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Framing a future-ready Radiography curriculum – A scoping review

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ABSTRACT

Radiography education is faced with increasing clinical, technological, and regulatory demands; therefore, this scoping review synthesises evidence to identify essential categories and themes for modernising radiography education. The education focuses on adapting to new clinical practices and integrating innovative teaching modalities to prepare graduates for future healthcare environments. A qualitative scoping review was conducted via searches in PubMed, Google Scholar, and ScienceDirect. A generative artificial intelligence (AI) tool supported dual-reviewer screening and full-text analysis. Data on curriculum elements were extracted and synthesised inductively, resulting in a framework of six core domains. The synthesis produced a framework of six interdependent domains: pedagogical innovation, technological integration, curriculum content and structure, clinical education and practice, professionalism and ethics, and strategic alignment. A key finding is the interconnected nature of the domains: Technological integration requires pedagogical innovation, and AI-driven healthcare demands renewed ethical focus. The framework that was identified offers an evidence-based structure for developing technically competent, adaptable, and ethically prepared radiographers. This study provides a unified, evidence-informed framework for radiography curriculum renewal. Key recommendations advocate for a shift in curriculum design, centring on the integration of technology, the adoption of adaptable modular programmes, and the embedding of 'ethics by design' principles. The study advances curricular theory by emphasising integration over additive skills and identifies critical research gaps, particularly, context-specific implementation in Africa and longitudinal studies on graduate outcomes.

Keywords: Future-ready radiography curriculum, Radiography curriculum framework, Pedagogical innovation, Technological integration, Curriculum design

INTRODUCTION

Radiography is a technologically driven, patient-centred health profession that is positioned at the intersection of imaging science, radiation safety, and clinical decision-making. It is a dynamic healthcare profession that blends advanced imaging technology with patient-centred care and requires practitioners to adapt to technological change, evolving clinical practices, and increasing patient complexity. Over the past two decades, rapid advances in technology, such as artificial intelligence (AI), advanced image processing, and digital workflow integration, have transformed both diagnostic

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and therapeutic radiography and have influenced clinical roles and competencies.[1] These shifts have not only enhanced diagnostic precision and efficiency but have also redefined the skillsets required of radiographers. In response, educators, professional bodies, and health services are re-examining what a 'future-ready' radiography curriculum should include and how to deliver it.

Globally and within South Africa, the radiography profession faces increasing demands. These demands include sustaining high reporting quality across professional roles,[2] adapting curricula to novel clinical models and evolving regulatory frameworks,[3] and embedding innovative teaching modalities such as simulation and blended learning, the adoption of which was accelerated by the COVID-19 pandemic. Competencies, defined as the behaviours, technical skills, and professional attributes that underpin effective job performance,[4] are, therefore, central to curriculum design. However, these competencies require continual review and alignment with technological, clinical and societal developments to ensure ongoing relevance.

Emerging computational capabilities are also reshaping the radiographer's role. Competence in programming, data analytics, machine learning, and digital image processing now enables the development of advanced imaging algorithms, optimisation of imaging protocols, and enhancement of diagnostic workflows in radiography.[5] Alongside such technological fluency, sustainability is increasingly recognised as a professional imperative. Embedding education for sustainable development within curricula equips graduates to practice in an environmentally responsible manner while addressing resource limitations across diverse healthcare contexts.[6]

For the purposes of this review, a future-ready radiography curriculum refers to an educational programme that integrates advanced technologies, sustainability principles, interdisciplinary collaboration, and lifelong learning strategies to prepare graduates for rapidly evolving healthcare environments. The programme must develop graduates who can safely and flexibly apply evolving technologies, engage with evidence and research, work across multidisciplinary teams, and contribute to sustainable healthcare. The literature highlights important gaps: variation in scope and depth of technology training across programmes, inconsistent inclusion of research and evidence-based practice, and uneven preparation for digital-first workflows and AI-enabled tools.[7] At the same time, practice trends, such as expanded radiographer reporting, image-guided therapy and growing expectations for clinical autonomy in some jurisdictions, demand broader capabilities that range from critical thinking and quality assurance to data literacy and the ethical use of patient data.[8] These converging drivers justify a structured mapping of the education landscape to identify what has been tried, what works, and where gaps remain.

Scoping reviews are particularly valuable for clarifying key concepts and definitions in the literature, identifying characteristics or factors related to a topic, and highlighting gaps in evidence. They can serve as precursors to systematic reviews and address broader research questions that extend beyond the precise, targeted focus of systematic reviews.[9] This review was guided by the question,

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1 C. Malamateniou et al., "Artificial Intelligence in Radiography: Where Are We Now and What Does the Future Hold?," *Radiography* 27 (October 2021): S58–62, https://doi.org/10.1016/j.radi.2021.07.015.

2 Maryann Hardy, "Radiography: Looking to the next Decade," *Imaging and Oncology*, 2010, 28–33.

3 J.P. McNulty, A. England, and M.C. Shanahan, "International Perspectives on Radiography Practice Education," *Radiography* 27, no. 4 (November 2021): 1044–51, https://doi.org/10.1016/j.radi.2021.04.004.

4 M.A. Mallinson, M. Hardy, and A.J. Scally, "Developing CT Workforce Competencies: What Knowledge and Skills Should We Expect of an Early Career Radiographer?," *Radiography* 30, no. 5 (August 2024): 1355–62, https://doi.org/10.1016/j.radi.2024.07.010.

5 Sibusiso Mdletshe and Alan Wang, "Enhancing Medical Imaging Education: Integrating Computing Technologies, Digital Image Processing and Artificial Intelligence," *Journal of Medical Radiation Sciences* 72, no. 1 (March 7, 2025): 148–55, https://doi.org/10.1002/jmrs.837.

6 T.N. Akudjedu, R. Toomey, and H. Precht, "Sustainability in Radiography: Securing the Future through Greener Clinical Practice and Education," *Radiography* 30 (June 2024): 117–18, https://doi.org/10.1016/j.radi.2024.08.013; A. Ramlaul and R. Khine, "'HOW TO' ……. Incorporating Education for Sustainable Development within a Radiography Curriculum: A Narrative Review," *Radiography* 30 (June 2024): 102–7, https://doi.org/10.1016/j.radi.2024.07.018.

7 J.G. Couto et al., "Competency Level in Radiotherapy across EU Educational Programmes: A Cross-Case Study Evaluating Stakeholders' Perceptions," *Radiography* 28, no. 1 (February 2022): 180–86, https://doi.org/10.1016/j.radi.2021.10.015.

