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Research Article

From Concept to Clinical Competence: Ernest Cook University's Integrated Model for Anatomy Education in Medical Imaging in a Resource Constrained Setting

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Abstract

Background: The evolution of diagnostic imaging demands a paradigm shift in anatomy education, moving from passive memorization to the active cultivation of spatial reasoning and three-dimensional (3D) visuospatial skills. In Sub-Saharan Africa (SSA), this need is acute, where traditional, lecture-heavy pedagogies often fail to equip graduates with the practical competencies required for independent clinical practice amidst significant resource limitations. This paper presents and rationalizes a conceptual model for an integrated, competency-based anatomy curriculum implemented at Ernest Cook University (ECU), Uganda, designed specifically for non-physician imaging students.

Methods: The model employs a multimodal educational framework, synergistically combining four core modalities: cadaveric dissection, plastic anatomical models, 3D virtual dissection (Anatomy table), and live ultrasound scanning in a dedicated skills laboratory. Guided by Competency-Based Medical Education (CBME) principles, the curriculum is structured to manage cognitive load through staged learning. A blueprint-driven assessment system prioritizes practical competence, with 70% of the final course grade derived from multi-station Objective Structured Practical Examinations (OSPEs) in a "steeplechase" format.

Results: This integrated approach creates a scalable, hands-on learning ecosystem that bridges theoretical knowledge and clinical application. The heavy weighting of practical assessment aligns student effort with demonstrable skill acquisition in anatomical identification, image interpretation, and procedural ultrasound competency.

Conclusion: The model demonstrates that high-fidelity, clinically relevant anatomy education is achievable in resource-constrained settings through the strategic integration of traditional and digital tools. It offers a sustainable template for training imaging professionals in SSA, directly enhancing graduate readiness for clinical practice. Future research must evaluate its long-term impact on diagnostic accuracy, patient outcomes, and its applicability to other allied health disciplines.

Keywords: Anatomy education; Competency-based medical education; Medical imaging; Radiography; Sonography; Sub-saharan africa; Resource-limited; Multimodal learning; Ultrasound; Virtual dissection; Ernest cook university

INTRODUCTION

Anatomy forms the cornerstone of clinical reasoning in diagnostic medical imaging, where the interpretation of two-dimensional shadows and sonographic echoes necessitates a profound, three-dimensional understanding of human structure

[1]. Effective practice requires more than factual recall; it demands advanced spatial reasoning, the ability to mentally rotate structures, and correlate cross-sectional anatomy with dynamic, real-time imaging [2,3]. Globally, anatomy education is undergoing a significant transformation, driven by technological advancements, pedagogical shifts towards active learning, and the widespread adoption of Competency-Based Medical Education (CBME), which prioritizes observable, measurable outcomes over time-based progression [4,5].

However, this evolution is markedly uneven. In many high-income countries, curricula are increasingly enriched with sophisticated digital tools, simulation, and early clinical immersion [6,7]. In contrast, institutions across sub-Saharan Africa frequently grapple with profound challenges that impede educational modernization: chronic shortages of cadavers, limited access to digital infrastructure, high student-to-faculty ratios, and curricula overburdened with theory at the expense of practice [8,9]. For non-physician imaging professionals such as radiographers and sonographers who constitute the backbone of diagnostic services in the region this gap is particularly critical. Their education must fuse deep anatomical knowledge with precise technical skill, preparing them for autonomous decision-making in often high-volume, poorly resourced clinical environments [10].

While the literature extensively documents innovative anatomy teaching tools and CBME frameworks, there is a paucity of models demonstrating their effective, contextualized integration within the unique constraints of SSA's health professions education [11,12]. Most reports focus on singular interventions (e.g., standalone ultrasound or virtual reality) rather than coherent, multimodal curricula designed for systemic implementation. This paper addresses this gap by presenting a detailed conceptual model of an integrated, competency-based anatomy curriculum for imaging students at Ernest Cook University (ECU) in Kampala, Uganda. We describe its design principles, multimodal structure, and assessment strategy, arguing that it represents a viable, scalable blueprint for enhancing imaging education in resource-constrained settings across the region.

METHODS

Study setting and institutional context

This curriculum model is operationalized within the Bachelor of Medical Radiography, Bachelor in Diagnostic Ultrasound and Diploma in Medical Radiography programmes at Ernest Cook University (ECU), Kampala, Uganda. ECU is a nationally recognized leader in imaging education, producing both undergraduates and postgraduates who serve within Uganda, across Sub-saharan Africa and internaltionally to other parts of the world. The programmes are explicitly designed to align with the human resource priorities of the Ugandan Ministry of Health, focusing on generating clinically competent, practice-ready radiologists and imaging technologists.

