

**Creating a Significant Learning Environment in Cardiac Sonography:
Integrating CRUX, a Flipped-Lab Imaging Library,
Into an Outcome-Based Instructional Design**

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ABSTRACT

Cardiac sonography education requires instructional environments that support the development of psychomotor skill, clinical reasoning, and professional judgment. Traditional laboratory structures often devote substantial time to repeated instructor demonstrations, limiting opportunities for supervised scanning practice and feedback. This paper presents an integrated instructional design plan that incorporates CRUX, a flipped-lab, indexed, on-demand imaging library, into a blended learning module for foundational echocardiographic image acquisition. Grounded in Outcome-Based Education, Backward Design, Creating Significant Learning Environments (CSLE), and the COVA (Choice, Ownership, Voice, Authenticity) framework, the design reallocates instructional time toward deliberate practice, feedback, and metacognitive development. Foundational theories of multimedia learning, cognitive load, deliberate practice, and retrieval practice are blended with current peer-reviewed research in flipped learning, ultrasound education, and health professions pedagogy. A 16-week implementation outline demonstrates how CRUX supports pre-lab preparation, structured practice, and reflective learning. The integrated design strengthens alignment between learning outcomes, instructional activities, and assessments while improving clinical readiness and supporting sustainable program innovation.

INTRODUCTION

Cardiac sonography education demands more than conceptual understanding; it requires the development of procedural fluency, clinical reasoning, and professional judgment under real-time conditions. Students must coordinate transducer manipulation, anatomical recognition, image optimization, and measurement accuracy while maintaining patient comfort and safety. These skills develop through structured repetition, timely feedback, and opportunities for reflection, conditions that are often constrained by limited laboratory capacity in community college allied health programs.

In many sonography programs, early laboratory sessions rely heavily on repeated instructor-led demonstrations of standard cardiac windows and measurement techniques. Although demonstration is essential for initial modeling, excessive reliance on live demonstration reduces the time available for supervised scanning practice, which is the primary driver of psychomotor skill acquisition (Sidhu et al., 2017). As a result, students may enter clinical rotations with adequate theoretical knowledge but insufficient hands-on experience to perform consistently and independently.

To address these instructional constraints, the program director developed CRUX: a flipped-lab, indexed, on-demand imaging library designed to shift foundational modeling outside scheduled laboratory hours. CRUX provides standardized video demonstrations, probe-handling exemplars, and measurement models that students review asynchronously before lab. This innovation aligns with current research demonstrating that flipped learning improves performance in health professions education when pre-class preparation is intentionally connected to active, coached practice (Chen et al., 2017; Naing

et al., 2023). By reallocating instructional time toward guided repetition and feedback, CRUX strengthens the conditions under which procedural fluency develops.

This instructional design plan integrates CRUX into a blended learning module focused on foundational echocardiographic image acquisition. The design is grounded in Outcome-Based Education (OBE), Backward Design, Creating Significant Learning Environments (CSLE), and the COVA framework. These approaches emphasize alignment, authenticity, learner agency, and intentional structuring of learning experiences. The plan also incorporates foundational theories, including multimedia learning (Mayer, 2009), cognitive load (Sweller, 1988), deliberate practice (Ericsson, 2004), and retrieval practice (Roediger & Karpicke, 2006), alongside current peer-reviewed research in ultrasound education, flipped learning, and clinical skill development (Custer et al., 2022; McCoy et al., 2015; Staal et al., 2023).

The purpose of this paper is to present a fully integrated instructional design plan that demonstrates how CRUX enhances online and blended learning in cardiac sonography. The plan includes contextual analysis, theoretical grounding, a three-column alignment table, a 16-week implementation outline, assessment strategies, and considerations for accessibility, learner support, and program sustainability. Through this integration, the design supports deeper learning, improved clinical readiness, and long-term instructional coherence within the cardiac sonography program.

Context

Cardiac sonography education occurs within a complex instructional environment shaped by limited laboratory capacity, high clinical performance expectations, and the developmental needs of adult learners preparing for entry-level practice. Students enrolled in an Associate of Applied Science (AAS) degree program must acquire foundational knowledge of cardiac anatomy, echocardiographic imaging principles, and professional communication while simultaneously developing psychomotor fluency in transducer manipulation, image optimization, and diagnostic reasoning. These demands require instructional designs that integrate conceptual understanding with authentic practice opportunities.

