Digital Technologies in Professional Education and Skills' Development for Radiographers

Kleanthis Konstantinidis[1], Ioannis Apostolakis[2]

[1]Radiographer MSc, KAT General Hospital of Attica, Greece
kleon12@yahoo.gr
[2]PhD, School of Medicine, National & Kapodistrian University of Athens, Greece
ioannis.a61@gmail.com

Abstract

Radiography curriculum in Greece includes a series of courses, which provide the basic knowledge to the graduate Radiographer, to work in a department of medical imaging, radiotherapy or nuclear medicine. Lifelong education and skills' development of the Radiographer is considered necessary during his professional career, due to the evolution of biomedical technology and the new imaging and therapeutic techniques. This paper aims to propose a digital model of lifelong professional education and development for Radiographers. A literature review was conducted in the PubMed database on the principles governing the construction of digital training models for Radiographers. The design of a digital education platform will include e-learning tools, which are already available and used by educational organizations. The establishment of an experienced interdisciplinary team is essential both in the educational process and model's design.

Keywords: Radiographers, Digital Technologies, Education, Development.

1. Introduction

In Greece, the graduates of the Radiographic Science School have received their degree, completing a program, which includes the basic knowledge for practicing radiographic science. During their professional career, Radiographers will implement and develop the acquired knowledge in daily clinical practice, to optimize the imaging or radiotherapeutic outcome. According to Greek regulation and the code of conduct for the practice of radiographic profession, Radiographers works closely with Radiologists, Nuclear Physicians, Radiotherapists and Medical Physicists, performs all imaging, radioisotopic and radiotherapeutic operations, evaluates their outcome, while observing the Radiation Protection Regulation. Radiographers can work on more than one imaging or radiotherapeutic modalities. This freedom of choice of Radiographer is considered beneficial for him and the department. In this way, Radiographer can expand his skills during daily clinical practice, improving his overall professional performance (Prentakis et al., 2016).

ISBN: 978-960-578-084-5

However, as medical imaging and radiotherapy techniques and biomedical technology are evolving rapidly, the continuing professional training of Radiographers depends on each one's personal interest to be trained individually. Also, new entrants to the labor market and seniors need to specialize or expand their knowledge on a specific modality. The purpose of this paper is to propose a distance professional education framework for the lifelong development of Radiographers' skills, which will utilize Information and Communication Technologies (ICT). A search at PubMed database was conducted for the principles of designing and development of distance learning tools for the lifelong education of healthcare professionals involved in medical imaging, radiation therapy and nuclear medicine.

The second section briefly reviews e-learning applications, which have been used through time. The third section refers to the steps, which must be followed for the development of an e-learning platform. The fourth section makes an extensive report in building an e-learning platform for Radiographers, the tools and features needed. The fifth section refers to the educational process and the learning models which can be used to achieve successful outcomes. At the last two sections we discuss the findings from the international literature and summarize the findings of our research.

2. An Overview of Distance Learning

2.1 Distance Learning in Healthcare Professionals

Many studies have been conducted internationally, which investigate the outcomes of the distance learning implementation using e-learning tools in healthcare. Distance learning is not simply a set infrastructure, but rather a concept of learning that incorporates different technologies and learning media (Masic et al., 2009). The trend towards distance learning has reduced the cost of e-learning tools, making this method an attractive training choice for many healthcare professionals. The advantages of this method over traditional learning are the portability and accessibility to a large amount of educational content via the Internet, as well as the use of educational multimedia, which can integrate image, sound and text in a single file or presentation. Also, the eligibility of synchronous or asynchronous access to educational content and time flexibility is another advantage of distance learning over traditional learning.

The COVID-19 pandemic has forced educational organizations and scientific societies to stop in-class courses, conferences and seminars for students and healthcare professionals. To continue delivering educational services, these organizations and societies implemented distance learning using e-learning tools. And this was achieved at some point.

The knowledge of the practical aspects of the imaging or therapeutic methods and patient management are key points in Radiographer's daily practice that ensure the provision of high-quality healthcare services. With the development of ICTs, the

ISBN: 978-960-578-084-5

distance professional education and qualifications' development of Radiographers can be carried out through open-source educational software, like learning management systems (LMS), which can be used to build and deliver electronic courses while monitoring the progress of trainees and getting feedback for educational process.

2.2 E-learning Applications for Radiographers

International experience and literature have many examples to show for e-learning applications related to distance education in medical imaging, radiotherapy and nuclear medicine.

