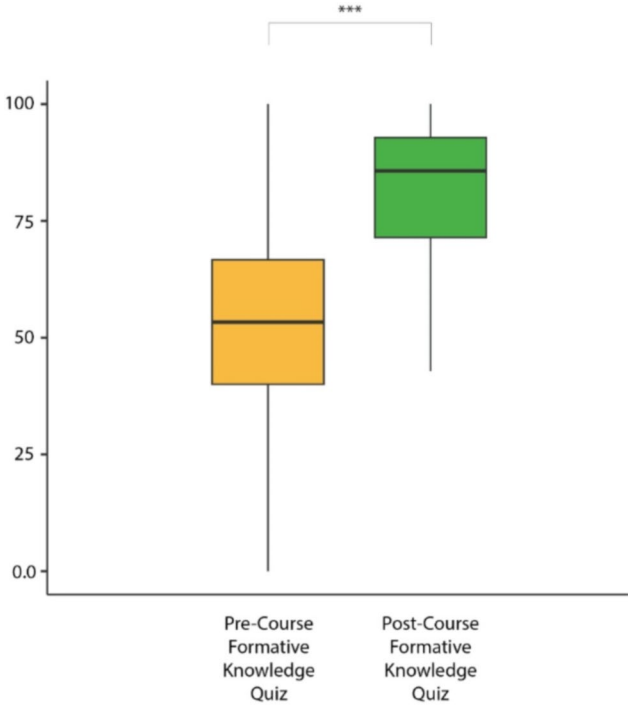

Fig. 2 Box-and-whiskers plot of participants' formative quiz scores before and after the course. The box represents the Interquartile Range (IQR), from the 25th to the 75th percentile, with the horizontal line inside indicating the median. The whiskers show the range of non-outlier values. Orange indicates pre-course quiz results, green indicates post-course quiz results, and *** shows a *p*-value < 0.001

Perceived confidence

771 (50.9) participants completed both the pre- and post-course surveys. The median (IQR) pre-course expectation score was 8 (6–10). After completing the course, the median (IQR) score for "how well the course fulfilled their expectations" increased to 10 (8–10). This change was statistically significant (Wilcoxon Signed-Rank Test, $p < 0.001$) with a Cohen's d of -0.519. Table 2 presents a comparative analysis of participants' perceived confidence between the pre- and post-course surveys.

There was a significant improvement in participants' overall perceived confidence in EFAST and its specific components. Box-and-whiskers plot of participants' perceived confidence in EFAST before and after the course are presented in Fig. 3.

Table 2 Comparative analyses of participants' perceived confidence (*N* = 771)

Questions	Pre-Course	Post-Course	*P* value	Effect Size
Expectation and Fulfilment of Expectation	8 (6–10)	10 (8–10)	< 0.001	-0.519
Current perceived overall confidence level about EFAST	5 (3–7)	8 (7–10)	< 0.001	-0.844
Current perceived confidence on			< 0.001	-0.935
Ultrasound physics and knobology	4 (2–6)	8 (7–10)	< 0.001	-0.950
Recognizing pericardial effusion	5 (2–7)	9 (7–10)	< 0.001	-0.939
Recognizing intraperitoneal free fluid	5 (2–7)	9 (7–10)	< 0.001	-0.936
Recognizing pelvic free fluid	4 (1–6)	8 (7–10)	< 0.001	-0.922
Recognizing pleural free fluid / hemothorax	4 (2–7)	8 (7–10)	< 0.001	-0.922
Recognizing pneumothorax	5 (2–7)	9 (7–10)	< 0.001	-0.900
Recognizing IVC collapse	4 (1–6)	8 (6–9)	< 0.001	-0.905