Curriculum design and pedagogical framework

The anatomy curriculum is structured on foundational educational principles. It adopts a spiral curriculum approach, where key anatomical concepts are revisited at increasing levels of complexity and clinical integration throughout the programme [13]. Instructional design is informed by cognitive load theory, sequencing activities from simple (concrete models) to complex (live scanning) to optimize working memory and schema construction [14]. The overarching framework is CBME, ensuring all learning objectives and assessments are mapped to the essential competencies required for entry-level imaging practice [4].

The multimodal learning environment

Teaching occurs in a purpose-designed anatomy complex comprising four integrated zones:

a. Physical model section: Housing prosected specimens, osteological models, and plastic organ systems for repetitive, tactile learning (Figure 1).

b. Virtual anatomy section: Centered on an anatomage table, enabling 3D visualization, virtual dissection, and the correlation of anatomy with imported CT and MRI datasets (Figure 2).

c. Ultrasound skills laboratory: Equipped with multiple ultrasound machines for students to practice scanning on peer models, translating anatomical knowledge into real-time sonographic image acquisition and interpretation (Figure 3).

d. Cadaveric dissection section: For hands-on exploration of real tissue planes, anatomical variation, and depth relationships (Figure 4).

Organization of Integrated Learning Sessions

Following a one-hour physical lecture, student cohorts (divided into groups of ~10) rotate through scheduled practical sessions. Each session is objective-driven and the objectives are gotten from the physical lecture, requiring students to investigate the same anatomical region using all four modalities. For example, when studying the hepatobiliary system, students would: identify structures on plastic models, dissect and explore relationships in a cadaveric specimen, perform a virtual dissection and correlate with CT anatomy on the Anatomage table, and finally, identify the liver, gallbladder, and portal vasculature using live ultrasound on a peer. Faculty an interdisciplinary team of anatomists, practising radiologists and radiographers, and sonographers supervise each station, providing immediate feedback and reinforcing clinical relevance.

Competency-driven assessment strategy

Assessment is blueprint-aligned and heavily weighted towards practical skill demonstration [15]. Each module concludes with a formative, multi-station Objective Structured Practical Examination (OSPE) contributing 40% to the module mark. The summative end-of-semester examination comprises a 30% theoretical component and a 30% comprehensive practical OSPE. Consequently, 70% of the final course grade is derived from practical assessments. The OSPE "steeplechase" format requires students to sequentially perform tasks such as identifying a structure on a cadaver and or plastic model, then interprete its appearance on a provided radiograph or CT slice, ultrasound image and/or demonstrating its location with an ultrasound probe under timed conditions.

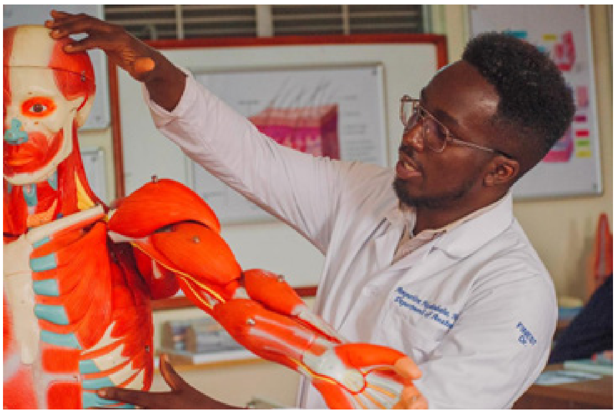

Figure 1: Showing one of the anatomy lecturers in a skills lab practical session demonstrating structures on a plastic model to students. In the background, visual aids and learning charts of anatomy can been seen as well.

Figure 2: Showing one of the anatomy lecturers teaching anatomy using a virtual anatomage table. On the table screen you can appreciate one the various modules the table uses correlating visual models, then cadaver appearance and CT at the same time.

Figure 3: Showing students in a self-directed learning session in the ultrasound skills lab.

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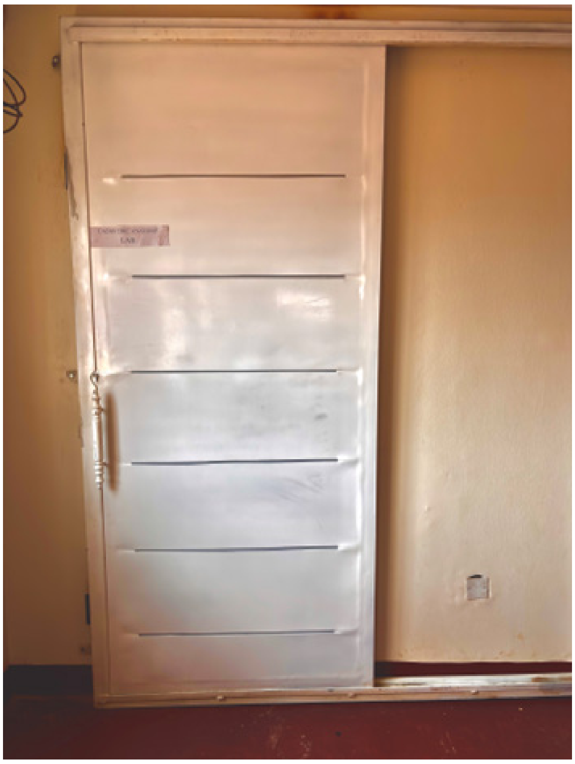

Figure 4: Showing the entrance to the caderveric dissecting room.