8 Couto et al., "Competency Level in Radiotherapy across EU Educational Programmes: A Cross-Case Study Evaluating Stakeholders' Perceptions."

9 Danielle Pollock et al., "Recommendations for the Extraction, Analysis, and Presentation of Results in Scoping Reviews," *JBI Evidence Synthesis* 21, no. 3 (March 2023): 520–32, https://doi.org/10.11124/JBIES-22-00123.

What categories and themes can be incorporated into a framework for modernising radiography education programmes to meet future demands? and sought to generate an evidence-informed framework for curriculum developers tasked with preparing radiography graduates for the future. A scoping review is well-suited for this topic, for three reasons. First, the question is broad and exploratory: it seeks to map the categories and themes relevant to modernising radiography education, rather than to test a narrowly framed effectiveness hypothesis.[10] Second, the relevant literature is likely to be diverse and include empirical studies, curriculum descriptions, competency frameworks, consensus documents, professional position statements, and the grey literature of professional societies and regulators. Scoping review methodology enables systematic identification, selection, and charting of such varied sources. Third, scoping reviews are appropriate if the aim is to synthesise evidence to inform policy and curriculum development by identifying gaps and priorities for research and practice; that is precisely the intended outcome of this work.Guided by the overarching question, the intention of this scoping review was:

1. To map and synthesise the existing peer-reviewed literature on curriculum elements that contribute to preparing radiography graduates for future healthcare contexts;
2. To identify and categorise the domains and themes that characterise a future-ready radiography curriculum, as described in studies done in South Africa and other countries;
3. To clarify how competencies, pedagogical approaches, clinical education practices, professionalism, ethics, and system-level strategies are represented within the literature; and
4. To highlight gaps and opportunities for further curriculum development to ensure that radiography education remains aligned with technological, clinical, and societal shifts.

GUIDING THEORIES FOR CURRICULUM TRANSFORMATION

To guide this scoping review and inform curriculum development, a composite theoretical framework was adopted, integrating competency-based education (CBE), transformative learning theory, and sociotechnical systems theory. This triadic model provides a robust conceptual foundation for understanding how radiography curricula can be modernised to meet future healthcare demands.

Competency-Based Education

CBE offers a structural foundation for aligning educational outcomes with the evolving roles and responsibilities of radiographers. It emphasises demonstrable learning outcomes, workplace relevance, and flexible progression based on mastery rather than time.[11] In the context of radiography, CBE supports the systematic inclusion of competencies such as AI literacy, sustainability, and interdisciplinary collaboration. It also enables curriculum designers to map educational content to real-world performance expectations, ensuring that graduates are equipped to navigate complex clinical environments.

Transformative Learning Theory

Transformative Learning Theory, developed by Mezirow, provides a pedagogical lens through which to foster critical thinking, ethical reasoning, and professional identity formation.[12] It emphasises the importance of critical reflection, perspective transformation, and dialogic engagement, key processes for preparing radiographers to adapt to technological change, engage with ethical dilemmas, and contribute to sustainable healthcare. This theory is particularly relevant for embedding values-based competencies such as digital professionalism, environmental stewardship, and patient-centered care into the curriculum.[13]

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[10] Pollock et al., 'Recommendations for the Extraction, Analysis, and Presentation of Results in Scoping Reviews'.
[11] Jason R. Frank et al., "Competency-Based Medical Education: Theory to Practice," *Medical Teacher* 32, no. 8 (August 27, 2010): 638–45, https://doi.org/10.3109/0142159X.2010.501190.
[12] Jack Mezirow, *Transformative Dimensions of Adult Learning*, vol. 350 (Jossey-bass San Francisco, CA, 1991).
[13] Edward W Taylor and Patricia Cranton, *The Handbook of Transformative Learning: Theory, Research, and Practice* (John Wiley & Sons, 2012).

Sociotechnical Systems Theory

Sociotechnical Systems Theory offers a systems-level perspective that recognises the interdependence between human actors, technologies, and organisational structures.[14] It is especially pertinent in radiography, where digital workflows, AI-enabled tools, and resource constraints shape both practice and education. This theory supports the design of curricula that prepare graduates to function effectively within complex healthcare ecosystems, balancing technical proficiency with human-centred care and systemic awareness. It also reinforces the need for curricula to be contextually responsive – adapting to both global innovations and local healthcare realities.

Integrative Application

Together, these three theories provide a comprehensive framework for analysing and synthesising the literature on future-ready radiography education. CBE structures the identification of core competencies; Transformative Learning Theory informs pedagogical strategies; and Sociotechnical Systems Theory contextualises curriculum within broader healthcare systems. This integrated approach ensures that the review is grounded in educational theory while remaining responsive to the technological, ethical, and systemic challenges facing the profession.

METHODOLOGY

Search Strategy

A qualitative scoping review was conducted to inform the development of a future-ready radiography curriculum framework based on PRISMA-ScR (Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews).[15] The objective was to identify, synthesise, and integrate literature on curriculum elements that prepare radiography graduates for evolving healthcare contexts. Searches were performed in PubMed, Google Scholar, and ScienceDirect, which were selected for their coverage of peer-reviewed medical and scientific literature. Search terms combined keywords and controlled vocabulary related to radiography, curriculum design, and future readiness, including *radiography curriculum design, future-ready radiography education, modern radiography curriculum,* and *modern radiography training.*

Screening and Selection

Screening was conducted in two phases. In the initial phase, a generative AI-powered PDF reader processed the full texts in response to a prompt 'Identify strategies, concepts, or ideas proposed by the authors to enhance radiography curricula for the future'. Subsequently, two reviewers independently evaluated these AI outputs for the presence of relevant curriculum elements. The reviewers then verified the accuracy of the AI's extraction against the source. Any disagreements regarding the inclusion of a source were resolved through discussion until a consensus was reached on the final selection of literature, ensuring it conformed to the predefined inclusion and exclusion criteria. Duplicates were also removed at this stage.

