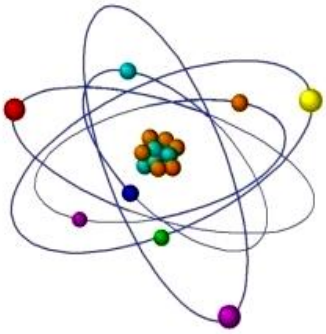
IMPLEMENTATION AND OPTIMISATION OF MEDICAL PHYSICS EDUCATION AND MENTORSHIP IN GEORGIA



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ABSTRACT: *The growing complexity of radiation-based medical technologies has increased the need for highly qualified medical physicists capable of ensuring radiation safety, quality assurance, and effective clinical implementation of diagnostic and therapeutic procedures. This review examines international approaches to medical physics education and mentorship and discusses their relevance to the development of medical physics training in Georgia. International recommendations developed by the International Atomic Energy Agency (IAEA), International Organisation for Medical Physics (IOMP), European Federation of Organisations for Medical Physics (EFOMP), and American Association of Physicists in Medicine (AAPM) emphasise competency-based education, structured clinical training, mentorship, and continuing professional development as essential components of professional preparation. These principles provide an important framework for countries seeking to strengthen their medical physics workforce. Current challenges in Georgia include limited educational pathways, insufficient structured clinical training opportunities, and a shortage of qualified medical physicists. At the same time, ongoing modernisation of radiation medicine, increasing access to advanced technologies, and growing international collaboration create favourable conditions for educational development. A national framework is proposed that integrates academic education, clinical training, mentorship, research activities, and continuing professional development. The proposed approach aims to support workforce sustainability, improve radiation safety, strengthen quality assurance practices, and contribute to the continued advancement of healthcare services in Georgia.*

Keywords: medical physics education; mentorship; radiation safety; medical physics workforce;

INTRODUCTION

Medical physics has evolved into an essential healthcare profession that integrates principles of physics, engineering, biology, and medicine to support the safe and effective use of radiation and other advanced technologies in healthcare. Medical physicists play key roles in radiation oncology, diagnostic radiology, nuclear medicine, radiation protection, and quality assurance. Their responsibilities include radiation dosimetry, optimization of diagnostic and therapeutic procedures, quality control of medical equipment, and implementation of safety standards.

The rapid development of radiation-based technologies has increased the need for highly qualified medical physicists capable of ensuring both technological performance and patient safety. Recognizing these developments, international organizations including the International Atomic Energy Agency

(IAEA), International Organization for Medical Physics (IOMP), European Federation of Organisations for Medical Physics (EFOMP), and American Association of Physicists in Medicine (AAPM) have emphasized the importance of structured educational pathways, competency-based training, supervised clinical experience, mentorship, professional certification, and continuing professional development. Contemporary educational frameworks increasingly recognize that successful preparation of medical physicists requires not only scientific and technical knowledge but also critical thinking, clinical reasoning, communication skills, leadership abilities, and lifelong learning competencies. Despite significant technological progress in radiation medicine worldwide, workforce shortages and educational challenges remain common. International reports have identified insufficient numbers of clinically qualified medical physicists as a major limitation affecting the implementation of advanced technologies, quality assurance programmes, and radiation safety systems in many healthcare environments. Consequently, the development of sustainable educational systems capable of producing competent medical physics professionals has become a strategic priority internationally.

Georgia has experienced substantial modernization of radiation medicine during recent decades. The expansion of radiotherapy, diagnostic imaging, and nuclear medicine services has been accompanied by increasing demand for qualified medical physicists capable of ensuring radiation safety, quality assurance, equipment performance evaluation, and clinical optimization of increasingly sophisticated technologies. Similar workforce challenges have been reported internationally, particularly in countries undergoing rapid technological modernization [1–4].

The introduction of advanced radiotherapy technologies, modern diagnostic imaging systems, hybrid nuclear medicine equipment, and increasingly sophisticated quality assurance procedures has expanded the technological capabilities of the healthcare system. However, the development of educational pathways and workforce capacity has not always progressed at the same pace as technological advancement. The growing complexity of contemporary radiological technologies has therefore created an increasing need for educational programmes capable of preparing future medical physicists according to international standards while addressing national healthcare priorities.