2.2.1 Computer-based Interface

A first approach using computer-based application as e-learning tool were digitized x-ray films combined with a computer interface. These x-ray films were scanned and imported as jpeg images in the interface. The user was able to manipulate parameters of image projected on screen, like zoom in/out, brightness, contrast and position. Also, he was able to use features of annotation and magnification. The main disadvantage of this primary approach was memory management, due to the limited random-access memory (RAM) of computer in contrary with memory resources needed for images storage and manipulation (Stein et al., 1991).

2.2.2 Web-based Teaching Files

Evolution of the previous approach is the web-based teaching file system (Henderson et al., 2004). This system contains digital content with pedagogical value coming directly from Picture Archiving & Communication Systems (PACS). The advantages of this system against a computer-based application were the accessibility via the Internet, the high quality of digital images coming from PACS and the constantly updated content.

2.2.3 Web-based Applications and Platforms

The most recent approaches in distance learning for healthcare professionals in medical imaging, radiotherapy and nuclear medicine including Radiographers regard the construction of web-based applications, which incorporate e-modules, e-courses, multimedia, distance practice and knowledge assessment. The following applications are indicative:

- CTSim - Computed Tomography Simulation (Stowe et al., 2021), open-source simulator consisted of web-based graphical user interface
- E-learning Course on Breast Imaging for Radiographers (Moreira et al., 2015), web-based platform using simple and wide-spread technologies, such as Hypertext Preprocessor (PHP), HyperText Markup Language (HTML), JavaScript and Extensible Markup Language (XML).

ISBN: 978-960-578-084-5

- OpenPhys - Open Education Physics for Medical Radiation Technologists (Vo & Sharp, 2019), web-based software developed with open-source tools and capable of housing all content types, such as text, images, graphics etc.

Also, there are several web-based platforms with pedagogical content for Radiographers' continuing education. Eurorad is a web-based platform, where healthcare professionals from the fields of medical imaging, radiotherapy and nuclear medicine can browse teaching cases, submit their own cases and take quizzes. Medical Professionals website delivers text-based, interactive and animated courses for Radiographers and Radiologic Technologists, while providing accreditation with course's completion. Radiology EDU is a web-based company, which provides online training for Radiographers and Radiologic Technologists with a membership. RadTrain is another company, which provides online continuing professional development to Radiographers working in computed tomography.

Societies of Radiographers and Radiologic Technologists have also contributed to the spread of continuing education using digital technologies. Indicatively, the European Federation of Radiographers Societies (EFRS), the International Society of Radiographers and Radiologic Technologists (ISRRT), the International Atomic Energy Agency (IAEA) and the American Society of Radiologic Technologists (ASRT) offer online resources for radiography continuing education. These continuing education resources contain recorded lectures, presentations, blogs, e-modules and multimedia for the concepts' comprehension. Tele-education platforms such as Webex and Zoom are used to deliver live lectures and presentations.

2.2.4 Simulation in Virtual Environment

Virtual environment is the term used to describe the human-computer interaction when human is integrated into a computer-generated imaginary world. The term emphasizes the absorption of the object by the virtual environment. (Apostolakis & Stamouli, 2008). The next step in personalized radiography distance learning seems to be the virtual teaching (Wilcha, 2020). This approach regards simulation in a virtual environment, using web-based simulation platforms and virtual reality (VR) equipment, such as VR glasses. The main advantage of this approach is that the user can develop his clinical skills in a safe environment (O'Connor et al., 2021), making errors without the risk on the patient and reduce errors in real clinical practice.

2.2.5 Social Media-based Content, Web and Mobile Apps

It should not be overlooked to mention the digital educational material created from Radiographers, which is freely accessible via the Internet. Such material is wikis, podcasts, blogs, vidcasts and all kind of multimedia content in social media, like videos and images, explaining radiographic or radiotherapeutic aspects. They offer dynamic information in training of health professionals, including clinical research, giving at the

ISBN: 978-960-578-084-5

same time the opportunity for participation and cooperation (Apostolakis & Egglezopoulou, 2012). Also, mobile applications or apps for smartphones and tablets are included in this category. These apps integrate images and text, to deliver radiographic or radiotherapeutic aspects, such as patient positioning, dose management and procedures' protocols (Kauffman et al., 2020).