The inclusion criteria encompassed a wide range of peer-reviewed literature that identified or recommended content for modern radiography curricula. This included experimental, observational, and descriptive study designs (e.g., curriculum interventions, cohort studies, case series), as well as literature reviews, consensus statements, and framework proposals relevant to preparing graduates for future practice. Studies were excluded if they did not directly address radiography curriculum competencies or content, or if they focused solely on clinical practice without educational implications. Research exclusive to other healthcare professions, non-peer-reviewed materials, grey literature, and publications not in English were also excluded. To ensure contemporary relevance, articles published prior to 2015 were excluded unless they provided foundational insights directly pertinent to a future-

[14] Chris W Clegg, "Sociotechnical Principles for System Design," *Applied Ergonomics* 31, no. 5 (October 2000): 463–77, https://doi.org/10.1016/S0003-6870(00)00009-0; E. L. Trist and K. W. Bamforth, "Some Social and Psychological Consequences of the Longwall Method of Coal-Getting," *Human Relations* 4, no. 1 (February 1, 1951): 3–38, https://doi.org/10.1177/001872675100400101.

[15] Pollock et al., 'Recommendations for the Extraction, Analysis, and Presentation of Results in Scoping Reviews'.

ready framework. The PRISMA-ScR flow diagram (Figure 1) illustrates the screening and selection process.[16]

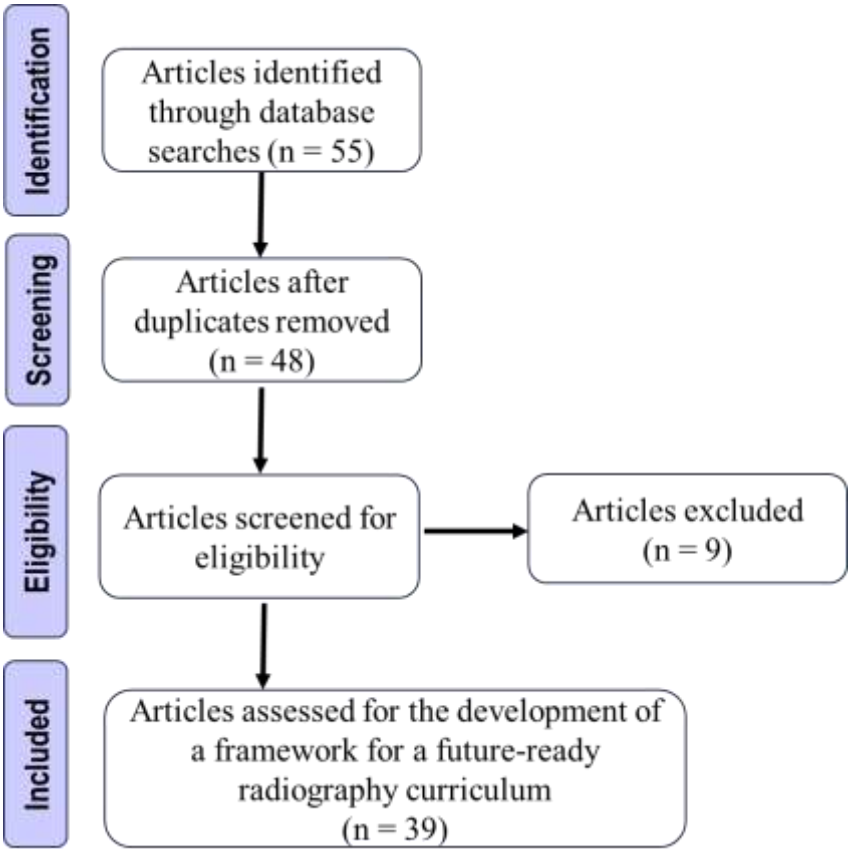

Figure 1: The PRISMA-ScR Flow Diagram

Data Extraction and Synthesis

Data extraction involved identifying curriculum elements, pedagogical approaches, and competency-related strategies. An inductive thematic synthesis was undertaken in three stages: 1) Coding extracted curriculum aspects; 2) Grouping related codes into recurring themes; and 3) Organising themes into six overarching domains: *pedagogical innovation, technological integration, curriculum content and structure, clinical education and practice, professionalism and ethics,* and *strategic and system-level alignment.* Each theme was supported by at least one source. The final framework synthesised current evidence to provide a structured guide for curriculum development, evaluation, and alignment with emerging professional and societal needs in radiography education.

PRESENTATION OF FINDINGS

The analysis of the selected literature revealed a range of interconnected themes that collectively define what constitutes a future-ready curriculum for radiography. The synthesis of the radiography literature revealed six core domains essential for designing a future-ready curriculum; each domain encompasses interrelated themes that collectively address the evolving demands of the profession (Table 1). Each of these domains – *pedagogical innovation, technological integration, curriculum content and structure, clinical education and practice, professionalism and ethics,* and *strategic and system-level alignment* – contains multiple mutually reinforcing themes that, together, form a comprehensive educational framework for preparing graduates for the demands of contemporary and emerging healthcare landscapes.

[16] Andrea C. Tricco et al., "PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation," *Annals of Internal Medicine* 169, no. 7 (October 2, 2018): 467–73, https://doi.org/10.7326/M18-0850.

Table 1: Radiography Curriculum Framework for Preparing Graduates to Meet the Demands of Modern Radiography Practice

Domain	Theme	Description	Sources
1. Pedagogical innovation	Simulation-based learning	Embedded virtual reality, augmented reality, screen-based, and role-play simulations as core tools linked to outcomes and assessments, to bridge theory and practice	Hayre & Kilgour; Kumsa et al.; Ohagwu et al.; Susiku et al.; Shafuda et al. ; Tay & McNulty; Tootell et al.
	Problem-based learning	Student-centred, real-world scenario learning that fosters autonomy, critical thinking, and collaboration.	Couto et al.; Lawal et al.; Ohagwu et al.; Pieterse et al.; Ramlaul & Khine
	Active and reflective learning	Emphasis on critical thinking, reflection, and inquiry-based strategies to deepen understanding	Bafaraj & Elkhadir; dos Reis et al.; England & McNulty; Hedges et al.Kumsa et al.; McNulty et al.
	Flexible and modular curriculum	Elective tracks, blended learning, and modular structures to support personalisation and adaptability	Akudjedu et al.; Bafaraj & Elkhadir; dos Reis et al.; England & McNulty; Kumsa et al.; Ohagwu et al.; Shafuda et al.
	Authentic assessment	Use of real-world tasks, simulation-based evaluations, and structured rubrics	Couto et al.; Crotty et al.; Kumsa et al.; Mdletshe & Wang; Pieterse et al.
2. Technology integration	AI and machine learning	Exposure to AI applications in radiography, including automated image analysis, workflow optimisation, and decision-support systems, fosters critical evaluation and ethical use of AI tools	Ago et al.; Couto et al.; Crotty et al.; Kumsa et al.; Malamateniou et al.; Mdletshe & Wang; Wuni et al.
	Virtual and augmented reality	Use of immersive simulation environments to replicate clinical scenarios, enhancing spatial understanding, procedural skills, and safe practice without patient risk	Akudjedu et al.; Hayre & Kilgour; Tay & McNulty; Tootell et al.
	E-learning and blended learning	Adoption of online platforms, digital resources, and hybrid teaching models to increase accessibility, flexibility, and self-directed learning opportunities for students	Cooke et al.; Ohagwu et al.; Shafuda et al. Shah et al.
	Data management and analytics	Development of skills in handling, storing, analysing, and securing medical imaging data, including familiarity with data governance, privacy regulations, and clinical informatics	Barbosa et al.; Crotty et al.; Mdletshe & Wang; Ramlaul & Khine; Umar et al.

