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Integrating Scaffolding and Deliberate Practice Into Focused Cardiac Ultrasound Training: A Simulator Curriculum

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Abstract

Introduction: Focused cardiac ultrasound (FoCUS) is widely used for the point-of-care evaluation of basic cardiac pathology, and there is a need for efficient and consistent training in this modality. We designed a simulator-based FoCUS curriculum that integrates instructional scaffolding and deliberate practice to create a directed, self-regulated learning experience for novices. The goal of this strategy was to guide the novice's learning efforts more efficiently and moderate cognitive load while retaining the benefits of independent learning. **Methods:** The complex task of learning cardiac ultrasound is broken into discrete steps, with focused didactic information immediately followed by targeted simulator practice for each module. The practice complexity increases through successive modules, and learners ultimately apply their skills by completing unassisted simulator cases. Immediate visual and quantitative feedback is provided by the simulator whenever an ultrasound image was captured during practice. The entire curriculum is self-guided. **Results:** Sixteen nurse practitioners and resident physicians completed this FoCUS curriculum. In comparison to a previously validated, lecture-before-practice-style curriculum, the average time to completion decreased from 8.0 ± 2.5 hours to 4.7 ± 1.9 hours ($p < .0001$). There was no difference in posttraining cognitive or psychomotor outcomes between the curricula as measured by a simulator posttest. **Discussion:** A curriculum integrating scaffolding and deliberate practice provides a more efficient, but equally effective, means of teaching psychomotor and cognitive skills in FoCUS. These instructional design principles may translate to other operational learning tasks and allow novices to build skills and reach basic competency more rapidly.

Keywords

Simulation, Instructional Design, Self-Regulated Learning, Deliberate Practice, Cardiac Ultrasound, Scaffolding

Educational Objectives

After completion of this simulator curriculum, learners will be able to:

1. Obtain six standard cardiac ultrasound views in a supine patient using a portable ultrasound machine, either accurate within 15 degrees of the optimal view as measured by a high-fidelity simulator or determined to be of adequate quality by an expert instructor.
2. Identify the normal anatomical structures that should be visualized in each ultrasound view.
3. Analyze the appearance and function of anatomic structures as normal or abnormal based on learner-obtained cardiac ultrasound images.
4. Diagnose basic cardiac pathology through interpretation of learner-obtained cardiac ultrasound images.

Introduction

Focused cardiac ultrasound (FoCUS) is a widely used tool for the diagnosis of basic cardiac pathology at the point of care and is increasingly utilized by a range of providers in multiple specialties. Using a portable ultrasound machine, a provider performs a brief cardiovascular ultrasound in order to evaluate a

Appendices

- A. Simulator Setup and Interface.docx
- B. IDEL Curricular Outline and Didactic Text.docx
- C. Pre- and Posttests.docx
- D. Didactic Presentation.pptx

All appendices are peer reviewed as integral parts of the Original Publication.

limited number of cardiac diagnoses. Ideally this allows for rapid identification of specific pathology and aids clinical decision-making. However, cardiac ultrasound is a complex task that requires psychomotor skill for image acquisition, cognitive skill for image interpretation, and the ability to integrate information from multiple ultrasound views with the larger clinical picture to make diagnostic and management decisions. The accuracy and utility of FoCUS is largely dependent on user skill. Misinterpretation or incorrectly acquired images can lead to diagnostic error and clinical mismanagement, and such errors are higher when ultrasound is performed by providers who have had limited training compared with more experienced providers.¹⁻³

Despite the widespread usage and risks of operating with only brief or incomplete training, many trainees who perform FoCUS receive little or no formal training in image acquisition or interpretation. While there are no surveys on the prevalence of FoCUS training or teaching practices across specialties, data taken from anesthesia residency programs indicates that there is a paucity of formal FoCUS instruction.⁴ Similarly, need for improved training has also been recognized by the American Society of Echocardiography.⁵ Further, the fact that didactics are separated from episodes of hands-on practice that are delivered over few sessions is a limitation of existing resident training programs.⁶⁻¹⁰ Such programs are generally time-limited and do not allow flexibility for variation in learner needs to reach mastery of target skills.

At our institution, most residents receive no formal training in cardiac ultrasound. Within internal medicine, resident training is received on an informal basis through a traditional “see one, do one, teach one” approach. Our aim was to create a consistent and efficient training program in FoCUS for novices. We attempted to optimize a previously existing, didactic-before-practice-style simulator curriculum by incorporating the instructional design principles of scaffolding and deliberate practice. The goal of this approach was to build a directed and self-regulated learning experience¹¹ that guides the novice’s learning efforts more efficiently and moderates cognitive load,¹² while retaining the benefits of independent learning.

Scaffolding is an instructional technique wherein temporary support is provided for the early learner, either directly by an instructor or built into curricular structure.^{13,14} This allows the learner to reach a level of comprehension and master skills that they would not be able to easily reach alone. As the learner advances, the level of support gradually decreases until the learner reaches independent competence. The goal of deliberate practice is focused, repetitive training for constant improvement in a target skill.^{15,16} It is well established as an approach to reaching skill mastery and, when paired with simulator-based education appears superior to traditional clinical education.¹⁷ While the curricular materials presented here are tailored to simulator-based cardiac ultrasound, the integration of scaffolding and deliberate practice into training is a key concept that could be applied to a variety of other procedural or operational learning tasks that require a combination of cognitive and technical skills.