3. Development of an E-learning Platform

Coverage of the target population educational needs and ease of system's administration are essential for the success of a distance educational program. Therefore, detailed specifications are required, regarding the identification of educational needs, the validation, implementation and assessment of the educational program (Varlamis & Apostolakis, 2006). Figure 1 shows the proceeding for the implementation of a distance educational program from the identification of educational needs of potential trainees until program's evaluation from trainees. Each phase is explained in the next paragraphs:

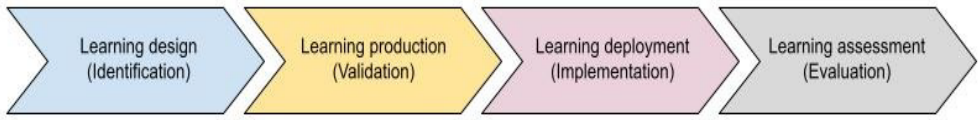

Figure 1. *Flowchart of Educational Program Implementation*

3.1 Learning Design

At this phase, research for the identification of target population specifications and trainees' profile is essential. The role of scientific associations is crucial, as they can deliver and collect questionnaires in many members, investigating their educational needs. Also, scientific associations consist of senior Radiographers, who are informed for their colleagues needs.

3.2 Learning Production

The aim of this phase is the validation and adoption of the learning program's formation. The program with the contents in its final form recommends a product, which must be attractive to the prospective user. Therefore, a group of experts is required. Usually, this group consists of a program director, a specialist expert, a web designer, a multimedia technician, a program developer and a course designer (Chalazonitis et al., 2008).

3.3 Learning Deployment

This is the phase of the program's implementation at its final form.

ISBN: 978-960-578-084-5

3.4 Learning Assessment

This is the phase that will provide feedback for the delivered quality and possible future improvements of the program. The trainees will complete an online anonymous questionnaire for the evaluation of instructors and content for each module separately and for the overall evaluation of the entire program (Chalazonitis et al., 2008).

4. Characteristics of an E-learning Program for Radiographers

An extensive report is made below on the case of building an e-learning platform for Radiographers, based on the available e-learning tools currently used in Greece. Additional features are also suggested based on the international literature for future incorporation.

4.1 Learning Management System

Learning management system (LMS) is a web-based platform, usually accessible via user's registration to an educational program. E-class and Moodle are such platforms, used by many educational organizations in Greece, from elementary school to postgraduate programs. E-class is an open-source software and supports the asynchronous distance learning. Moodle is also an online open-source learning platform, which provides capabilities for asynchronous and synchronous distance learning. These platforms incorporate the following features:

- educational digital content library, which can be updated,
- e-mail for communication with instructors, administrators and other trainees,
- calendar and timetable,
- progress monitoring tools,
- links to external web locations,
- forum,
- tele-education for synchronous distance learning (Moodle),
- courses and instructors' evaluation tool,
- quizzes,
- capability of account personalization.

Thus, a LMS is essential to conduct and evaluate an educational program. Blackboard is another LMS referred in the literature and can integrate medical image viewer as a plug-in feature (Burbridge et al., 2019).

ISBN: 978-960-578-084-5

4.2 Tele-education Platforms

Webex, Zoom, Adobe Connect, GoToWebinar are platforms for synchronous distance learning. These platforms allow to users to meet online at the same time, using their camera and microphone. They incorporate the following features:

- webinar set up,
- files exchange,
- chat in public or privately,
- screen sharing for presentations,
- questions and answers (QA),
- breakout sessions for collaborative work in groups,
- session recording for uploading at LMS, web location or social media,
- polls.

The use of a tele-education platform is essential for synchronous learning and can integrate as an add-on feature with Moodle LMS, according to Moodle plugins directory.

4.3 Educational Content

The identification of cognitive topics should be done in collaboration with the potential trainees. The issues will concern theoretical and practical real problems and situations that the trainees are called to face in their work routine. Potential educational content is each file in digital format, that can be uploaded on the LMS. These files are:

- recorded lectures and presentations,
- e-books,
- learning resources and external web links,
- articles,
- multimedia files repository.

The educational content can follow the hierarchy course → modality → module → components. A system construction (fig.2) with the previous hierarchy can serve several courses, including different imaging or therapeutic modalities. The following modalities are indicatively mentioned:

- computed tomography (CT),
- magnetic resonance imaging (MRI),
- linear accelerator (LINAC),
- digital radiography (DR),
- interventional radiology (IR).

Each modality can be separated in e-modules, including lectures for the theoretical issues of each modality. Subsequently, each module can include the components for

ISBN: 978-960-578-084-5

the comprehension of the practical issues of each modality, such as animations, simulation, illustrations and examples (Zhao et al., 2013).