Effect size ≤ 0.2 = Small effect, 0.5 = Moderate effect, ≥ 0.8 = Large effect

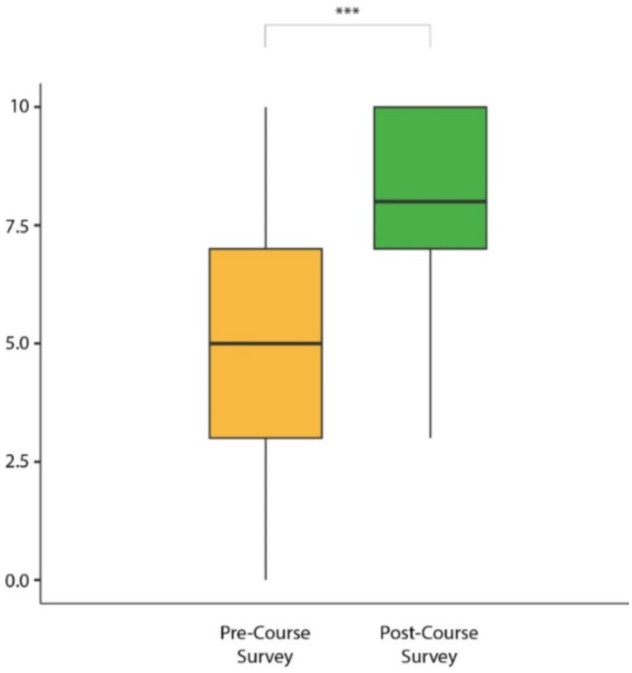

Fig. 3 Box-and-whiskers plot of participants' perceived confidence in EFAST before and after the course. The box represents the Interquartile Range (IQR), from the 25th to the 75th percentile, with the horizontal line inside indicating the median. The whiskers show the range of non-outlier values. Orange indicates pre-course perceived confidence results, green indicates post-course perceived confidence results, and *** shows a *p*-value < 0.001

Final exam

Of the 1515 participants, 1190 (78.6%) reached the final (course completion) exam stage, with 1144 (96.1%) passing the exam. The median (IQR) passing score was 80 (75–90).

Qualitative results

Out of the 938 participants, who completed the post-course survey, 220 (23.5%) provided written feedback.

From the qualitative data, 14 codes were extracted, and three themes emerged based on these codes: Content Delivery and Engagement, Technical and Structural Improvements, Positive Learning Experience.

Content delivery and engagement

Participants emphasized the need for enhanced content delivery and engagement, with frequent requests for more videos, particularly showcasing abnormal cases and practical scenarios. Several respondents suggested including interactive elements, such as clinical case quizzes, to enhance their learning experience and apply theoretical knowledge more effectively. Additionally, there was a desire for hands-on assessments and real-time feedback opportunities, with some suggesting integrating practical demonstrations or video-recorded assignments to make the course more immersive and engaging. This feedback reflects the participants' preference for dynamic, experiential learning over passive consumption of content.

> *Make a hands-on assessment through a video clip that the student can record and share for evaluation.*
> *A participant from USA.*

> *Interactive quizzes with clinical cases would improve the learning experience.*
> *A participant from Mexico.*

> *Make a hands-on assessment through a video clip that the student can record a short clip about the assessment and share a link with you so you can assess the practical side and operative capabilities of the trainees and also open a portal so the trainers can share interesting cases they diagnosed. Thank you for this amazing course I learned a lot.*
> *A participant from USA.*

Technical and structural improvements

Participants provided suggestions for technical and structural improvements, such as the need for better video quality and more concise content to enhance the learning experience. Several respondents found some videos too short or lacking in clarity, requesting longer, higher-quality videos with clearer labelling to aid comprehension. Others felt that the course could be shortened or structured more efficiently, reducing redundant quizzes and focusing more on critical concepts. The feedback suggests a desire for simplified content delivery, balancing it with efficiency while maintaining engagement and comprehension.

> *Some ultrasound videos need to be extended, probably 15 s as opposed to the 6 s.*
> *A participant from USA.*

> *"Improve video quality and include proper labelling of structures in all the videos."*
> *A participant from India.*

> *The Pneumothorax and the IVC parts are not as in depth as the rest of the exam's explanation. More videos, like split screen, in one side we see the sonographer manipulate the transducer, the other side a real time image of the ultrasound.*
> *A participant from Algeria.*

Positive learning experience

Participants expressed positive feedback about the course, stating that it was helpful, well-structured, and effective in enhancing their knowledge and skills. Many emphasized that the course content was easy to understand and well-organized, contributing to their confidence in applying the EFAST concepts in practice. Some participants appreciated the practical focus and clarity of the materials, while others praised the course for being accessible and enriching, stating that it not only boosted their clinical competence but also improved their career prospects. This feedback reflects the course's success in delivering practical, impactful learning and creating a positive educational experience for the participants.