Methods

We incorporated the concepts of scaffolding and deliberate practice into a standard curriculum, termed the integrated didactic and experiential learning (IDEL) curriculum, by breaking the complex learning task of cardiac ultrasound into the discrete steps described below. In general, focused didactic information was immediately followed by targeted simulator practice for each module. Except for initial instruction on how to use the simulator interface, an instructor was not present during training. No prerequisite knowledge was required for learners. Learners completed the curriculum over multiple sessions of variable length based on their individual availability. All training was self-paced, and learners could repeat practice cases as desired. The practice complexity increased through successive modules, and learners ultimately applied their skills by completing unassisted simulator cases.

Materials needed:

- Cardiac ultrasound simulator with mannequin, mock transducer, and computer with monitor.
- Patient cases with ultrasound images and clinical report of findings and diagnoses.

- Didactic presentations.
- Pre- and posttests.

All FoCUS training was implemented using a high-fidelity simulator previously developed at the University of Washington (Appendix A).¹⁸ Immediate visual and quantitative feedback on image accuracy was provided by the simulator whenever an ultrasound image was captured during training. Learners had the opportunity to obtain multiple images during practice and could then choose the one they believed to be highest quality. This simulator was previously associated with a locally developed and validated standard curriculum that followed a traditional didactic-before-practice approach.¹⁹ Didactic information provided via the simulator, was presented in entirety at the beginning of training, with instruction in how to obtain six standard views, identify normal anatomy, and interpret abnormal findings. This was followed by a series of practice cases, where the learner was asked to obtain six views and interpret findings for each case.

The IDEL curriculum (Appendix B) was composed of 19 required modules. Scaffolding was built into the curricular design through graduated skills and increasing difficulty of learning tasks. There was an initial focus on technical acquisition and the normal anatomy, viewed one at a time, followed by assessment of pathologic findings of cardiac structures, viewed one at a time. Opportunity for deliberate practice included specific scanning tasks that could be repeated as needed based on quantitative and visual feedback from the simulator, as well as review of targeted feedback on common novice errors provided with the didactic material.

Modules one and two introduced basic cardiac ultrasound principles and patient positioning. Modules three through eight presented standard cardiac views: parasternal long axis (PLAX) and parasternal short axis at the levels of the mitral valve and mid-ventricle, apical four chamber, subcostal four chamber, and inferior vena cava. Instruction on the technical acquisition and expected anatomy for each of the standard cardiac views was immediately followed by practice in image acquisition on a simulator case of a normal heart.

Modules 10 through 16 focused on the diagnosis of basic pathology and were presented by cardiac structure. Instructions on how to evaluate a specific cardiac structure, such as the left ventricle or pericardium, were followed by simulator-based practice scanning of abnormal hearts to obtain and interpret pathology in that structure. Modules 17 through 19 presented cases when learners performed a full FoCUS exam, obtaining all the standard cardiac views and identifying pathology. Modules 20 through 21 offered additional practice cases as optional training.

Learners completed multiple-choice question tests (Appendix C) addressing cognitive skill in FoCUS before and after training. Learners also completed a pretraining scanning test of psychomotor skill, which consisted of either one simulator case or scanning a standardized patient. All learners completed a posttraining scanning test of psychomotor skill, which consisted of three simulator cases.

This curriculum is potentially translatable to a lower resource setting if there is no high-fidelity simulator available, although the need for instructors and standardized patients would significantly increase the personnel requirements for implementation. While all didactics in the IDEL curriculum are integrated into the simulator, the same material could be presented in a variety of nonsimulator settings (PowerPoint, printed or electronic self-study modules, etc.). See Appendix D for prepared PowerPoint slides that could be used for didactic teaching, and additional pictures and diagrammatic illustrations may be used to supplement these slides and are readily available online. As stated previously, in lieu of the simulator for hands-on practice, volunteer or standardized patients can be used. An instructor should be present to observe the practice scanning and offer real-time feedback on image quality. Pre- and posttraining scanning tests should be performed on a standardized patient.

The key principles of scaffolding and deliberate practice that should be maintained are as follows:

- Present didactics on acquisition and normal anatomy one view at a time.
- Immediately practice each view after didactics, with the opportunity to repeat as needed.

- Present analysis of pathology by cardiac structures, one structure at a time, integrating information from multiple views as needed.
- Immediately practice assessing each structure, with the opportunity to repeat as needed.
- Have multiple patients/cases available if possible so learners are exposed to clinical variety.

Results

Sixteen subjects trained on the IDEL curriculum, including eight first-year internal medicine residents, one second-year internal medicine resident, and six nurse practitioners. Their results were compared to 22 first-year residents who had previously trained on the standard curriculum. This group was composed of 18 internal medicine residents, two in anesthesiology, and one each in family medicine and surgery (Table).