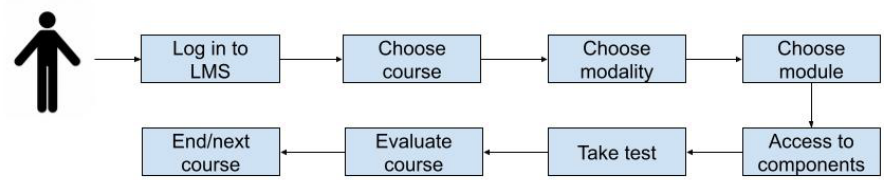

Figure 2. *Flow diagram of the proposed LMS model*

4.4 Medical Images Repository and Viewer

The purpose of this features is to deliver high-resolution medical images to trainees, to understand how the exposure, scan and reconstruction parameters affect the quality of the image. Also, high-resolution medical images are useful for the comprehension of anatomical regions of the body and pathologies.

According to literature, a medical image viewer can be integrated as a plug-in feature in a Blackboard LMS (Pinelle et al., 2012). A PACS server for medical images retrieval and a web-based medical images repository for image cases storage are essential components (Hsiao et al., 2006). Medical Imaging Resource Center (MIRC) is a server program, which can be used as a repository (Gentili et al., 2007). Briefly, the steps for viewing and interacting with medical images through the LMS are explained below and shown in figure 3.

- The course designer must retrieve an image or a dataset of images from PACS server, create a teaching case on his workstation and store it on the MIRC server with a unique URL address (Tchoyoson et al., 2003).
- Secondly, the designer must create a corresponding course web page in Blackboard LMS with the same URL address, created in Hyper-Text Markup Language (HTML).
- When a user of the LMS visits that course web page, the web page requests content from the MIRC server and loads an image viewer plug-in. That allows user to view and interact with the image stored in the server via LMS.

Theoretically, the same actions can be done in any LMS, which supports integration of HTML pages with embedded JavaScript (Pinelle et al., 2012). Today, they existence of open-access medical images repositories on the Internet can facilitate course designers to search and integrate the desired medical images in LMS, without the use of a PACS server.

ISBN: 978-960-578-084-5

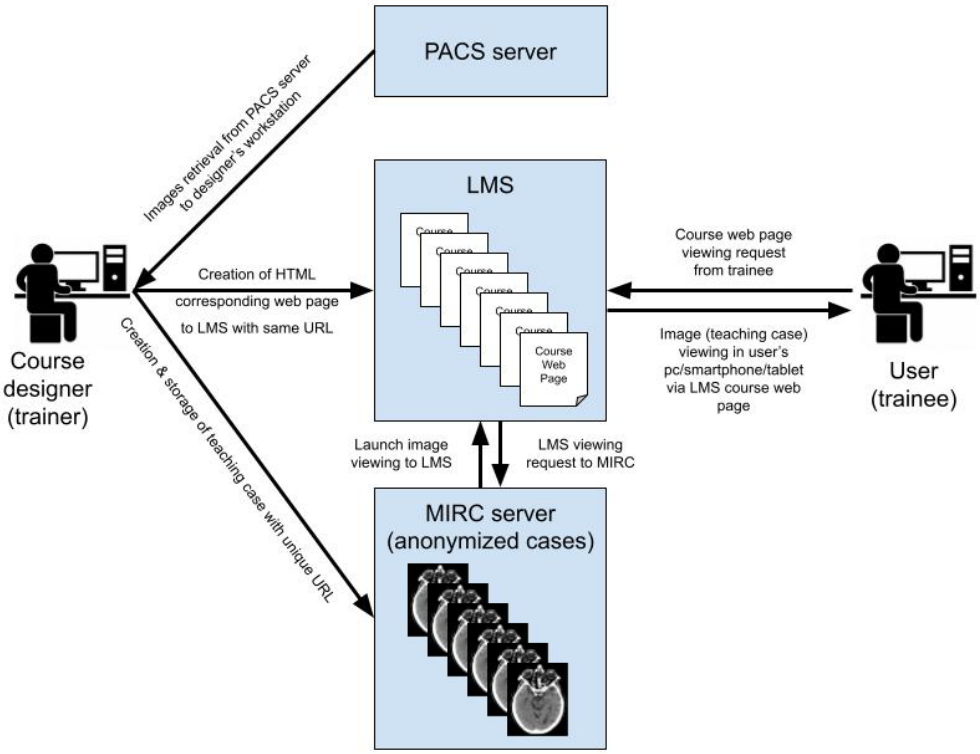

Figure 3. *Representation of LMS operations for image viewing*

An alternative option for medical images viewing is the web based DICOM viewers and DICOM image libraries. DICOM is the acronym for Digital Imaging and Communications in Medicine standard and created by the National Electrical Manufacturers Association (NEMA). DICOM standard is used to store, exchange and transmit medical images, produced from medical imaging modalities, such as CT, MRI, ultrasonography and digital radiography (Kahn et al., 2007).