The instructional module described in this design is positioned at the early-to-mid stage of the cardiac sonography curriculum, where learners transition from basic terminology and anatomy into applied scanning behaviors. At this stage, students often demonstrate conceptual knowledge but struggle to translate that knowledge into consistent image acquisition. Research in health professions education indicates that early learners benefit from structured modeling, guided practice, and timely feedback to support the development of procedural fluency (Staal et al., 2023; Sidhu et al., 2017). However, traditional laboratory structures frequently devote substantial time to repeated instructor demonstrations, reducing opportunities for supervised scanning practice.

In the program's current structure, students complete a single 80-hour laboratory course prior to their first clinical rotation. Faculty logs indicate that 50–60% of early

laboratory sessions are spent on live demonstration, leaving limited time for coached repetition. First-attempt competency pass rates average approximately 62%, with nearly one-third of students requiring remediation before clinical placement. These indicators suggest that instructional time is not being used in a manner that optimally supports psychomotor skill development.

The instructional design presented in this paper addresses these constraints by integrating CRUX: a flipped-lab, indexed, on-demand imaging library developed by the program director to restructure how foundational modeling occurs. CRUX provides standardized video demonstrations, probe-handling exemplars, measurement models, and troubleshooting guidance that students review asynchronously before participating in laboratory practice. This innovation aligns with current research demonstrating that flipped learning improves academic and clinical performance in health professions education when pre-class preparation is intentionally connected to active, coached practice (Chen et al., 2017; Naing et al., 2023).

CRUX Innovation Integration

CRUX is designed to shift foundational instruction from live demonstration to an accessible digital format, thereby reallocating laboratory time toward supervised scanning practice, guided troubleshooting, and individualized feedback. The imaging library includes segmented modules organized by cardiac window, anatomical structure, measurement category, and difficulty level. This structure supports rapid retrieval, reduces cognitive load, and provides consistent modeling across cohorts.

The integration of CRUX into this instructional design is grounded in several evidence-based principles:

1. Instructional Reallocation

Flipped learning research consistently demonstrates that learning gains arise not from pre-class exposure alone, but from the intentional reallocation of in-class time toward active engagement (Jensen et al., 2015; Strelan et al., 2018). CRUX operationalizes this principle by ensuring that students arrive to lab with foundational modeling already completed, allowing instructors to focus on coached repetition and feedback.

2. Multimedia Learning

Mayer's (2009) multimedia learning theory emphasizes that segmented, well-designed instructional materials reduce cognitive overload and enhance understanding. CRUX modules follow a consistent structure: setup, probe placement, image optimization, and measurement, which supports schema development and reduces extraneous cognitive load during live scanning.

3. Deliberate Practice

Expert performance develops through structured, goal-oriented repetition paired with immediate feedback (Ericsson, 2004). By reducing the proportion of lab time spent on demonstration, CRUX increases opportunities for deliberate practice, enabling students to refine technique under instructor guidance.

4. Retrieval Practice

Indexed digital resources facilitate retrieval practice by allowing learners to access relevant examples during performance. Retrieval practice strengthens long-term retention and supports transfer of learning (Roediger & Karpicke, 2006). CRUX's searchable structure enables students to revisit difficult views and apply corrective adjustments during the same practice attempt.

5. Ultrasound-Specific Evidence

Recent research in sonography education supports blended and flipped instructional models. Custer et al. (2022) found that instructional format influences both learner perceptions and performance outcomes in diagnostic medical sonography. McCoy et al. (2015) demonstrated that video-assisted instruction improves ultrasound performance compared to traditional lecture-based methods. CRUX aligns with these findings by providing structured digital modeling that complements hands-on practice.

6. Implementation Science and Sustainability

Sustainable instructional innovation requires alignment among pedagogy, leadership practice, evaluation systems, and financial feasibility (Fullan, 2016; Thomas et al., 2016). CRUX is designed as a maintained instructional system rather than a one-time product. Indexed categories, faculty calibration sessions, and iterative module updates ensure long-term relevance and accuracy.

Positioning CRUX Within the Instructional Design Plan

CRUX is not an add-on; it is an instructional engine that strengthens the entire design.