Domain	Theme	Description	Sources
			Wuni et al.,
	Equipment familiarity and upgrades	Ensuring students are trained on or exposed to up-to-date radiography equipment and emerging technologies to maintain readiness for contemporary clinical environments	Ago et al. ; Chaka & Hardy ; Klontzas & Karantanas; Mallinson et al. ; Shafuda et al.; Wuni et al.
3. Curriculum content and structure	Interprofessional education	Structured learning experiences in which radiography students collaborate with learners from other health disciplines to develop teamwork, communication, and patient-centred care skills	Barbosa et al.; Couto et al.; Cox et al.; dos Reis et al.; Friel et al.; Govindasami & Singh; McNulty et al. ; Ramlaul & Khine ; Shafuda et al.; Tootell et al.
	Research and evidence-based practice	Development of skills to locate, appraise, and apply scientific evidence in clinical decision-making, fostering critical thinking and a culture of inquiry	Ago et al.; Akudjedu et al.; Barbosa et al.; Chaka & Hardy; Couto et al.; Cooke et al.; Di Michele et al.; England & McNulty ; Friel et al. ; Kumsa et al.; McNulty et al.; Pieterse et al.; Susiku et al.; Wuni et al.
	Ethics and professionalism	Education on ethical standards, professional conduct, and legal responsibilities to ensure safe, respectful, and accountable radiographic practice	Cooke et al.; Govindasami & Singh; Malamateniou et al.; Shafuda et al. Wuni et al.
	Lifelong learning and professional development	Encouragement of continuous skill enhancement and adaptability through ongoing education, reflective practice, and engagement with professional growth opportunities	Barbosa et al.; Chau et al.; Couto et al. ; Cooke et al.; England & McNulty; Friel et al.; Tootell et al.
	Sustainable and socially responsible practice	Integration of environmental sustainability, social accountability, and equitable healthcare principles into radiographic practice and decision-making	Akudjedu et al.; Chau et al.; Ramlaul & Khine.
4. Clinical education and practice	Structured clinical placements	Planned, progressive clinical exposure that aligns with academic learning outcomes. Includes supervised practice, defined learning	Cooke et al.; Friel et al.; Govindasami & Singh; Hayre & Kilgour; McNulty et al.

Domain	Theme	Description	Sources
		objectives, and assessment mechanisms to ensure competency development	Ofori-Manteaw et al.
	Preceptorship and tutor training	Preparation and ongoing development of clinical educators (preceptors, tutors) to effectively guide students in the workplace. Includes training in feedback provision, role modelling, and facilitation of reflective learning	Chaka & Hardy; Lawal et al.; Mallinson et al.; Ofori-Manteaw et al.; Ohagwu et al. Scaramelli et al.
	Integration of workplace learning	Intentional integration of academic knowledge with workplace practice through clinical placements, simulation-based learning, and reflective activities. Aims to bridge the gap between theory and practice for enhanced readiness	Cox et al.; Ofori-Manteaw et al.; Wuni et al.
5. Professionalism and ethics	Ethical and legal understanding	Ability to interpret and apply ethics principles, legal requirements, and professional codes of conduct in radiography practice. Includes knowledge of patient rights, consent, confidentiality, and regulatory compliance	Akudjedu et al.; Couto et al.; Kumsa et al.; McNulty et al.; Ofori-Manteaw et al.
	Professional conduct and accountability	Demonstrating appropriate professional behaviour, integrity, responsibility, and reflective practice in clinical and academic contexts. Encompasses maintaining professional boundaries, effective communication, and commitment to continual improvement	Cox et al.; Malamateniou et al.; McNulty et al.; Ramlaul & Khine.
	Cultural competence and inclusivity	Delivering equitable, respectful, and patient-centred care to individuals from diverse cultural, linguistic, and social backgrounds. Involves recognising and addressing health disparities and bias	Couto et al.; Cooke et al.; Govindasami & Singh; Kumsa et al.; Lawal et al.
	Reflective practice and self-awareness	Engaging in ongoing self-assessment, critical reflection, and feedback-seeking to improve professional competence and patient care. Includes recognising personal strengths, weaknesses, and biases	McNulty et al.; Pieterse et al.; Scaramelli et al.; Shafuda et al.
6. Strategic and system-level alignment	Alignment with national and international standards	Ensuring the curriculum meets recognised global and national benchmarks, accreditation requirements, and professional guidelines to maintain quality and comparability in radiography education	Ago et al.; Bafaraj & Elkhadir; Couto et al.; dos Reis et al.; Friel et al.; McNulty et al.

Domain	Theme	Description	Sources
	Collaboration and partnerships	Fostering strategic collaboration between academic institutions, clinical partners, industry, and professional bodies to support curriculum relevance and graduate employability	Chau et al.; dos Reis et al.; McNulty et al.
	Policy and regulatory compliance	Ensuring that curricula adhere to healthcare, education, and professional regulations, as well as legal frameworks that govern radiography practice	Mallinson et al.; Ofori-Manteaw et al.; Ramlaul & Khine.
	Sustainable workforce planning	Linking curriculum design to long-term healthcare system needs, workforce supply-demand trends, and evolving radiography roles to ensure future service readiness.	Akudjedu et al.; Mallinson et al.; McNulty et al.