This review examines contemporary approaches to medical physics education and mentorship, analyses major international educational frameworks, and discusses their relevance to the development of medical physics education in Georgia. Particular attention is given to workforce development, mentorship, competency-based education, and the relationship between educational capacity and the continuing expansion of the radiological technology sector. The article also proposes practical recommendations for strengthening medical physics education and supporting the long-term sustainability of radiation medicine services in Georgia.

2. International Standards in Medical Physics Education

The educational preparation of medical physicists has undergone substantial transformation during recent decades. Historically, medical physics was primarily considered a scientific discipline, and many professionals entered the field through traditional university programmes in physics, engineering, or related sciences. Clinical competencies were frequently acquired through workplace experience and informal professional training. However, the increasing complexity of modern healthcare technologies has fundamentally changed the role of medical physicists and consequently the requirements for their education and professional development. Today, medical physicists are recognized internationally as healthcare professionals who contribute directly to patient care, radiation safety, quality assurance, treatment planning, imaging optimization, and clinical decision-making. Their responsibilities extend beyond technical support and increasingly involve participation in multidisciplinary healthcare teams. As a result, contemporary educational programmes are expected to integrate scientific knowledge with clinical competence, communication skills, professionalism, leadership, and lifelong learning.

International organizations have played a central role in defining educational standards for the profession. The IAEA, IOMP, EFOMP, and AAPM have all emphasized that medical physics education should be based on structured academic preparation, supervised clinical training, competency-based assessment, and continuing professional development. Although educational systems differ among countries, these organizations consistently promote a common set of professional principles aimed at ensuring patient safety, quality assurance, and effective implementation of advanced medical technologies. Among these organizations, the IAEA has had a particularly important influence on the development of international educational frameworks. Through a series of Human Health Reports, Training Course Series publications, and professional guidance documents, the Agency has established recommendations intended to support workforce development across a wide range of healthcare environments. The IAEA educational model is based on the integration of academic education, clinical training, and continuing professional development. This educational philosophy reflects the broader international transition from knowledge-based curricula toward competency-based educational models that emphasize measurable professional outcomes, practical skills, and independent clinical performance [5–8].

Academic programmes are expected to provide comprehensive instruction in radiation physics, radiation dosimetry, radiobiology, radiation protection, medical imaging, radiation oncology physics, nuclear medicine physics, anatomy, physiology, and research methodology. Clinical training is regarded as equally important because professional competence cannot be achieved through theoretical education alone. The concept of competency-based education has become increasingly influential within medical physics. Rather than focusing exclusively on course content, competency-based approaches define educational outcomes according to the professional responsibilities that graduates are expected to perform. This shift reflects the recognition that modern medical physicists must possess not only technical expertise but also professional judgment, communication skills, ethical awareness, and the ability to function effectively within complex healthcare systems.

The principles established by the IAEA have been further reinforced by IOMP, EFOMP, and AAPM recommendations, all of which emphasize structured education, supervised clinical training, competency-based assessment, and lifelong professional development.

An important feature common to all contemporary educational models is the recognition that clinical competence requires structured supervised practice. Medical physicists must acquire practical experience within clinical environments where theoretical knowledge can be applied to real healthcare situations involving radiation oncology, diagnostic radiology, nuclear medicine, radiation protection, quality assurance, treatment planning, imaging optimization, and equipment commissioning. Such experiences contribute to the development of professional judgment, decision-making abilities, and independent problem-solving skills.

Recent advances in educational science have also influenced the evolution of medical physics education. Traditional lecture-based teaching methods are increasingly supplemented by active learning strategies, case-based instruction, simulation-based training, problem-based learning, and flipped classroom approaches. Future educational requirements will increasingly reflect developments in artificial intelligence, automation, quantitative imaging, adaptive radiotherapy, and digital healthcare technologies. Consequently, medical physics programmes must remain sufficiently flexible to incorporate emerging scientific and technological advances while maintaining strong foundations in physics, radiobiology, dosimetry, and radiation protection [8–10].