4.5 Simulation and Virtual Learning Environments

A virtual learning environment (VLE) is a simulation system in a computer, where the trainee can interact with the system to understand concepts. A VLE can be used to offer more engagement to the trainee. The simulation system incorporates different simulation scenarios, which are an artificial representation of the real-world events (Harrington & Simon, 2021). Animations are also used for concepts' comprehension. The importance of simulation in clinical skills' development is the practice in a safe environment, without any risk to patients, giving the chance to trainees to investigate and reduce errors. Designing an effective simulation system requires careful planning.

ISBN: 978-960-578-084-5

According to Harrington & Simon (2021) the following must be determined before designing the system:

- Awareness of the prospective users' cognitive and empirical background is crucial, so that the delivered system can fulfill its purpose.
- Intended outcomes, including the knowledge acquired and the reaction (perception, expectations, behavior) of the trainee from interaction with the system.
- Context, including type of cases and equipment.
- Goals and objectives from the system's implementation. S.M.A.R.T. criteria template must be used for the goals and objectives of the simulation system before its design. Thus, goals and objectives must be **S**pecific, **M**easurable, **A**chievable, **R**elevant and **T**imely.

To deliver high-quality imaging services, a Radiographer must be highly qualified. An online interactive simulation system can enhance Radiographer's skills in clinical practice and systems operation and configuration. Knowledge of the following aspects in daily practice of Radiographer is necessary:

- Patient positioning, management and safety.
- Patient dose optimization.
- Image quality optimization.
- Imaging techniques and protocols.
- Physical principles of imaging methods.
- Quality assurance of imaging and equipment.

Taking these points into consideration, a VLE for Radiographers in medical imaging for example can consists of mostly used imaging modalities, such as digital radiography (DR), digital mammography (DM), computed tomography (CT) and magnetic resonance imaging (MRI). Each modality section can include the following modules, as shown in figure 4 (Dikshit et al., 2005):

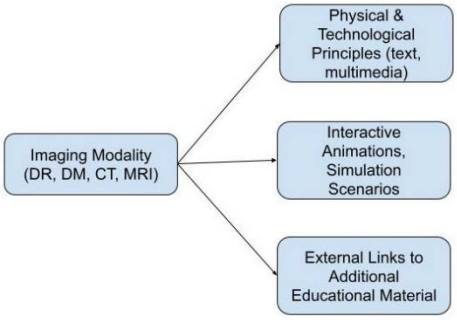

Figure 4. *Features of a Simulation System*

ISBN: 978-960-578-084-5

5. Educational Process

Distance and e-learning environments need new learning models to deliver successful operation and outcomes (Apostolakis et al., 2008). These models are explained below:

- In collaborative learning both instructor and trainee are involved in the learning process and learn from each other. The interaction between them helps the increase of knowledge and communication skills' improvement. Collaborative learning is supported from web tools such as tele-education and tele-conference platforms and forums.
- In active learning the instructors assume the role of mentors, while learners set their goals and decide how they will succeed. This learning process is not based only on the resources suggested by instructors, but trainees gradually discover and use material from their own research.
- In constructive learning the educational content is based on the cognitive and empirical background of the trainees. This model regards a way of training, where the instructor and trainee interact in a unique way, with emphasis in trainee's role.
- In personalized learning the trainee learns, researches and deepens independently of other trainees, even though belongs to the learning community. Computers and the Internet facilitate the personalized learning since the trainee is in constant interaction with the educational material. Thus, each trainee is responsible for his progress.

It is concluded that the previous models put the trainees in the center of the educational process, in order that they are responsible for their choices. Trainers can be Radiographers, Radiologists and Medical Physicists with academic and scientific background and with extensive experience in imaging or therapeutic modalities. Professional recognition and special training at adults' education are required to inspire a sense of confidence in trainees.