Note. AI = artificial intelligence

Together, the six domains form a cohesive framework that balances technological advancements, pedagogical rigour, clinical preparedness, and ethical grounding and would equip radiography graduates to thrive in dynamic healthcare environments. The integration of these themes addresses current gaps while anticipating future challenges and positions radiography education as a proactive force for shaping the trajectory of the profession. The robustness and interdependence of these domains suggest that this framework could serve as a foundational model for future accreditation benchmarks, to ensure that radiography programmes worldwide meet a consistent, high standard of education quality and graduate preparedness.

Pedagogical innovation was constructed as a foundational domain in future-ready radiography curricula, with five interrelated themes shaping contemporary educational strategies. Simulation-based learning was widely endorsed; it integrates virtual reality, augmented reality, and screen-based and role-play modalities to bridge theory and practice while aligning with learning outcomes and assessments.[17] Problem-based learning featured prominently as a student-centred approach that promotes autonomy, collaboration, and critical thinking through real-world scenarios.[18] Active and reflective learning strategies were emphasised to deepen understanding via inquiry, reflection, and critical engagement.[19]A flexible and modular curriculum structure that incorporates electives, blended learning, and adaptable modules was identified as key to personalisation and responsiveness to diverse learner needs.[20] Finally, authentic assessment practices, including real-world tasks and simulation-based evaluations supported by structured rubrics, were advocated for to ensure meaningful competency evaluation.[21]

Technology integration was constructed as a transformative domain for shaping a future-ready radiography curriculum; this reflects the profession's rapid digital transformation. Exposure to *AI and machine learning* was consistently highlighted, with emphasis on automated image analysis, workflow optimisation, and ethical decision-support systems.[22] The use of *virtual and augmented reality* was strongly endorsed by several studies; this enables immersive simulation of clinical scenarios that enhance spatial reasoning, procedural competence, and safe practice.[23] *E-learning and blended learning* approaches were widely adopted, offering flexible, accessible, and self-directed learning environments through digital platforms and hybrid models.[24] Finally, *data management and analytics* emerged as a critical theme, with curricula increasingly incorporating skills in handling, securing and interpreting medical imaging data within frameworks of clinical informatics and data governance.[25]

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[17] Susiku, Hewitt–Taylor, and Akudjedu, "Graduate Competencies, Employability and the Transnational Radiography Workforce Shortage: A Systematic Literature Review of Current Pre-Registration Radiography Education and Training Models."

[18] Couto et al., "Competency Level in Radiotherapy across EU Educational Programmes: A Cross-Case Study Evaluating Stakeholders' Perceptions"; Ramlaul and Khine, "'HOW TO' ……. Incorporating Education for Sustainable Development within a Radiography Curriculum: A Narrative Review."

[19] Bafaraj and Elkhadir, "Evaluation of Diagnostic Radiography Technology Curriculum from the Graduates Perspective"; Kumsa et al., "Clinical Placement Challenges Associated with Radiography Education in a Low-Resource Setting: A Qualitative Exploration of the Ethiopian Landscape."

[20] Akudjedu, Toomey, and Precht, "Sustainability in Radiography: Securing the Future through Greener Clinical Practice and Education."

[21] Crotty et al., "Artificial Intelligence in Medical Imaging Education: Recommendations for Undergraduate Curriculum Development."

[22] Jacob Leonard Ago et al., "Insights into Radiography Education in Ghana: Document Analysis of Curricula Contents and Perspectives of Selected Stakeholders," January 13, 2025, https://doi.org/10.21203/rs.3.rs-5759313/v1; Kumsa et al., "Clinical Placement Challenges Associated with Radiography Education in a Low-Resource Setting: A Qualitative Exploration of the Ethiopian Landscape"; Mdletshe and Wang, "Enhancing Medical Imaging Education: Integrating Computing Technologies, Digital Image Processing and Artificial Intelligence."

[23] Akudjedu, Toomey, and Precht, "Sustainability in Radiography: Securing the Future through Greener Clinical Practice and Education"; Tay and McNulty, "Radiography Education in 2022 and beyond - Writing the History of the Present: A Narrative Review."

[24] Cooke et al., "Radiographer Educational Requirements for Adaptive Radiotherapy Techniques: A Mixed-Methods Regional Scoping Study."

[25] Crotty et al., "Artificial Intelligence in Medical Imaging Education: Recommendations for Undergraduate Curriculum Development"; Ramlaul and Khine, "'HOW TO' ……. Incorporating Education for Sustainable Development within a Radiography Curriculum: A Narrative Review"; Umar, Ibrahim, and Joseph, "Integration of Virtual Radiography Simulation Software into Radiography Education: Assessing Educators' Proficiency and Students' Satisfaction."

In addition, familiarity with equipment and regular upgrades were highlighted as essential for maintaining clinical relevance, with curricula increasingly ensuring that students train on or are exposed to contemporary radiography technologies and emerging modalities to support workplace readiness and adaptability.[26]

Curriculum content and structure were identified as a critical domain in shaping a future-ready radiography curriculum; it encompasses five key themes. *Interprofessional education* features prominently and involves promoting collaborative learning across health disciplines to enhance teamwork, communication, and patient-centred care.[27] The integration of *research and evidence-based practice* was widely supported to foster critical thinking and clinical decision-making through the appraisal and application of scientific evidence.[28] *Ethics and professionalism* emerged as a foundational theme, with curricula embedding legal, ethical, and professional standards to ensure safe and accountable practice.[29] The importance of *lifelong learning and professional development* was consistently emphasised as encouraging adaptability and continuous growth through reflective practice and engagement with evolving professional roles.[30] Finally, *sustainable and socially responsible practices* were increasingly integrated, thereby aligning radiographic education with environmental stewardship, social accountability, and equitable healthcare delivery.

Clinical education and practice were consistently identified as a cornerstone of future-ready radiography curricula, with three interrelated themes shaping their evolution. *Structured clinical placements* were widely endorsed and planned, progressive exposure was aligned with academic outcomes, and supported by supervision, defined learning objectives, and competency-based assessments. The role of *preceptorship and tutor training* was highlighted as essential for quality workplace learning, with the emphasis on educator preparation to give feedback and do role modelling, and reflective facilitation.[31] *Integration of* w*orkplace learning* emerged as a critical strategy to bridge the gap between theory and practice by incorporating simulation-based learning, reflective activities, and intentional alignment between academic and clinical environments.[32]

Professionalism and ethics were constructed as a foundational domain for future-ready radiography curricula that encompasses four interrelated themes. *Ethical and legal understanding* was consistently prioritised, with curricula embedding knowledge of patient rights, informed consent,

[26] Ago et al., "Insights into Radiography Education in Ghana: Document Analysis of Curricula Contents and Perspectives of Selected Stakeholders."