Within this module:

- CRUX supports Outcome-Based Education by aligning pre-lab preparation with performance outcomes.
- CRUX enhances Backward Design by providing targeted modeling that directly supports desired evidence of learning.
- CRUX contributes to Creating Significant Learning Environments by reducing cognitive overload, increasing learner confidence, and supporting authentic practice.
- CRUX expands COVA by giving learners choice, ownership, and voice in how they prepare for lab and reflect on their performance.

By integrating CRUX throughout the module, the instructional design becomes more coherent, more efficient, and more aligned with how adult learners develop expertise in healthcare education.

Design Approach: Outcome-Based Education

The instructional design for this cardiac sonography module is grounded in Outcome-Based Education (OBE), an approach that emphasizes clarity of learning outcomes, alignment between instruction and assessment, and intentional structuring of learning experiences to support meaningful performance. OBE is particularly appropriate

in healthcare education, where learners must demonstrate integrated knowledge, technical skill, clinical reasoning, and professional judgment rather than isolated competencies.

In cardiac sonography, students must not only identify anatomical structures but also apply that understanding to real-time scanning decisions, image optimization, and diagnostic interpretation. OBE supports this integration by focusing on what learners should be able to do with their knowledge. The approach aligns with current research indicating that health professions learners benefit from instructional designs that emphasize application, reflection, and performance-based assessment (Naing et al., 2023; Staal et al., 2023).

CRUX strengthens the OBE framework by providing structured, standardized pre-lab preparation that directly supports the module's learning outcomes. Because students engage with foundational modeling before participating in hands-on practice, laboratory time can be devoted to coached repetition, troubleshooting, and feedback. This alignment ensures that assessments measure applied understanding rather than passive recall.

Backward Design

The instructional design is further grounded in Backward Design, a framework developed by Wiggins and McTighe (2005) that begins with the end in mind. Backward Design requires instructors to identify desired learning outcomes, determine acceptable evidence of learning, and then design instructional activities that support those outcomes.

This approach prevents instruction from becoming content-driven rather than learning-driven.

In cardiac sonography, Backward Design is essential because learners must demonstrate performance, not simply knowledge. A student may memorize the location of cardiac structures but still struggle to obtain or interpret the correct sonographic view. By beginning with the desired performance outcomes, such as acquiring diagnostic transthoracic echocardiographic views, the instructor ensures that instructional activities and assessments support authentic clinical application.

CRUX enhances Backward Design by providing targeted pre-lab instructional materials that align directly with the desired evidence of learning. Each CRUX module is structured around the specific performance outcomes required for laboratory success: probe placement, image plane formation, optimization techniques, and measurement accuracy. This alignment ensures that students arrive to lab prepared to engage in the performance tasks that assessments will measure.

Creating Significant Learning Environments (CSLE)

Creating Significant Learning Environments (CSLE) emphasizes the importance of designing learning contexts that support motivation, engagement, reflection, and the development of learner identity (Fink, 2013). CSLE recognizes that learning is shaped not only by instructional materials but also by relationships, expectations, feedback, culture, and opportunities for practice.

In cardiac sonography, CSLE is essential because learners must develop confidence, persistence, and professional thinking while acquiring technical skills. The National Academies (2018) emphasize that effective learning environments must account for learners' prior knowledge, motivation, social context, and opportunities for metacognition. This is particularly relevant for adult community college learners who balance academic, financial, and personal responsibilities.

CRUX contributes to CSLE by reducing cognitive overload during laboratory sessions, increasing opportunities for coached practice, and supporting learner confidence through repeatable access to high-quality demonstrations. By shifting foundational modeling outside the lab, CRUX allows instructors to focus on individualized feedback, collaborative problem-solving, and guided practice, key components of significant learning environments.

COVA: Choice, Ownership, Voice, and Authentic Learning

The COVA framework supports student-centered learning by giving learners choice, ownership, voice, and authentic learning opportunities (Harapnuik et al., 2018). In cardiac sonography, learners must develop independence, confidence, and self-regulation to succeed in clinical practice. COVA encourages learners to engage actively with content, reflect on their performance, and take ownership of their learning.