The key components of contemporary medical physics education are summarized in Figure 1.

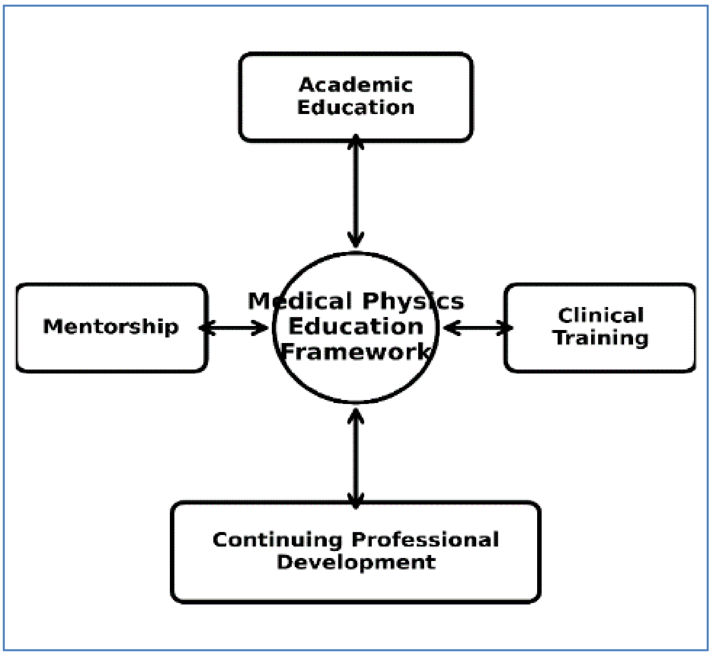

Figure 1. Conceptual framework illustrating the four interconnected pillars supporting professional development in medical physics.

3. Mentorship and Professional Development in Medical Physics

The preparation of competent medical physicists extends beyond the acquisition of scientific knowledge and technical skills. Contemporary educational frameworks increasingly recognize mentorship as a fundamental component of professional development. While formal education provides the theoretical foundations required for clinical practice, mentorship facilitates the integration of knowledge, professional judgment, communication skills, and ethical responsibility within real healthcare environments.

The growing complexity of modern radiation medicine has further increased the importance of mentorship. Medical physicists work at the interface of science, technology, and clinical medicine, where professional decisions directly influence patient safety, treatment quality, and healthcare outcomes. Consequently, the transition from academic learning to independent clinical practice requires guidance from experienced professionals capable of supporting both technical and professional development.

Evidence from healthcare education indicates that structured mentoring programmes may improve professional confidence, facilitate competency acquisition, enhance research engagement, and increase workforce retention [11–13]. In medical physics, mentorship supports the development of professional competence, clinical judgment, communication skills, and professional identity.

Clinical mentorship is particularly important because many professional competencies can only be acquired through supervised practice. During clinical training, experienced medical physicists guide trainees through activities such as radiation dosimetry, treatment planning, quality assurance, equipment commissioning, imaging optimisation, radiation protection, and risk assessment. These experiences enable trainees to apply theoretical knowledge within real clinical environments while developing independent decision-making skills.

The increasing sophistication of radiotherapy, diagnostic imaging, and nuclear medicine technologies has further strengthened the importance of mentoring. Effective mentorship involves not only technical instruction but also the transmission of professional values, ethical standards, communication skills, and multidisciplinary collaboration practices [14].

International professional organizations increasingly recognize mentorship as an essential element of medical physics education. The AAPM WGTEACH Report 366 emphasizes the importance of mentoring relationships in supporting critical thinking, clinical reasoning, professional identity formation, and lifelong learning. Mentorship therefore serves as a key mechanism for maintaining professional standards and ensuring workforce sustainability. Together with academic education and supervised clinical training, mentorship contributes to the development of competent professionals capable of supporting radiation safety, quality assurance, and patient care. The interaction between academic, clinical, and peer mentoring activities is illustrated in Figure 2.