DISCUSSION

The ECU curriculum model represents a deliberate and structured response to the dual imperative of modernizing anatomy education and addressing region-specific resource constraints. By integrating four complementary learning modalities within a CBME framework, it fosters a robust, clinically-relevant anatomical understanding essential for imaging professionals.

Advantages of this model over traditional learning and textbooks

This integrated approach offers several distinct advantages over traditional, textbook-centric models:

a. Development of robust visuospatial skills: The repeated, multi-platform engagement with anatomical structures from handling a physical model to manipulating a 3D virtual model to locating it in a living body forces cognitive integration that is impossible from textbooks alone. This is crucial for building the mental "library" of cross-sectional anatomy required for interpreting diagnostic images [3,16].

b. Early and authentic clinical correlation: Embedding live ultrasound training within the core anatomy curriculum breaks down the traditional preclinical-clinical barrier. Students learn anatomy not as an abstract science but as a living, dynamic system they can visualize in real-time, directly mirroring their future professional tasks [7,17].

c. Enhanced learner engagement and depth of processing: The active, hands-on, and varied nature of the sessions caters to diverse learning styles and promotes deeper cognitive processing compared to passive lecture attendance [18]. The immediate application of lecture content in the lab reinforces learning and motivates students.

d. Efficient use of limited resources: While cadaveric material remains invaluable but scarce, its educational impact is multiplied when used in concert with other tools. A single cadaveric dissection is enhanced by pre-training with models and virtual reality, allowing more focused, efficient use of precious specimens. Digital tools provide unlimited opportunities for repetition without consumable costs.

Limitations of this learning model

Despite its strengths, the model faces inherent challenges:

a. High initial and sustained costs: Although more scalable than a pure cadaver-based programme, the acquisition and maintenance of an Anatomage table and ultrasound machines represent a significant investment for institutions in SSA. Sustaining hardware, software updates, and equipment repairs is an ongoing challenge.

b. Faculty development demands: Successful implementation requires faculty who are not only experts in anatomy but also proficient in digital technology and ultrasound. Continuous professional development is essential, adding to institutional workload and cost [19].

c. Scalability and time tabling: The small-group, rotation-based model is resource-intensive in terms of faculty time and physical space. Scaling this to larger student cohorts without compromising the quality of hands-on interaction presents a logistical challenge.

d. Dependence on stable infrastructure: The digital components are vulnerable to power outages and unreliable internet connectivity, common issues in many SSA settings, which can disrupt planned teaching sessions.

AREAS OF FUTURE RESEARCH

This conceptual model opens several avenues for empirical investigation:

a. Outcomes-based research: Longitudinal studies tracking graduates from this curriculum against those from traditional programmes are needed. Key metrics include clinical supervisor ratings, objective structured clinical examination (OSCE) performance, diagnostic error rates, and job readiness confidence surveys.

b. Comparative efficacy of modalities: Research could dissect the relative contribution of each modality (cadaver, model, virtual, ultrasound) to specific learning outcomes. This would help optimize resource allocation, determining the most effective combinations for different anatomical regions or competencies.

c. Cost-effectiveness and sustainability analysis: A detailed analysis of the total cost of ownership, operational costs, and educational return on investment compared to traditional methods is crucial for informing policy and adoption by other resource-constrained institutions.

d. Adaptation and implementation science: Research should explore the adaptability of this model to other allied health disciplines (e.g., physiotherapy, surgery) and in different institutional contexts within SSA, identifying critical success factors and common barriers to implementation.

CONCLUSION

The integrated, competency-based anatomy curriculum at Ernest Cook University provides a replicable model for transforming imaging education in sub-Saharan Africa. It demonstrates that strategic, context-sensitive integration of traditional and technological tools can overcome resource limitations to deliver high-quality, clinically focused education. By anchoring assessment in practical competence, the model ensures graduates are not merely knowledgeable but are proficient in the essential skills required for modern diagnostic practice. While challenges of cost and sustainability remain, this approach offers a promising pathway to closing the gap between anatomical science and clinical imaging practice, ultimately contributing to stronger healthcare systems through better-trained professionals. Its continued evaluation and refinement are imperative.

DECLARATIONS

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Conflict of interests.

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Data Availability Statement

The data that supports the findings of this manuscript are available from the corresponding author upon reasonable request.

Ethics approval

Informed consent was obtained from the department for this publication.

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