The course has been awesome! I have really understood it, and now I am confident about EFAST because it has given me ample knowledge.
A participant from Uganda.

I really loved this course. It was simple and easy to apply on real trauma patients.
A participant from UAE.

I found it very helpful. I admire what you have prepared in this teaching sessions. I really appreciate the effort and willingness to share such easy-to-understand training. It has made my knowledge on EFAST go to another level, thanks."
A participant from Ethiopia.

Integration of qualitative and quantitative results

The integration of qualitative insights with quantitative findings provides a deeper understanding of participants' experiences, learning outcomes, and areas for improvement. The quantitative data demonstrated a significant increase in participants' knowledge, perceived confidence in performing EFAST and recognizing pathological findings across all domains. However, qualitative feedback sheds light on how participants internalized these improvements and highlights specific areas that require further refinement. By triangulating these findings, a clearer picture emerges of how different aspects of the course influenced learning, engagement, and overall satisfaction.

One of the dominant themes in qualitative responses was Content Delivery and Engagement, where participants highlighted the need for more interactive and experiential learning methods to better reinforce theoretical knowledge. Many respondents emphasized the value of video-recorded hands-on assessments, real-time feedback, and interactive case-based quizzes. These reflections align with the quantitative data showing that 66.4% of participants had never attended a prior ultrasound course, highlighting a significant gap in hands-on training. The increase in perceived confidence scores across all assessed domains suggests that while the course effectively boosted confidence, learners still felt the need for practical, interactive reinforcement to solidify their skills.

Another key theme was Technical and Structural Improvements, where participants provided suggestions for enhancing video quality, content clarity, and module organization. Many requested longer ultrasound video clips for better visualization of anatomical structures and pathological conditions, modules could be streamlined to reduce redundancy in quizzes and enhance content efficiency. These concerns complement the quantitative results indicating that while participants rated the overall quality of videos, quizzes, and text-based content highly, some still felt the need for refinements. Additionally, participants from lower-income regions, where access to high-resolution imaging may be limited, may have faced greater difficulty with video clarity, making this an important area for improvement. The request for split-screen video demonstrations, where one side shows transducer manipulation and the other displays the corresponding ultrasound image in real time, aligns with the observed increase in confidence for ultrasound physics and knobology, suggesting that more comprehensive visual guidance could further reinforce learning.

Lastly, the Positive Learning Experience theme emerged strongly, with participants expressing gratitude for the knowledge gained and their newfound confidence in performing EFAST. This feedback align with the high post-course satisfaction ratings, where participants rated the likelihood of recommending the course at a median score of 10 [IQR: 8–10], indicating that the structured curriculum met the expectations of learners across diverse backgrounds. Additionally, the high final exam pass rate (96.1%) suggests that participants not only perceived the course as beneficial but also effectively retained the knowledge necessary for practical application. The strong correlation between perceived confidence improvements and knowledge gains (as demonstrated in the significant effect sizes across domains) confirms that the structured approach to learning was successful, though qualitative insights suggest that adding practical components could further enhance these positive outcomes.

By integrating qualitative and quantitative findings, it becomes evident that while the course significantly improved knowledge and confidence, participants' qualitative feedback highlights the need for more interactive learning, technical enhancements, and structural refinements to further enhance engagement and practical application. The quantitative trends confirm these qualitative observations, reinforcing the importance of experiential learning in medical education. These insights

also provide valuable guidance for optimizing future iterations of the course, ensuring that both knowledge acquisition and hands-on competence are effectively addressed.

Discussion

This study did not intend to validate online learning as a substitute for practical training but rather as a complementary tool to enhance theoretical knowledge and confidence in preparation for hands-on training. Our results have shown the effectiveness and global reach of an online EFAST course, with its impact on participants' knowledge, perceived confidence, and satisfaction. These findings have demonstrated a significant increase in both knowledge and perceived confidence following the course. Learners' benefit was during the mitigation and response periods of the COVID-19 infectious disaster preparing them for the recovery period.