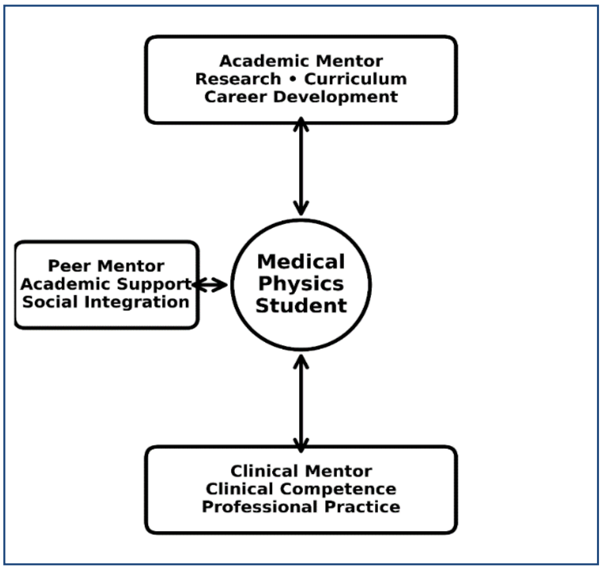

Figure 2. Proposed three-tier mentorship model integrating academic, clinical, and peer support throughout professional development.

4. Current Status, Challenges and Opportunities for Medical Physics Education in Georgia

The healthcare sector in Georgia has undergone substantial modernization during the past two decades, particularly in areas involving radiation-based technologies. Significant investments in diagnostic imaging, radiation oncology, nuclear medicine, and interventional procedures have expanded the technological capabilities of healthcare institutions and improved access to advanced diagnostic and therapeutic services. Contemporary radiological practice increasingly relies on sophisticated technologies including multidetector computed tomography (CT), magnetic resonance imaging (MRI), digital radiography, mammography, image-guided radiotherapy systems, stereotactic radiosurgery platforms, hybrid imaging technologies, and advanced treatment planning systems. The development of the radiological technology sector in Georgia reflects broader healthcare modernization processes occurring throughout Eastern Europe and the Caucasus region.

Table 1. Principal components of the Georgian radiological technology infrastructure and potential sources of inventory information.

Segment	Technologies	Suggested Data Source
Radiotherapy	LINACs, cobalt units, brachytherapy systems, CT simulators, treatment planning systems	Agency of Nuclear and Radiation Safety; IAEA DIRAC
Diagnostic Radiology	CT, MRI, digital radiography, fluoroscopy, mammography	Ministry of Health; NCDC; IAEA IMAGINE
Nuclear Medicine	Gamma cameras, SPECT, SPECT/CT, PET/CT, radionuclide therapy units	IAEA IMAGINE; Nuclear Medicine Centres
Interventional Radiology	Angiography systems, fluoroscopy units, hybrid operating rooms	Ministry of Health; Hospital procurement databases
Quality Assurance and Dosimetry	Ionization chambers, dose calibrators, survey meters, phantoms, QA software	Radiation Safety Agency; Hospital QA Departments

The data sources listed in Table 1 are largely derived from international infrastructure databases, including the IAEA Directory of Radiotherapy Centres (DIRAC) and the IAEA IMAGINE database, which support assessment of radiotherapy and medical imaging resources worldwide [15, 16]. While the table provides an overview of the main segments of the radiological technology sector, there is currently no comprehensive national inventory of radiological equipment publicly available.

The creation of a centralized national registry would enhance workforce planning, infrastructure evaluation, and future educational initiatives.