CRUX enhances COVA by providing learners with choice in how they prepare for laboratory practice. Students can revisit difficult views, explore indexed categories, and self-pace their preparation. This supports metacognition and self-directed learning, which

are essential for developing professional judgment. CRUX also supports authentic learning by providing real-world imaging examples that learners can analyze, critique, and apply during hands-on practice.

Within the module, COVA is operationalized through reflective journals, peer feedback, self-assessment checklists, and opportunities for learners to analyze their own images. These activities encourage learners to monitor their progress, identify areas for improvement, and engage in meaningful dialogue about clinical performance. CRUX strengthens these activities by providing consistent models that learners can compare against their own work.

Integrating CRUX Across Instructional Frameworks

CRUX is woven throughout the instructional design as a foundational component that strengthens alignment, authenticity, and learner agency. Within OBE, CRUX ensures that pre-lab preparation aligns with performance outcomes. Within Backward Design, CRUX provides targeted modeling that supports desired evidence of learning. Within CSLE, CRUX enhances the learning environment by reducing cognitive load and increasing opportunities for practice. Within COVA, CRUX expands learner choice, ownership, and voice.

By integrating CRUX across these frameworks, the instructional design becomes more coherent, more efficient, and more aligned with how adult learners develop expertise in healthcare education. The result is a blended learning module that supports deeper learning, improved clinical readiness, and sustainable instructional innovation.

Design Artifact: Three-Column Alignment Table

The three-column table below aligns learning goals, learning activities, and assessment activities according to Outcome-Based Education, Backward Design, CSLE, and COVA. CRUX is embedded throughout the design as a foundational instructional resource that supports pre-lab preparation, retrieval practice, and standardized modeling.

Big Hairy Audacious Goal (BHAG)

By the end of this module, cardiac sonography students will demonstrate the foundational knowledge, technical reasoning, and reflective habits necessary to acquire, evaluate, and explain standard transthoracic echocardiographic views in a manner that supports safe, ethical, and patient-centered clinical practice.

Learning Goals	Learning Activities	Assessment Activities
Students will identify key cardiac structures and describe their appearance in standard echocardiographic views.	Interactive online anatomy review; CRUX pre-lab modules demonstrating labeled cardiac structures in standard views; Instructor mini-lecture; Guided practice with labeled image sets; Peer discussion analyzing anatomical variation	Low-stakes image labeling quiz; Discussion post explaining structure identification; Module exam (structure identification + view recognition)
Students will explain the relationship between transducer position, image plane, and displayed cardiac anatomy.	CRUX modules demonstrating probe placement, orientation, and image plane formation; Virtual scanning orientation activity; Small-group discussion analyzing view formation; Instructor-guided breakdown of image plane geometry	Short written explanation of image plane formation; Image-plane matching activity; Instructor-reviewed knowledge check
Students will apply basic image optimization principles to improve	CRUX modules demonstrating optimization techniques (depth, gain, sector width, focus); Case-based comparison of optimal and suboptimal images; Lab demonstration of optimization strategies;	Image critique assignment; Scanning lab optimization checklist; Instructor feedback on optimization performance

Learning Goals	Learning Activities	Assessment Activities
echocardiographic image quality.	Student practice using equipment controls; Peer coaching during lab	
Students will demonstrate foundational scanning behaviors for selected transthoracic echocardiographic views.	Face-to-face lab practice; CRUX pre-lab modules for each required view; Guided scanning stations; Instructor modeling and corrective feedback; Peer observation and coaching	Performance-based scanning evaluation; Formative lab observation; Self-assessment checklist comparing personal performance to CRUX exemplars
Students will reflect on their scanning progress and identify specific strategies for improvement.	Reflective journal; CRUX module review to identify areas of difficulty; Peer feedback; Goal-setting activity; Review of instructor feedback	Reflection submission; Personal improvement plan; Participation in peer review
Students will connect classroom learning to clinical expectations and professional sonographer behaviors.	Clinical scenario discussion; Professional standards review; CRUX modules demonstrating professional scanning workflow; Case reflection	Scenario-based response; Professionalism rubric; Final reflective synthesis

Integration Summary

CRUX is embedded across all learning goals as a foundational instructional resource that:

- standardizes modeling of cardiac views and measurements,
- reduces cognitive load during lab,
- supports retrieval practice and self-paced review,
- increases time available for coached repetition,
- strengthens alignment between learning outcomes and assessments, and
- enhances learner agency through choice, ownership, and reflection.