[27] Friel et al., "Clinical Insights into Cross-Sectional Imaging Integration in Radiography Education"; Govindasami and Singh, "Diagnostic Radiographers' Perspectives on Dental Radiography in Selected Provinces in South Africa"; Ramlaul and Khine, "'HOW TO' ……. Incorporating Education for Sustainable Development within a Radiography Curriculum: A Narrative Review"; Shafuda, Daniels, and Karera, "Bridging Theory and Practice: Experiences of Diagnostic Radiography Students during Clinical Training in Resource-constrained Settings."

[28] Akudjedu, Toomey, and Precht, "Sustainability in Radiography: Securing the Future through Greener Clinical Practice and Education"; Cooke et al., "Radiographer Educational Requirements for Adaptive Radiotherapy Techniques: A Mixed-Methods Regional Scoping Study"; Di Michele et al., "Enhancing Evidence-Based Practice in Radiography Education: Evaluation of an Applied Curriculum Intervention"; Friel et al., "Clinical Insights into Cross-Sectional Imaging Integration in Radiography Education"; Ago et al., "Insights into Radiography Education in Ghana: Document Analysis of Curricula Contents and Perspectives of Selected Stakeholders"; Susiku, Hewitt–Taylor, and Akudjedu, "Graduate Competencies, Employability and the Transnational Radiography Workforce Shortage: A Systematic Literature Review of Current Pre-Registration Radiography Education and Training Models."

[29] Cooke et al., "Radiographer Educational Requirements for Adaptive Radiotherapy Techniques: A Mixed-Methods Regional Scoping Study"; Govindasami and Singh, "Diagnostic Radiographers' Perspectives on Dental Radiography in Selected Provinces in South Africa"; Shafuda, Daniels, and Karera, "Bridging Theory and Practice: Experiences of Diagnostic Radiography Students during Clinical Training in Resource-constrained Settings."

[30] Chau et al., "From Classroom to Global Impact: How Radiography Education Advances the Sustainable Development Goals"; Cooke et al., "Radiographer Educational Requirements for Adaptive Radiotherapy Techniques: A Mixed-Methods Regional Scoping Study"; Friel et al., "Clinical Insights into Cross-Sectional Imaging Integration in Radiography Education."

[31] Mallinson, Hardy, and Scally, "Developing CT Workforce Competencies: What Knowledge and Skills Should We Expect of an Early Career Radiographer?"; E. Scaramelli et al., "A Tutor Training Framework for Radiographers: Basic Concepts to Effectively Train Future Generations of Professionals," *Radiography* 30 (December 2024): 96–103, https://doi.org/10.1016/j.radi.2024.10.023.

[32] Ofori-Manteaw, Yeboah, and Wuni, "Enhancing Radiography Education: The Roles and Challenges of Preceptors in the Clinical Supervision and Training of Student Radiographers"; A.-R. Wuni, B.O. Botwe, and T.N. Akudjedu, "Impact of Artificial Intelligence on Clinical Radiography Practice: Futuristic Prospects in a Low Resource Setting," *Radiography* 27 (October 2021): S69–73, https://doi.org/10.1016/j.radi.2021.07.021.

confidentiality, and regulatory compliance to support safe and accountable practice.[33] *Professional conduct and accountability* featured prominently and emphasise integrity, responsibility, and reflective practice across academic and clinical contexts.[34] *Cultural* competence and inclusivity were increasingly integrated, thereby promoting equitable, respectful and patient-centred care for diverse populations, and addressing bias and health disparities.[35] Finally, *reflective practice and self-awareness* were widely endorsed as mechanisms for professional growth that encouraged ongoing self-assessment, feedback-seeking, and recognition of personal strengths and limitations.[36]

Finally, **strategic and system-level alignment** was constructed as a critical domain for the development of a future-ready radiography curriculum. This domain reflects the need for coherence between educational design and broader healthcare, regulatory, and workforce imperatives. *Alignment with national and international standards* was consistently emphasised, with the aim of ensuring curricula meet accreditation benchmarks and global competencies to support graduate mobility and quality assurance.[37] *Collaboration and partnerships* were widely advocated through strategic alliances between academic institutions, clinical sites, industry, and professional bodies, which could enhance curriculum relevance, innovation, and employability.[38] *Policy and regulatory compliance* was a recurring theme, thereby highlighting the importance of embedding legal, ethical, and professional standards to ensure safe and accountable practice.[39] Finally, *sustainable workforce planning* was foregrounded by linking curriculum design to evolving service demands, role diversification, and long-term healthcare system needs.[40]

The conceptual map (Figure 2) illustrates the six interconnected domains that define a future-ready curriculum for radiography: pedagogical innovation, technology integration, curriculum content and structure, clinical education and practice, professionalism and ethics, and strategic and system-level alignment. Each domain comprises specific themes that highlight both the evolving educational methodologies and the broader systemic considerations required to prepare graduates for contemporary and future healthcare contexts. The map visually demonstrates how innovative teaching approaches (such as simulation and problem-based learning) integrate with advances in technology, structured content, and clinical experiences, while being underpinned by professionalism, ethical practice, and alignment with national and international standards. By depicting these domains and themes together, the map emphasises their interdependence. It shows that future readiness in radiography education cannot be achieved through isolated interventions but requires a holistic, system-wide approach. This holistic view is precisely what makes the framework a robust blueprint for informing next-generation accreditation standards, moving beyond siloed metrics to a comprehensive evaluation of educational ecosystems. The map highlights how pedagogical innovation, technological integration, curriculum design, clinical education, professionalism, and system-level alignment work together to prepare graduates for evolving healthcare contexts.

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[33] Akudjedu, Toomey, and Precht, "Sustainability in Radiography: Securing the Future through Greener Clinical Practice and Education."

[34] Malamateniou et al., "Artificial Intelligence in Radiography: Where Are We Now and What Does the Future Hold?"; Ramlaul and Khine, "'HOW TO' ……. Incorporating Education for Sustainable Development within a Radiography Curriculum: A Narrative Review."

[35] Cooke et al., "Radiographer Educational Requirements for Adaptive Radiotherapy Techniques: A Mixed-Methods Regional Scoping Study"; Govindasami and Singh, "Diagnostic Radiographers' Perspectives on Dental Radiography in Selected Provinces in South Africa"; Kumsa et al., "Clinical Placement Challenges Associated with Radiography Education in a Low-Resource Setting: A Qualitative Exploration of the Ethiopian Landscape."