The online course attracted participants from 111 countries, which is a promising outreach to trainees from diverse backgrounds. Ultrasound training is important for LICs and LMICs, as it provides an accessible and cost-effective alternative to expensive diagnostic modalities such as computed tomography or magnetic resonance imaging. EFAST training can be effectively delivered through computer-based lectures, which have been shown to be non-inferior to traditional classroom lectures for residents without prior ultrasound education, thus offering a feasible alternative for training in regions with limited educational resources [7]. While the project's primary goal was to support trainees from LICs and LMICs [14–15], their participation was lower than that of UMICs and HICs. This aligns with the existing literature, which indicates that the use of online resources and massive open online courses (MOOCs) is often limited in LICs and LMICs due to various challenges such as infrastructure, language, and resources [14, 22, 23]. Rakhra et al. reported that the dissemination and implementation of MOOCs in eight LMICs was difficult due to unstable internet access and significant barriers to course participation and completion [24]. The development of MOOCs that incorporate local contexts and languages can enhance learner engagement and course completion rates [25]. A potential reason for their lower representation may relate to language barriers (using French or Spanish as the teaching language) as our course was given in English, the structure of medical curricula in these countries, where ultrasound training is not always emphasized, or internet access is limited [26]. However, we think that the high participation from the United Arab Emirates (UAE) may have influenced the overall distribution of participants by income category. Specifically, our use of a flipped classroom model to teach two ultrasound protocols in the emergency medicine clerkship, including EFAST [27], could have contributed to the significant representation from UAE (22.8%) with large number of medical students, which may have contributed to the higher percentage of HIC participants in our study. Although the proportion of participants from LICs and LMICs was lower than that from UMICs and HICs, we were satisfied with the study's ability to reach trainees from these regions.

Accessibility and flexibility are essential, as e-learning platforms enable healthcare professionals to develop their skills regardless of location or resource limitations [28]. Online training was found efficient to enhance knowledge, confidence and satisfaction on advanced medical concepts, including ultrasound skills [29–31]. Similar to others, we have found significant improvement in knowledge scores of participants in our online course. Our confidence evaluation, however, was relying on participants perception, which was also significantly improved at the end of the course. Studies in health professions education highlight that self-assessed confidence often does not correlate with actual competence, suggesting that objective measures should be prioritized over self-perceptions [32].

Qualitative analysis indicated that participants requested more hands-on training opportunities and recorded demonstrations. Integrating interactive video-based assessments or hybrid learning models, which combine online education with in-person workshops, could enhance skill acquisition and participant engagement [33]. Participants have emphasized the importance of real-time feedback in learning and expressed a strong desire for it. However, the course structure did not contain this critical component. This highlights the value of hands-on sessions in ultrasound training. As a practical application, it is essential for skill development in real or simulated environments. While online courses are effective in improving knowledge and confidence, hands-on practice remains crucial for mastery. Hybrid ultrasound courses offered during the COVID-19 pandemic, were successfully applied by incorporating hands-on components [33]. This model is valuable for local needs. However, it was not suitable for our course serving to global medical trainees. Nevertheless, delivering knowledge through an online platform and reserving face-to-face time for practical sessions is an optimal approach for hybrid courses. A key goal of this course was to use the online platform to bridge knowledge gaps and boost attendees' confidence, preparing them for in-person clinical practice at their institutions. This way, face-to-face sessions could be utilized more efficiently for practicing EFAST skills. However, given the large number of attendees who reported limited availability of ultrasound training at their institutions, many participants may not have

the opportunity to practice EFAST but may prepare them for overseas training.

We think that, despite their limitations, online courses offer significant advantages, such as time flexibility and the ability to overcome resource, geographical barriers and global challenges. Furthermore, using online courses to cover the knowledge component allows for more effective planning for face-to-face sessions, optimizing hands-on learning opportunities in clinical settings.