This alignment ensures that students engage with foundational modeling before lab, allowing laboratory time to focus on deliberate practice, feedback, and clinical reasoning, conditions supported by current research in health professions education (Custer et al., 2022; Naing et al., 2023; Staal et al., 2023).

16-Week Implementation Outline

This 16-week implementation plan operationalizes the instructional design by integrating CRUX throughout online preparation, laboratory practice, assessment, and reflection. The structure aligns with Outcome-Based Education, Backward Design, CSLE, COVA, and current research in health professions education. Each week includes online learning, CRUX engagement, face-to-face laboratory practice, and assessment activities that support deliberate practice, retrieval, and metacognition.

Weeks 1–4: Foundations of Echocardiographic Imaging

Week 1 — Introduction to Cardiac Anatomy and Sonographic Orientation

Online Learning

- Overview of module outcomes and expectations
- Interactive anatomy review
- CRUX modules: basic cardiac anatomy, labeled structures, spatial orientation

Lab Practice

- Orientation to scanning equipment

- Introduction to transducer handling

Assessment

- Low-stakes anatomy quiz
- Discussion post: “What makes a diagnostic echocardiographic image?”

Week 2 — Standard Transthoracic Views: Conceptual Foundations

Online Learning

- CRUX modules: PLAX, PSAX, A4C, A2C overview
- Virtual scanning orientation activity

Lab Practice

- Guided scanning stations focusing on probe orientation

Assessment

- Image-plane matching activity
- Instructor-reviewed knowledge check

Week 3 — Image Plane Formation and Anatomical Relationships

Online Learning

- CRUX modules: probe placement, image plane geometry
- Small-group discussion analyzing view formation

Lab Practice

- Practice forming PLAX and PSAX views
- Instructor modeling and corrective feedback

Assessment

- Short written explanation of image plane formation

Week 4 — Introduction to Image Optimization

Online Learning

- CRUX modules: depth, gain, focus, sector width
- Case-based comparison of optimal vs. suboptimal images

Lab Practice

- Optimization practice using equipment controls

Assessment

- Image critique assignment

Weeks 5–8: Applied Image Acquisition and Optimization

Week 5 — PLAX and PSAX Acquisition

Online Learning

- CRUX modules: PLAX and PSAX acquisition steps

- Troubleshooting examples

Lab Practice

- Guided PLAX and PSAX acquisition
- Peer coaching

Assessment

- Formative lab observation checklist

Week 6 — A4C and A2C Acquisition

Online Learning

- CRUX modules: A4C and A2C acquisition
- Anatomical variation review

Lab Practice

- Guided A4C and A2C acquisition
- Instructor feedback

Assessment

- Low-stakes view identification quiz

Week 7 — Measurement Principles and Workflow

Online Learning

- CRUX modules: LV measurements, RV measurements, atrial dimensions

- Workflow modeling

Lab Practice

- Measurement practice using stored images

Assessment

- Measurement accuracy assignment

Week 8 — Optimization and Troubleshooting Integration

Online Learning

- CRUX modules: troubleshooting common errors
- Case-based optimization scenarios

Lab Practice

- Students troubleshoot suboptimal images
- Instructor-guided correction

Assessment

- Optimization performance checklist

Weeks 9–12: Deliberate Practice, Feedback, and Clinical Reasoning

Week 9 — Integrated View Acquisition

Online Learning

- CRUX modules: integrated scanning workflow
- Reflective review of difficult views