[36] Scaramelli et al., "A Tutor Training Framework for Radiographers: Basic Concepts to Effectively Train Future Generations of Professionals."

[37] Ago et al., "Insights into Radiography Education in Ghana: Document Analysis of Curricula Contents and Perspectives of Selected Stakeholders"; Friel et al., "Clinical Insights into Cross-Sectional Imaging Integration in Radiography Education."

[38] Chau et al., "From Classroom to Global Impact: How Radiography Education Advances the Sustainable Development Goals."

[39] Mallinson, Hardy, and Scally, "Developing CT Workforce Competencies: What Knowledge and Skills Should We Expect of an Early Career Radiographer?"; Ofori-Manteaw, Yeboah, and Wuni, "Enhancing Radiography Education: The Roles and Challenges of Preceptors in the Clinical Supervision and Training of Student Radiographers"; Ramlaul and Khine, "'HOW TO' ……. Incorporating Education for Sustainable Development within a Radiography Curriculum: A Narrative Review."

[40] Akudjedu et al., "Sustainability in Radiography"; Mallinson et al., "Developing CT Workforce Competencies."

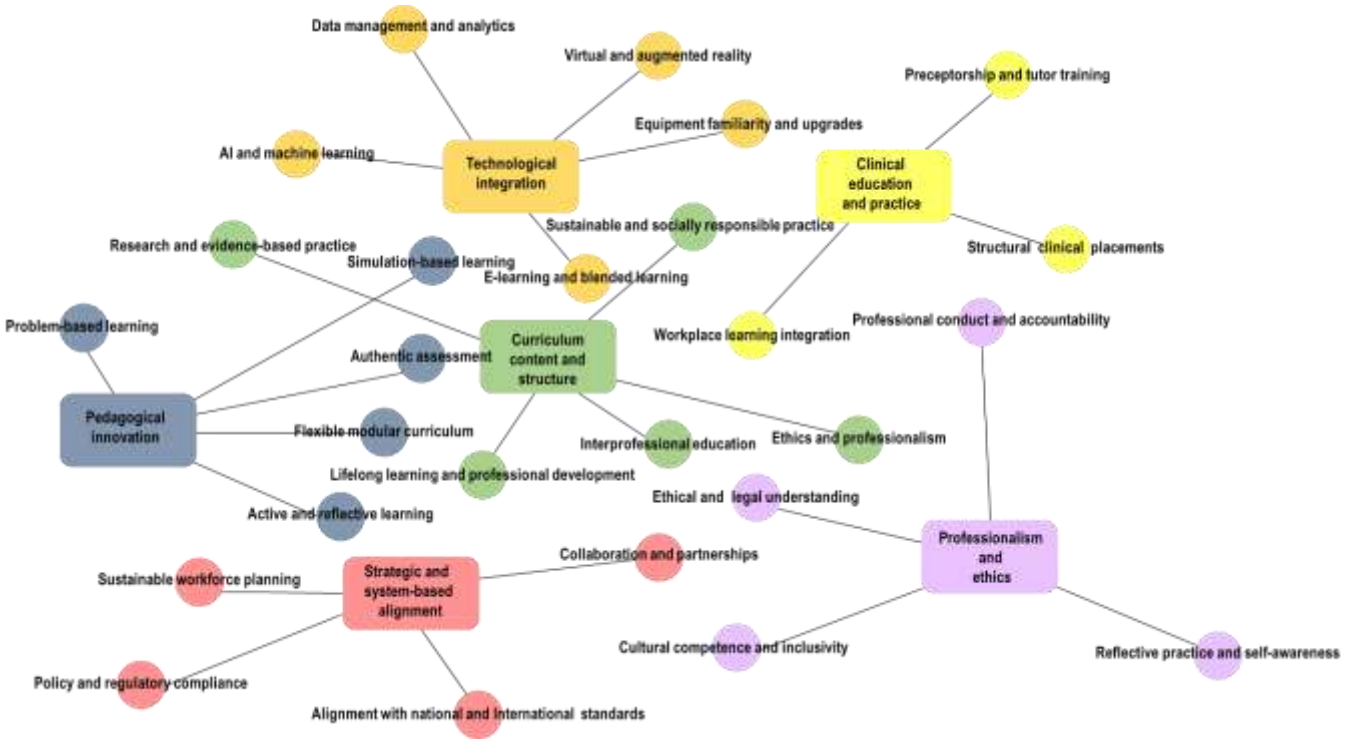

Figure 2: Conceptual Map of Domains and Themes Underpinning a Future-Ready Curriculum for Radiography

DISCUSSION

This scoping review synthesised the literature from South Africa and other countries to map six domains that collectively define a future-ready radiography curriculum. The framework highlights that preparing graduates for rapidly evolving healthcare environments requires more than adding discrete technological skills; it calls for systemic integration of pedagogical innovation, digital literacy, ethical practice, and alignment with workforce needs. While individual studies have previously examined isolated elements, such as simulation-based learning,[41] radiographer reporting,[42] or AI readiness,[43] this review demonstrates the value of unifying these strands into a coherent curricular framework.

Pedagogical innovation and technological integration were developed as mutually reinforcing domains. Simulation, problem-based learning, and flexible modular curricula create an adaptable foundation for embedding emerging technologies such as AI, data analytics, and virtual reality. These findings resonate with trends across health professions education, where experiential learning and digital tools are increasingly employed to serve as a bridge between theory and practice. Similarly, the domain of clinical education and practice underscores the continuing centrality of structured placements and preceptorship, while advocating for intentional integration of academic and workplace learning, an approach that ensures graduates are not only technically competent but also adaptable to diverse practice environments.

The domain of curriculum content and structure dictates the substantive knowledge and skills that must be delivered. The strong emphasis on interprofessional education and evidence-based practice ensures graduates are collaborative, inquiry-driven practitioners. Furthermore, the integration of themes such as lifelong learning and sustainable practice signals a shift from a static knowledge base to a curriculum that cultivates an adaptive, socially accountable, and forward-looking professional identity, to prepare graduates for evolving roles and responsibilities.