6. Discussion

According to international literature, there are several approaches, designing an interactive simulation system for Radiographers. An approach in Radiographers skills' development is the interactive manipulation of medical images. Papamichail et al. (2015) developed a web-based, open-access educational platform for image reconstruction and processing from tomographic modalities such CT. In this project, the pedagogical objective was the comprehension of the effect from reconstruction and processing's methods applied on medical images. This project implemented in medical students, but it could be a useful tool for newly qualified radiographers to familiarized with image reconstruction, processing and radiographic anatomy.

ISBN: 978-960-578-084-5

CTSim is an interactive computer simulation system for learning the fundamentals of dose optimization in CT (Lee et al., 2014). The simulation system calculates the CT dose index, effective dose and dose-length product, according to user's selected scan parameters, scan length and CT equipment (simulation scenario). Then, the system compares the delivered dose with the diagnostic reference levels, to determine whether the delivered dose is low, average or high. Stowe et al. (2021) also investigated the effectiveness of a CT simulation intervention in education. The pedagogical objective of the simulation system was the comprehension of the effect of different scan parameters in patient's image quality. The simulator implemented in student radiographers.

The case of Virtual Environment Radiotherapy Training (VERT) system illustrates the used with a virtual linear accelerator, equipment and a patient (Kane, 2018). This simulation system is used for training of radiation therapists.

Biermann (2016) described an online course for nuclear medicine specialists, delivered by an e-learning system. The system utilized the combination of three platforms, a web-conferencing platform, a nuclear medicine image viewing and processing system and Moodle LMS. The program consisted of online lectures and anonymized teaching images.

O'Connor et al. (2021) piloted a 3D virtual simulation tool in an undergraduate radiography curriculum, concluding that an interactive simulation tool is valuable in radiography education. The software used for the purpose of the study was one of the latest, built from 3D real-time datasets and using VR equipment. These offer interactive elements to users, so they can actively participate in the simulation environment through their avatar (Sapkaroski et al., 2018), instead of sitting in front of their computer screen. The latest years many simulation-based education systems are available as commercial products.

7. Conclusions

It turns out that the digital technologies for the development of an e-learning system for Radiographers' lifelong professional education are already available. Such a system can be built as a LMS with open-source software, such as E-class and Moodle. These platforms can incorporate lectures, presentations, multimedia, documentation and links to external web resources. Moodle can also incorporate add-on features with the use of third-party software plug-ins. Also, these platforms can be used to monitor trainees' progress and educational process feedback. So, our proposal primarily focuses on the development of a LMS using E-class or Moodle open-source software, which are already being used from many educational organizations, trainers and teachers in Greece. The development of a VLE is a more complex and costly task and concerns future work, as it requires special software design, specialized group of technicians and developers and additional equipment.

ISBN: 978-960-578-084-5

References

Apostolakis, I., & Egglezopoulou, A. (2012). Web 2.0 applications in medical and nursing education. *Iatriki*, *101*(6), 432-447.

Apostolakis, I., & Stamouli, A. (2008). Virtual reality systems. Simulation technology in health domain. *Iatriki*, *93*(2), 143–155.

Apostolakis, I., Varlamis, I., & Papadopoulou, A. (2008). *E-learning Communities (in Greek)*. Athens: Papazisis Pub.

Biermann, M. (2016). *A national e-learning platform for training specialists in Nuclear Medicine in Norway* [Working paper]. Program for universitetspedagogikk, Universitetet i Bergen. Retrieved from https://bora.uib.no/bora-xmlui/handle/1956/11945

Burbridge, B., Burbridge, C., Costa, J., & Carter, Y. (2019). ODIN: Adaptation of an HTML 5-Compatible DICOM Viewer for MIRC-TFS, Enhancing the Incorporation of Clinical Images into the Health Science Curriculum. *Medical Science Educator*, *29*(1), 11–17. Retrieved from https://doi.org/10.1007/s40670-018-00679-w

Chalazonitis, A., Koumarianos, D., & Apostolakis, I. (2008). e-learning. Basic principles and the presentation of a radiological educational project. *Archives Of Hellenic Medicine*, *25*(6), 811–822.