Lab Practice

- Students complete full scanning sequences
- Peer observation

Assessment

- Reflective journal entry

Week 10 — Clinical Reasoning During Image Acquisition

Online Learning

- CRUX modules: clinical reasoning examples
- Case-based interpretation

Lab Practice

- Students explain scanning decisions during acquisition

Assessment

- Scenario-based written response

Week 11 — Professional Behaviors and Communication

Online Learning

- CRUX modules: professional scanning workflow

- Review of professional standards

Lab Practice

- Communication practice with simulated patients

Assessment

- Professionalism rubric

Week 12 — Mid-Module Performance Evaluation

Online Learning

- CRUX review of all required views
- Self-assessment checklist

Lab Practice

- Formative performance evaluation
- Instructor feedback session

Assessment

- Mid-module scanning evaluation

Weeks 13–16: Mastery, Reflection, and Summative Assessment

Week 13 — Targeted Remediation and Skill Refinement

Online Learning

- CRUX modules selected based on individual needs
- Peer feedback discussion

Lab Practice

- Targeted remediation sessions

Assessment

- Personal improvement plan

Week 14 — Advanced Troubleshooting and Workflow Efficiency

Online Learning

- CRUX modules: advanced troubleshooting
- Efficiency strategies

Lab Practice

- Students refine workflow timing and transitions

Assessment

- Efficiency and troubleshooting checklist

Week 15 — Summative Scanning Performance Evaluation

Online Learning

- CRUX review of all views and measurements

- Final reflection prompts

Lab Practice

- Summative scanning evaluation
- Instructor feedback

Assessment

- Summative performance-based exam

Week 16 — Final Reflection and Clinical Readiness Synthesis

Online Learning

- Reflective synthesis assignment
- CRUX review of progress

Lab Practice

- Final coaching session
- Preparation for clinical rotation

Assessment

- Final reflective synthesis
- Completion of self-assessment checklist

Implementation Summary

This 16-week plan integrates CRUX as a core instructional engine that:

- standardizes pre-lab modeling,
- increases supervised scanning time,
- supports retrieval practice,
- reduces cognitive load,
- enhances learner agency, and
- strengthens alignment between outcomes, activities, and assessments.

The structure reflects current research demonstrating that flipped learning, multimedia modeling, deliberate practice, and feedback-rich environments improve performance in health professions education (Chen et al., 2017; Custer et al., 2022; Naing et al., 2023; Staal et al., 2023).

Assessment Strategy

Effective assessment in cardiac sonography education requires a balanced approach that evaluates conceptual understanding, technical skill, clinical reasoning, and reflective practice. This instructional design incorporates three interconnected forms of assessment, assessment of learning, assessment for learning, and assessment as learning, each aligned with Outcome-Based Education, Backward Design, CSLE, and COVA. CRUX is integrated throughout the assessment system to support pre-lab preparation, retrieval practice, and performance refinement.

Assessment of Learning

Assessment of learning evaluates whether students have achieved the stated learning outcomes at the end of the module. In cardiac sonography, summative assessments must measure both cognitive and psychomotor performance to ensure clinical readiness.

Summative Assessments in This Module

- Module exam assessing cardiac anatomy, view identification, and image-plane reasoning
- Summative scanning performance evaluation measuring acquisition of PLAX, PSAX, A4C, and A2C views
- Measurement accuracy assessment evaluating correct application of quantitative techniques
- Final reflective synthesis demonstrating integration of knowledge, reasoning, and professional judgment

These assessments provide evidence that learners can identify cardiac structures, explain image formation, optimize images, and perform foundational scanning behaviors. They align with current research emphasizing the importance of performance-based assessment in health professions education (Naing et al., 2023; Staal et al., 2023).

Role of CRUX in Assessment of Learning

CRUX strengthens summative assessment by ensuring that students arrive to performance evaluations with consistent exposure to standardized modeling. Because CRUX modules demonstrate correct technique, learners have a reliable reference point against which they can compare their own performance. This reduces variability in preparation and supports equitable assessment conditions.

Assessment for Learning

Assessment for learning occurs throughout the module and is used to guide instruction, support learner progress, and identify areas requiring additional practice. These formative assessments help learners recognize gaps before high-stakes evaluation and help instructors determine when reteaching or targeted coaching is needed.

Formative Assessments in This Module

- Low-stakes quizzes
- Knowledge checks
- Image critique assignments
- Formative lab observations
- Peer feedback discussions
- Instructor feedback during guided practice

These assessments align with research demonstrating that timely, specific feedback improves performance and supports deliberate practice (Ericsson, 2004; Hattie & Timperley, 2007).

Role of CRUX in Assessment for Learning

CRUX enhances formative assessment by providing:

- Immediate access to corrective models Learners can compare their images to CRUX exemplars and identify discrepancies.

- Opportunities for targeted review Students can revisit modules related to areas of difficulty identified through formative assessment.
- Support for feedback cycles Instructors can reference CRUX modules when providing corrective guidance, ensuring consistency across faculty.