Clinical education and practice remain the cornerstone of radiography training, but their evolution is critical. The findings advocate for moving beyond traditional apprenticeship models

[41] Malamateniou et al., "Artificial Intelligence in Radiography."
[42] Hardy, "Radiography: Looking to the next Decade."
[43] Mdletshe and Wang, "Enhancing Medical Imaging Education."

towards structured, competency-based placements that are intentionally integrated with academic learning.[44] The emphasis on trained preceptors and the integration of workplace learning with simulation and reflection ensures that the theory–practice gap is bridged systematically, to produce graduates who are not only technically competent on day one but also possess the adaptability to thrive in diverse clinical environments.

Professionalism and ethics, long-standing pillars of radiography education, acquire new urgency in the context of AI-driven decision-making, patient data governance, and cultural inclusivity. Themes such as reflective practice and cultural competence suggest that curricula must prepare students not only for technical change but also for the ethical and relational complexities of practice. Finally, the domain of strategic and system-level alignment situates the entire educational endeavour within its broader context. A curriculum, no matter how innovative, risks irrelevance if it is not aligned with national and international accreditation standards, healthcare policies, and long-term workforce plans. This domain ensures that educational output meets the actual needs of the health system, supports graduate mobility, and is sustainable in the face of evolving service demands and technological change.

In conclusion, the interdependence of these six domains is the core strength of the proposed framework. It demonstrates that future readiness cannot be achieved by simply adding a technology module or revising a clinical manual. Instead, it requires a holistic, system-wide approach where advancements in one domain, such as technology, are supported by innovations in pedagogy, reinforced by clinical education, grounded in ethics, and validated through strategic alignment. This integrated framework offers a comprehensive blueprint for educators, institutions, and policymakers to proactively shape a radiography workforce capable of meeting the challenges of modern and future healthcare.

RECOMMENDATIONS

By building on the synthesised framework, this review proposes a series of integrated recommendations to advance radiography education. Theoretically, the authors advocate for a pedagogical shift towards curricula in which technology integration (AI, virtual reality, data analytics) is not a standalone module but is embedded in innovative teaching methods such as simulation and problem-based learning, to create a symbiotic relationship between how students learn and what they learn. Practically, this necessitates developing flexible, modular curricular architectures that can rapidly adapt to new technologies and evolving professional scopes. A crucial new approach is the intentional design of ethics by design modules, which directly intertwine lessons on AI algorithm operation with ethical principles of patient data governance and cultural inclusivity, to ensure that ethical practice is an applied skill, not an abstract concept.

The ethics by design approach moves beyond teaching ethics as a discrete, abstract topic and instead systematically embeds ethical considerations into the very fabric of technological and clinical education. The goal is to produce graduates who do not merely understand ethical principles but are equipped to apply them proactively in complex, real-world scenarios, particularly those involving advanced technologies. Ethics by design modules can be operationalised by directly intertwining technical instruction with ethical deliberation. For instance:

- In AI and machine learning modules: Lessons on how AI algorithms operate for image analysis should be concurrently paired with critical discussions on algorithmic bias, data fairness, and accountability. Students should evaluate case studies where training data lacks diversity, leading to diagnostic disparities across different patient demographics.
- In data management and analytics training: While learning to handle and secure medical imaging data, the curriculum must integrate rigorous exercises on patient data governance, informed consent for data use in research, and the implications of data breaches, to ensure that privacy is a default practice.

[44] Sioux McKenna and Susan van Schalkwyk, "A Scoping Review of the Changing Landscape of Doctoral Education," *Compare: A Journal of Comparative and International Education* 54, no. 6 (August 17, 2024): 984–1001, https://doi.org/10.1080/03057925.2023.2168121.

- In virtual reality simulations: Immersive scenarios should be designed to challenge students' cultural competence and inclusivity. This could involve navigating communication barriers with patients with diverse linguistic or cultural backgrounds or recognising and mitigating personal biases in patient interaction.

By implementing 'ethics by design', ethical practice is transformed from a theoretical concept into an applied, critical skill. This ensures that, when radiographers leverage powerful new technologies, they are simultaneously fortified with the ethical judgment necessary to use them responsibly, and foster trust and ensure equitable patient care in an evolving healthcare landscape.
For further research, significant gaps remain in evaluating the real-world impact of radiographic curricula on graduate competencies and patient outcomes. To enhance policy relevance, a defined research agenda should prioritise investigating the measurable impact of curriculum renewal on graduate readiness and employability outcomes. Specifically, the authors suggest investigating contextually appropriate implementation strategies in the African education landscape. This region faces a unique confluence of constraints, including a critical shortage of trained radiographers, a reliance on older and often donated imaging equipment with limited functionality, and infrastructural challenges such as unreliable power and internet connectivity. These factors severely limit the direct transferability of curricula developed in high-resource settings. Future studies must, therefore, not only adopt innovative curricula but also longitudinally track their success against metrics such as graduate skill retention, employability rates, and their ability to improve diagnostic efficacy within resource-constrained environments. Establishing this evidence base is crucial for justifying educational investments and guiding effective policy decisions aimed at strengthening the radiography workforce across Africa.

CONCLUSION

This review provides a comprehensive framework that integrates pedagogical, technological, clinical, ethical, and systemic dimensions into a vision of a future-ready radiography curriculum. By mapping six domains and their interrelated themes, it offers educators and policymakers an evidence-informed guide for curriculum renewal. Implementing this framework can support the development of radiographers who are technologically fluent, ethically grounded, and adaptable to changing clinical and societal contexts. Future research should evaluate the effectiveness of specific curricular innovations and explore strategies for embedding sustainability and digital competencies across diverse educational settings.

Key Messages

- A future-ready radiography curriculum requires a holistic approach that integrates pedagogy, technology, clinical practice, professionalism, and system-level alignment.
- Six domains with interrelated themes were identified, thereby offering an evidence-informed framework to guide curriculum renewal in radiography.
- Preparing graduates for evolving healthcare demands entails technological fluency, ethical grounding, cultural competence, and adaptability.
- Research gaps remain regarding evaluating the effectiveness of curricular strategies and in embedding sustainability and digital capabilities across diverse contexts, particularly in Africa.

LIMITATIONS

This scoping review has several limitations. The search strategy was restricted to three major databases (e.g., PubMed, Scopus, Web of Science) and may have missed relevant studies indexed in smaller, regional, or discipline-specific databases. Furthermore, the inclusion of only documents that had been published in English introduced a potential for language and geographic bias, and the potential to overlook valuable insights from non-English-speaking contexts. Therefore, the findings may not fully capture the entire spectrum of literature on future-ready radiography curricula, particularly from underrepresented regions.

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