Dikshit, A., Wu, D., Wu, C., & Zhao, W. (2005). An online interactive simulation system for medical imaging education. *Computerized Medical Imaging and Graphics*, *29*(6), 395–404. Retrieved from https://doi.org/10.1016/j.compmedimag.2005.02.001

Gentili, A., Chung, C. B., & Hughes, T. (2007). Use of the MIRC DICOM Service for Clinical Trials to Automatically Create Teaching File Cases from PACS. *RadioGraphics*, *27*(1), 269–275. Retrieved from https://doi.org/10.1148/rg.271065110

Harrington, D. W., & Simon, L. V. (2021). Designing a Simulation Scenario. In *StatPearls*. StatPearls Publishing. Retrieved from http://www.ncbi.nlm.nih.gov/books/NBK547670/

Henderson, B., Camorlinga, S., & DeGagne, J.-C. (2004). A Cost-Effective Web-Based Teaching File System. *Journal of Digital Imaging*, *17*(2), 87–91. Retrieved from https://doi.org/10.1007/s10278-004-1001-y

Hsiao, C.-H., Hsu, T.-C., Chang, J. N., Yang, S. J. H., Young, S.-T., & Chu, W. C. (2006). Developing a Medical Image Content Repository for E-Learning. *Journal of Digital Imaging*, *19*(3), 207–215. Retrieved from https://doi.org/10.1007/s10278-006-0588-6

ISBN: 978-960-578-084-5

Kahn, C. E., Carrino, J. A., Flynn, M. J., Peck, D. J., & Horii, S. C. (2007). DICOM and Radiology: Past, Present, and Future. *Journal of the American College of Radiology*, *4*(9), 652–657. Retrieved from https://doi.org/10.1016/j.jacr.2007.06.004

Kane, P. (2018). Simulation-based education: A narrative review of the use of VERT in radiation therapy education. *Journal of Medical Radiation Sciences*, *65*(2), 131–136. Retrieved from https://doi.org/10.1002/jmrs.276

Kauffman, L., Raminpour, S., Weisberg, E. M., & Fishman, E. K. (2020). So You Want to Develop an App for Radiology Education? What You Need to Know to Be Successful. *Journal of Digital Imaging*, *33*(4), 1058–1064. Retrieved from https://doi.org/10.1007/s10278-020-00345-x

Lee, C. S., Reinhardt, E. B., & Smith-Bindman, R. (2014). CTSim: An Interactive Computer Simulation to Learn the Fundamentals of CT Dose Optimization. *Journal of the American College of Radiology*, *11*(3), 255–256. Retrieved from https://doi.org/10.1016/j.jacr.2013.12.013

Masic, I., Pandza, H., Kulasin, I., Masic, Z., & Valjevac, S. (2009). Tele-education as method of medical education. *Medicinski Arhiv*, *63*(6), 350–353. Retrieved from https://doi.org/10.5455/medarh.2009.63.350-353

Moreira, I. C., Ventura, S. R., Ramos, I., & Rodrigues, P. P. (2015). Development and Assessment of an E-Learning Course on Breast Imaging for Radiographers: A Stratified Randomized Controlled Trial. *Journal of Medical Internet Research*, *17*(1), e3344. Retrieved from https://doi.org/10.2196/jmir.3344

O'Connor, M., Stowe, J., Potocnik, J., Giannotti, N., Murphy, S., & Rainford, L. (2021). 3D virtual reality simulation in radiography education: The students' experience. *Radiography*, *27*(1), 208–214. Retrieved from https://doi.org/10.1016/j.radi.2020.07.017

Papamichail, D., Pantelis, E., Papagiannis, P., Karaiskos, P., & Georgiou, E. (2015). A Web Simulation of Medical Image Reconstruction and Processing as an Educational Tool. *Journal of Digital Imaging*, *28*(1), 24–31. Retrieved from https://doi.org/10.1007/s10278-014-9689-9

Pinelle, D., Burbridge, B., & Kalra, N. (2012). USRC: A New Strategy for Adding Digital Images to the Medical School Curriculum. *Journal of Digital Imaging*, *25*(5), 682–688. Retrieved from https://doi.org/10.1007/s10278-012-9473-7

Prentakis, A. G., Stefanoyiannis, A. P., Georgiadis, K., Coleman, L., Foley, S. J., Herlig, D., Kollas, P., Kowalik, A., Tomczak, J., & Chatziioannou, S. N. (2016). Education, training, and professional issues of radiographers in six European countries: A comparative review. *Journal of European CME*, *5*(1), 31092. Retrieved from https://doi.org/10.3402/jecme.v5.31092

ISBN: 978-960-578-084-5

Sapkaroski, D., Baird, M., McInerney, J., & Dimmock, M. R. (2018). The implementation of a haptic feedback virtual reality simulation clinic with dynamic patient interaction and communication for medical imaging students. *Journal of Medical Radiation Sciences*, *65*(3), 218–225. Retrieved from https://doi.org/10.1002/jmrs.288