CRUX therefore strengthens the feedback loop that is essential for skill acquisition in ultrasound education.

Assessment as Learning

Assessment as learning positions learners as active participants in monitoring their own progress. This form of assessment emphasizes metacognition, reflection, and self-regulation. These skills essential for safe, independent clinical practice.

Assessment as Learning Activities in This Module

- Reflective scanning journals
- Self-assessment checklists
- Peer feedback activities
- Personal improvement plans
- Final reflective synthesis

These activities encourage learners to evaluate their own images, recognize limitations, and identify strategies for improvement. This aligns with research emphasizing

the importance of metacognition and reflective practice in health professions education (National Academies, 2018).

Role of CRUX in Assessment as Learning

CRUX supports assessment as learning by providing:

- A consistent reference point Learners can compare their performance to standardized CRUX exemplars.
- Tools for self-directed improvement Students can independently review modules related to their identified weaknesses.
- Support for reflective practice CRUX enables learners to analyze their scanning decisions in relation to expert models, strengthening metacognitive awareness.

CRUX therefore enhances learner agency, ownership, and voice, which are key components of the COVA framework.

Integrated Assessment Summary

The assessment system in this instructional design is intentionally balanced:

- Assessment of learning ensures mastery of outcomes.
- Assessment for learning guides instruction and supports progress.
- Assessment as learning develops reflective practitioners capable of self-evaluation.

CRUX is woven throughout all three forms of assessment, strengthening alignment, supporting deliberate practice, and enhancing learner agency. This integrated approach

reflects current research demonstrating that blended assessment systems improve performance, retention, and clinical readiness in health professions education (Custer et al., 2022; Naing et al., 2023; Staal et al., 2023).

Support and Infrastructure

Effective implementation of this instructional design requires robust support structures that ensure learners have access to the tools, resources, and guidance necessary to succeed. Cardiac sonography students are adult learners who often balance academic responsibilities with employment, family obligations, and financial pressures. Therefore, the learning environment must provide flexibility, clarity, and reliable access to instructional materials.

The module relies on several key infrastructure components:

Learning Management System (LMS)

The LMS serves as the central hub for course communication, assignment submission, discussion forums, and access to digital learning materials. All module instructions, deadlines, rubrics, and supplemental resources are posted in the LMS to support transparency and ease of navigation.

CRUX Imaging Library

CRUX functions as a core instructional engine within the module. Students require continuous access to CRUX modules before, during, and after laboratory practice. Because CRUX is hosted outside the LMS, it remains available throughout the entire program, supporting longitudinal CRUX functions as a core instructional engine within the

module. Students require continuous access to CRUX modules before, during, and after laboratory practice. Because CRUX is hosted outside the LMS, it remains available throughout the entire program, supporting longitudinal learning and retrieval practice. The platform must be stable, mobile-friendly, and accessible across devices.

Scanning Laboratory and Equipment

Face-to-face laboratory sessions require functional ultrasound machines, simulation tools, and adequate space for guided practice. Equipment must be calibrated consistently to ensure that learners experience reliable imaging conditions. Faculty must be available to provide modeling, feedback, and troubleshooting support.

Technical Support

Students must have access to technical assistance for LMS navigation, CRUX access, video playback, and equipment troubleshooting. Reliable support reduces frustration and ensures that technical barriers do not impede learning.

Instructor Support and Collaboration

Faculty collaboration is essential for maintaining consistency in feedback, modeling, and assessment. Twice-annual calibration sessions ensure that instructors use consistent terminology, correction strategies, and performance expectations. This supports instructional coherence and reduces variability across cohorts.

Accessibility and Usability

Accessibility is a critical component of high-quality online and blended learning. The

design adheres to accessibility principles recommended by Quality Matters (2023) and the National Academies (2018), ensuring that all learners, including those with disabilities or learning differences, can engage fully with course materials.

Accessibility Features

- Captioned videos for all CRUX modules and instructor-created content
- Screen-reader compatible documents formatted with proper headings and alt text
- Clear navigation within the LMS and CRUX platform
- Readable design using accessible fonts, color contrast, and spacing
- Multiple means of engagement including video, text, images, and interactive activities
- Flexible pacing within online components to support adult learners

Usability Considerations

- Instructions are written clearly and concisely.
- Deadlines are posted in multiple locations (LMS calendar, module overview, weekly checklist).
- CRUX modules are indexed by view, anatomy, measurement, and difficulty level to support rapid retrieval.
- Lab expectations are communicated in advance to reduce cognitive load during practice.