Limitations

This study has several limitations. *First*, a part of the results relied on perceived confidence, which are subjective and may not accurately reflect participants' actual competence in performing EFAST in clinical settings. A follow-up study assessing knowledge retention and real-world application of EFAST would provide valuable insights into the long-term effectiveness of an online training program. *Second*, although knowledge improvement was demonstrated through quizzes, the study did not assess practical skills, limiting the evaluation of participants' ability to perform EFAST in real-world scenarios. While our study focused on evaluating knowledge improvement and perceived confidence due to the constraints of an online course, we acknowledge the importance of assessing practical skill acquisition. Future studies include objective assessments, such as in-person skill evaluations or video-based performance assessments, to better measure practical proficiency. Additionally, incorporating interactive and hands-on assessments, such as video-recorded submissions or real-time instructor feedback, could enhance skill development and bridge the gap between theoretical knowledge and practical application. *Third*, the voluntary and open nature of enrolment may have introduced selection bias, as the sample likely consisted of individuals already motivated to learn about ultrasound, reducing the generalizability of the findings. *Fourth*, the lack of long-term follow-up makes it unclear whether the improvements in knowledge and confidence persisted over time. *Fifth*, technological and regional inequalities could have affected participants from LICs and LMICs, potentially impacting their learning experience and course completion. Providing regional adaptations or mentorship programs to address geographical barriers and equipment disparities may help mitigate these challenges in future studies. *Sixth*, the absence of a control group limits the ability to attribute improvements solely to the course, as external factors such as opportunities to practice the protocol, might have influenced outcomes. *Seventh*, participants' engagement with the material may have varied, with individual differences in motivation and study habits potentially influencing results. Developing tiered learning pathways that offer basic, intermediate, and advanced modules based on participants' prior experience could help standardize engagement levels. *Eighth*, language barriers could have affected comprehension for non-English-speaking participants, limiting their engagement with the content. *Ninth*, the need for a follow up questionnaire to the participants to see whether it impacted their clinical practice remains an important consideration. Furthermore, improving video quality and annotation clarity may enhance learning comprehension and engagement, ensuring that key concepts are effectively conveyed. *Finally*, only 23.5% of participants provided qualitative feedback, introducing the potential for response bias, as the thematic analysis may reflect the views of those with particularly strong positive or negative experiences. Introducing objective practical skill assessments, potentially through case-based evaluations or hands-on workshops in hybrid learning models, could provide a more robust measure of skill acquisition and retention. Addressing these limitations in future studies could enhance the reliability and applicability of these findings.

Conclusions

Ultrasound training plays an important role in preparing medical trainees for modern patients' medical care by enhancing diagnostic skills, competence, and motivation. Our online EFAST course has effectively improved participants' knowledge and perceived confidence. This demonstrates the potential of e-learning platforms to address educational needs during disasters despite geographical locations and resource limitations. While online learning has significant benefits, it cannot fully replace hands-on ultrasound training. However, online education can serve as a preparatory step, ensuring that trainees enter practical sessions with a stronger theoretical foundation and increased confidence. Follow-up hands-on sessions to reinforce these skills in clinical practice can be performed during the recovery period. Future efforts should explore hybrid models that incorporate both online content and practical components to enhance learning outcomes and meet the needs of diverse learners worldwide. While the pandemic presented significant challenges to medical education, it also fostered innovation and adaptation, providing valuable learned lessons for future disasters to come.

Abbreviations

AAC	Arif Alper Cevik
COVID-19	Coronavirus disease 2019
CSV	Comma-separated values
LLM	Large Language Model
LMS	Learning Management System
MOOC	Massive Open Online Courses
PDF	Portable Document Format

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Author contributions
AAC launched the project's course platform. AAC was responsible for the instructional design, uploading the content to the learning management system, and conducting platform testing. AAC collected the data. AAC and FAZ jointly analysed the data. AAC and FAZ wrote the manuscript. AAC prepared the Figures. 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
Per the United Arab Emirates University Research and Graduate Studies Ethics Guidelines, this educational evaluation study was exempt from ethical review, as it did not involve sensitive personal data or identifiable information (ERS_2020_6130). Participants were informed that completing the pre- and post-surveys was optional, both prior to starting the course and before each survey.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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