The radiological technology market in Georgia encompasses a broad range of diagnostic, therapeutic, and quality assurance technologies. Continued investments in radiotherapy, diagnostic imaging, nuclear medicine, and interventional radiology reflect ongoing modernization of healthcare infrastructure. Modern radiotherapy centres increasingly employ advanced image-guided and intensity-modulated treatment technologies, while diagnostic imaging and nuclear medicine services have expanded through the introduction of CT, MRI, SPECT/CT, and PET/CT systems. These developments have significantly enhanced healthcare capabilities but have simultaneously increased demand for qualified medical physicists. Modern radiological technologies require specialized expertise in equipment commissioning, quality assurance, radiation dosimetry, treatment verification, imaging optimisation, radiation protection, and regulatory compliance. Consequently, the effectiveness of technological investments depends not only on equipment acquisition but also on the availability of appropriately trained professionals. A notable characteristic of the Georgian radiological technology market is its reliance on imported high-technology equipment supplied by international manufacturers. Although this provides access to state-of-the-art technologies, it also highlights the need for a highly qualified workforce capable of operating, optimizing, and maintaining these systems according to international standards.

Similar workforce challenges have been reported internationally, particularly in radiation oncology, diagnostic radiology, and nuclear medicine, where the scope of medical physics practice continues to expand [17, 18]. In addition to traditional responsibilities in radiation therapy, medical physicists are increasingly involved in imaging optimisation, patient dose management, equipment performance evaluation, quality management, and radiation protection programmes.

Despite substantial technological progress, several challenges remain regarding workforce development and education. Historically, many medical physicists in Georgia have entered the profession through academic backgrounds in physics, engineering, mathematics, or related scientific disciplines and subsequently acquired specialized competencies through professional practice and continuing education. Although this pathway has contributed significantly to the development of radiation medicine services, it may not provide sufficient capacity to meet future workforce demands associated with ongoing technological expansion.

Another important challenge is the limited availability of structured clinical training opportunities. International organizations consistently emphasize that professional competence requires both academic preparation and supervised clinical experience. As radiological technologies become increasingly sophisticated, systematic clinical training becomes progressively more important.

At the same time, the relatively small size of the Georgian medical physics community creates opportunities for close collaboration among universities, healthcare institutions, professional organizations, and regulatory authorities. Such cooperation may facilitate coordinated educational initiatives aligned with national healthcare priorities and international professional standards. International experience demonstrates that sustainable development of radiation medicine depends on the integration of workforce planning, educational capacity, and healthcare infrastructure development [11–13]. International collaboration provides an additional opportunity for workforce development through access to educational resources, professional networks, scientific exchange, and best practices developed in more mature healthcare systems. International initiatives promoting the visibility, recognition, and professional identity of medical physicists' further support workforce development worldwide [22]. These partnerships may accelerate educational development and strengthen integration of Georgian medical physics into the international professional community. Overall, the continuing modernization of radiation medicine in Georgia is creating increasing demand for qualified medical physicists. Strengthening educational pathways, clinical training opportunities, and professional development programmes will therefore be essential for supporting healthcare quality, radiation safety, and the effective utilization of advanced radiological technologies.

5. Proposed Framework for Medical Physics Education and Mentorship in Georgia

The analysis of international educational models and current healthcare needs in Georgia suggests that future workforce development should be based on an integrated framework combining academic education, structured clinical training, mentorship, research engagement, and continuing professional development. Academic programmes should provide a strong foundation in radiation physics, dosimetry, radiobiology, radiation protection, medical imaging, radiation oncology, nuclear medicine, and research methodology. Structured clinical training should complement academic education by ensuring the acquisition of practical competencies in radiation oncology, diagnostic radiology, nuclear medicine, quality assurance, equipment commissioning, treatment planning, imaging optimisation, and clinical risk management. Mentorship should represent a central component of professional preparation, facilitating the transition from student to healthcare professional while supporting technical development, professional identity formation, and career progression. Academic, clinical, and peer mentoring activities may collectively strengthen professional competence and workforce sustainability. Research engagement, continuing professional development, and international collaboration should complement formal education and clinical training. Together, these elements can support the development of a sustainable medical physics workforce capable of meeting future healthcare demands while maintaining high standards of radiation safety and clinical quality [23]. The proposed educational model for Georgia is summarized in Figure 3.