Stein, L. D., Snydr-Michal, J., & Greenes, R. A. (1991). Realistic viewing and manipulation of radiographic images on a personal computer—A user interface for educational applications. *Journal of Digital Imaging*, *4*(3), 169–176. Retrieved from https://doi.org/10.1007/BF03168162

Stowe, J., O'Halloran, C., Photopoulos, G., Lia, A. D., Quinn, M., Tschan, F., Verwoolde, R., & Buissink, C. (2021). CTSim: Changing teaching practice in radiography with simulation. *Radiography*, *27*(2), 490–498. Retrieved from https://doi.org/10.1016/j.radi.2020.10.017

Tchoyoson, C. C., Yang, G. L., Nowinski, W. L., & Hui, F. (2003). Medical Image Resource Center–making electronic teaching files from PACS. *Journal of Digital Imaging*, *16*(4), 331–336. Retrieved from https://doi.org/10.1007/s10278-003-1660-0

Varlamis, I., & Apostolakis, I. (2006). The Present and Future of Standards for E-Learning Technologies. *Interdisciplinary Journal of E-Skills and Lifelong Learning*, *2*, 59–76. Retrieved from https://www.informingscience.org/Publications/401

Vo, M. K., & Sharp, J. C. (2019). Design, Development, and Content Creation for an Open Education Physics Website for MRT Education. *Journal of Medical Imaging and Radiation Sciences*, *50*(2), 212–219. Retrieved from https://doi.org/10.1016/j.jmir.2019.03.180

Wilcha, R.-J. (2020). Effectiveness of Virtual Medical Teaching During the COVID-19 Crisis: Systematic Review. *JMIR Medical Education*, *6*(2), e20963. Retrieved from https://doi.org/10.2196/20963

Zhao, W., Bessell, A. G., Erdol, N., McGoron, A. J., & Rhodes, W. T. (2013). *Collaborative Development of Internet-Accessible, Interactive, Medical Imaging Teaching Courseware and Application to Undergraduate Curricula*. 23.296.1-23.296.9. Retrieved from https://peer.asee.org/collaborative-development-of-internet-accessible-interactive-medical-imaging-teaching-courseware-and-application-to-undergraduate-curricula

ISBN: 978-960-578-084-5

Περίληψη

Το πρόγραμμα σπουδών της Ακτινοτεχνολογίας στην Ελλάδα περιλαμβάνει μαθήματα, τα οποία παρέχουν τις βασικές γνώσεις στον απόφοιτο Τεχνολόγο Ακτινολόγο, προκειμένου να εργαστεί στα τμήματα ιατρικής απεικόνισης, ακτινοθεραπείας ή πυρηνικής ιατρικής. Η δια βίου εκπαίδευση και ανάπτυξη του Τεχνολόγου Ακτινολόγου θεωρείται απαραίτητη κατά τη διάρκεια της επαγγελματικής του σταδιοδρομίας, λόγω της εξέλιξης της βιοϊατρικής τεχνολογίας και των νέων τεχνικών ιατρικής απεικόνισης και ακτινοθεραπείας. Αυτή η εργασία έχει ως στόχο να προτείνει ένα ψηφιακό μοντέλο δια βίου επαγγελματικής εκπαίδευσης και ανάπτυξης για τους Τεχνολόγους Ακτινολόγους. Μια βιβλιογραφική ανασκόπηση πραγματοποιήθηκε στη βάση PubMed σχετικά με τις αρχές που διέπουν την κατασκευή ψηφιακών μοντέλων εκπαίδευσης για Τεχνολόγους Ακτινολόγους. Ο σχεδιασμός μιας πλατφόρμας ψηφιακής εκπαίδευσης θα περιλαμβάνει εργαλεία ηλεκτρονικής μάθησης, τα οποία είναι ήδη διαθέσιμα και χρησιμοποιούνται από εκπαιδευτικούς οργανισμούς. Η συγκρότηση μιας έμπειρης διεπιστημονικής ομάδας είναι απαραίτητη τόσο στην εκπαιδευτική διαδικασία όσο και στο σχεδιασμό του μοντέλου.

Λέξεις κλειδιά: Τεχνολόγοι Ακτινολόγοι, Ψηφιακές Τεχνολογίες, Εκπαίδευση, Ανάπτυξη.

ISBN: 978-960-578-084-5