Table. Pre- and Posttraining Test Scores^a

Skill and Curriculum	M ± SD (n)
Psychomotor skill ^b pretraining	
Standard curriculum	83 ± 28 (22)
IDEL curriculum	73 ± 48 (6)
Psychomotor skill ^b posttraining	
Standard curriculum	36 ± 24 (22)
IDEL curriculum	26 ± 25 (16)
Cognitive skill pretraining	
Standard curriculum	44 ± 19 (22)
IDEL curriculum	44 ± 19 (6)
Cognitive skill posttraining	
Standard curriculum	72 ± 8 (22)
IDEL curriculum	65 ± 14 (16)

Abbreviation: IDEL, integrated didactic and experiential learning.

^aAll *p* values nonsignificant.

^bDegree of angle error.

The average pretraining test scores were not significantly different between the standard and IDEL curriculum groups in either the technical or cognitive skill domains. After training on the IDEL curriculum, learners' psychomotor and cognitive skills were similar to the skill levels reached on the standard curriculum. Both groups showed significant gain in psychomotor skill as measured by the degree of angle error between learner-acquired image plane and the optimal image plane. Two of the learners on the standard curriculum had an increase in their angle error after training due to scanning with the probe rotated 180 degrees, causing left-right reversal. It should be noted that the IDEL curriculum group completed training in significantly less time (4.7 ± 1.9 hours) than the standard curriculum group (8.0 ± 2.5 hours), $p < .0001$.

Discussion

We optimized an existing simulator-based FoCUS curriculum by integrating instructional scaffolding and deliberate practice to create a directed, self-regulated learning experience for novices. Compared to the previously validated, simulator-based curriculum, the level of posttraining psychomotor and cognitive skill achieved by our subjects was comparable to that of the standard didactic curriculum. However, the IDEL curriculum was associated with significantly faster skill acquisition compared to the traditional "didactic-before-practice" curriculum.

The simulator technology used in both the IDEL and standard curricula has key features for facilitating effective learning, including the provision of immediate feedback, clinical variety, and a range of difficulty.²⁰ The IDEL curriculum was modified to maximize the integration of adult and experiential learning techniques as well as provide an iterative learning process.²¹ Each segment of the didactic information was immediately connected with targeted practice scanning to create a problem-centered approach that placed the trainee at the center of the learning process and increased the amount of active learning time. The curriculum was scaffolded by separating normal from abnormal anatomy, and parsing out the overall learning goal into graduated tasks. In addition to the immediate quantitative feedback provided by the simulator on psychomotor skill, qualitative feedback on common novice errors was

offered to encourage learner self-reflection and facilitate the ability of trainees to identify and correct their errors. While these modifications were built into the simulator in this curriculum, these are core instructional design principles that can be applied to other teaching modalities.

Although FoCUS training is optimal when provided by expert faculty on a one-on-one basis,²² and mentored training in ultrasound is recommended by both the American Society of Echocardiography and the European Society of Echocardiography,^{1,23} expert sonographers and cardiology faculty are a limited resource. A unique advantage of this simulator-based IDEL curriculum model for FoCUS is the integration of entirely self-directed didactics and independent simulator training that does not require faculty presence. The utilization of this curriculum removes potential barriers to training, such as in situations when there are large numbers of learners or remote learners with limited access to one-on-one teaching by expert faculty. Further, this format also allows for variation in the rate of skill acquisition between trainees, as each individual learner is able to invest as much practice time as needed to attain the desired level of skill. This could allow simulation to be used as an initial training step in providing early instruction and ensuring a basic level of competence so that expert faculty time can be directed to more advanced training. Independent learning and practice could also allow for ongoing maintenance of skills as needed.

While the independent nature of this curriculum provides potential benefits, there may be an inherent limit on the degree of skill that a novice can independently gain in FoCUS given the complexity of the learning task. Although the IDEL curriculum offered anticipatory feedback for common novice errors, the onus remained on the learner to self-diagnose and correct their technical deficiencies. This may have contributed to the similar posttest cognitive and psychomotor skill levels seen in the standard and IDEL curricula. The small number of learners was likely an additional limiting factor in demonstrating significant difference.

The employment of historical controls and small number of learners in this analysis are potential limitations on the generalizability of the present results. We have already initiated a prospective study in which learners are randomized between the two curricula. Additionally, all outcome measures were validated and quantitative skill metrics based on scanning a mannequin rather than on live patients. The correlation between simulator-based skill assessment and assessment on live patients is also ongoing.

Although it is impossible to assess the effect size for each curricular change made in this analysis, the net increased efficiency of integrating and scaffolding didactics with deliberate practice demonstrated in this analysis has potentially far-reaching implications for efficiency of novice training. Further study on larger samples is needed to confirm the present findings. However, these results support shifting curriculum away from the lecture before practice and the “see one, do one” paradigms of learning. This approach may also be effective if applied to other learner groups or methods of training and merits further study in these settings.

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Disclosures

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Ethical Approval

This publication contains data obtained from human subjects and received ethical approval.

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