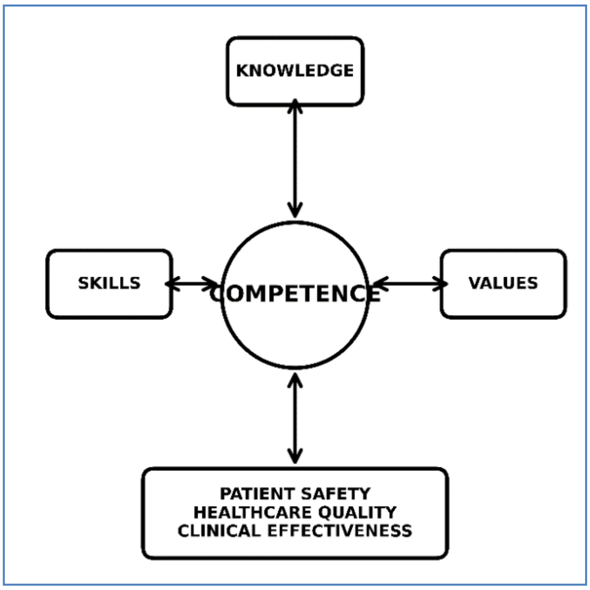

Figure 3. Relationship among knowledge, skills, professional values, and competence in contemporary medical physics education.

6. DISCUSSION

The findings of this review demonstrate that the effectiveness of modern radiation medicine depends increasingly on the alignment between technological development and workforce capacity. International experience indicates that investments in advanced radiotherapy, diagnostic imaging, and nuclear medicine technologies must be accompanied by appropriate educational and training infrastructures to ensure their safe and effective clinical implementation [11-13,19]. A consistent theme across international educational frameworks is the transition from knowledge-based training toward competency-based professional preparation. Contemporary medical physicists are expected not only to possess strong scientific foundations but also to demonstrate clinical competence, professional judgement, communication skills, and the ability to work within multidisciplinary healthcare teams.

Consequently, effective educational programmes require integration of academic education, supervised clinical training, mentorship, and lifelong professional development. The Georgian experience reflects challenges observed in many countries undergoing rapid healthcare modernisation. Expansion of radiotherapy, diagnostic imaging, and nuclear medicine services has increased demand for medical physicists with competencies extending beyond traditional radiation oncology practice. Modern medical physicists are increasingly involved in imaging optimisation, patient dose management, quality assurance, equipment commissioning, regulatory compliance, and implementation of quality management systems. As a result, workforce planning must account not only for current staffing needs but also for future technological expansion. An important finding is the close relationship between the radiological technology market and educational requirements.

The introduction of increasingly sophisticated medical equipment inevitably generates demand for specialized expertise in dosimetry, radiation protection, quality assurance, and clinical risk management. Failure to align educational capacity with technological growth may limit effective utilization of healthcare technologies and create workforce shortages. Mentorship represents an additional factor supporting workforce development. Because many professional competencies are acquired through supervised practice, mentoring relationships facilitate the transfer of practical expertise, clinical judgement, and professional standards. This function may be particularly important in smaller professional communities where efficient knowledge transfer is essential for long-term workforce sustainability. Future educational programmes must also remain adaptable to emerging technologies, including artificial intelligence, radiomics, adaptive radiotherapy, quantitative imaging, automation, and digital healthcare systems. These developments are expected to expand the scope of medical physics practice and increase the importance of interdisciplinary collaboration, data literacy, critical thinking, and continuous professional development. Overall, the evidence reviewed in this article suggests that educational development, workforce planning, and technological modernization should be considered complementary components of healthcare development. In Georgia, strengthening medical physics education and mentorship may contribute not only to workforce sustainability but also to improvements in healthcare quality, radiation safety, and the effective utilization of advanced radiological technologies.

7. CONCLUSIONS

In conclusion, sustainable development of radiation medicine in Georgia will depend not only on continued technological modernization but also on the availability of qualified medical physicists capable of supporting the safe and effective implementation of advanced healthcare technologies. Strengthening educational pathways, clinical training opportunities, and mentorship programmes may therefore contribute substantially to healthcare quality, radiation safety, and long-term workforce sustainability.

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