These features align with research indicating that accessible and usable learning environments improve engagement, reduce cognitive burden, and support deeper learning (National Academies, 2018).

Learner Support

Learner support is essential for student success in rigorous health professions programs. This module incorporates multiple layers of support:

Instructor Support

Instructors provide modeling, corrective feedback, guided practice, and individualized coaching. Feedback is timely, specific, and aligned with performance standards, consistent with research demonstrating the importance of feedback in skill acquisition (Hattie & Timperley, 2007).

Peer Support

Peer coaching, discussion forums, and collaborative activities encourage social learning and shared problem-solving. Peer feedback supports metacognition and reflective practice.

Academic Support Services

Students have access to tutoring, writing assistance, accessibility services, and academic advising. These services support learners who may need additional help with study strategies, time management, or academic skills.

Clinical Readiness Support

CRUX provides ongoing support for clinical readiness by allowing students to revisit foundational modules throughout the program. This supports retrieval practice and long-term retention (Roediger & Karpicke, 2006).

Quality Matters Alignment

The instructional design aligns with the Quality Matters Higher Education Rubric (7th ed.) across multiple standards:

1. Course Overview and Introduction

The module provides clear expectations, outcomes, and navigation instructions. CRUX access instructions are included in the course introduction.

2. Learning Objectives

Learning objectives are measurable, clearly stated, and aligned with assessments and activities. CRUX modules directly support these objectives.

3. Assessment and Measurement

Assessments measure both conceptual understanding and clinical performance. Rubrics and checklists provide transparency and consistency.

4. Instructional Materials

CRUX modules, instructor videos, readings, and image sets are aligned with learning outcomes and support learner engagement.

5. Learning Activities and Interaction

Activities promote active learning, collaboration, and authentic practice. CRUX enhances interaction by supporting pre-lab preparation and reflective analysis.

6. Course Technology

CRUX and LMS tools support learning objectives and are accessible, reliable, and user-friendly.

7. Learner Support

The module provides academic, technical, and accessibility support consistent with QM standards.

8. Accessibility and Usability

All materials meet accessibility guidelines, including captioning, screen-reader compatibility, and clear navigation.

By aligning with Quality Matters standards, the instructional design ensures academic quality, accessibility, and learner support while integrating CRUX as a sustainable instructional innovation.

Conclusion

Cardiac sonography education requires instructional environments that intentionally integrate conceptual understanding, psychomotor skill development, clinical reasoning, and reflective practice. Traditional laboratory structures often devote substantial time to repeated instructor demonstrations, limiting opportunities for supervised scanning

practice and feedback, conditions essential for procedural fluency. This instructional design plan addresses these constraints by integrating CRUX, a flipped-lab, indexed, on-demand imaging library, into a blended learning module grounded in Outcome-Based Education, Backward Design, Creating Significant Learning Environments (CSLE), and the COVA framework.

CRUX strengthens the instructional design by shifting foundational modeling outside scheduled laboratory hours, thereby increasing time available for deliberate practice, guided troubleshooting, and individualized feedback. The innovation aligns with current research demonstrating that flipped learning improves performance in health professions education when pre-class preparation is intentionally connected to active, coached practice. CRUX also supports multimedia learning principles, reduces cognitive load, enhances retrieval practice, and provides standardized modeling that improves consistency across cohorts.

The 16-week implementation plan operationalizes CRUX throughout online preparation, laboratory practice, assessment, and reflection. The design incorporates balanced assessment strategies, assessment of, for, and as learning, that evaluate conceptual understanding, technical skill, clinical reasoning, and metacognitive development. Accessibility, usability, and learner support are embedded throughout the module, aligning with Quality Matters standards and ensuring equitable access for adult learners.

By integrating CRUX across instructional frameworks, learning activities, assessments, and support structures, the design becomes more coherent, more efficient,

and more aligned with how adult learners develop expertise in healthcare education. The result is a significant learning environment that strengthens clinical readiness, supports sustainable instructional innovation, and prepares students to enter cardiac sonography practice as competent, reflective, ethical, and patient-centered professionals.

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