The Impact of Virtual Reality in Medical Ionizing Radiation Sciences Education: A Systematic Review of the International Literature

Kleanthis A. Konstantinidis and Ioannis A. Apostolakis

Abstract — Studies in medical ionizing radiation sciences apply to a wide range of medical and allied health professions. The students in those sciences learn the basic principles and effects of ionizing radiation on patients for diagnostic and therapeutic purposes, as well as the theoretical background in biomedical equipment operation. It is fundamental for those students to receive proper hands-on training, to successfully connect the theory with practice. In addition, the COVID-19 pandemic has pushed education to a new normal, establishing the use of emerging technologies to facilitate distance learning and virtual interaction. In this paper, we reviewed the literature for applications of virtual reality (VR) learning environments in the education of medical ionizing radiation sciences. We performed a literature search in the databases PubMed and Epistemonikos for the last decade (2012-2022), using combinations of keywords. We also performed a manual search in ResearchGate electronic repository. We identified 11 studies investigating the impact of the application of VR learning environments on students in medicine and allied health professions relevant to medical ionizing radiation sciences. The application of VR can lead to the improvement of learning outcomes, the development of clinical and soft skills, facilitate the comprehension of theoretical concepts through visualization and increase the level of confidence of students before clinical practice. In addition, it is an attractive method of training, offering the benefits of repetition and practice in a safe environment for the students. None of the studies refer that VR learning environments have replaced the clinical placements of the students, which are considered a critical component of their clinical practice. Concluding, there is only a little, regional, and relatively recent quantitative evidence, demonstrating the successful incorporation of VR learning environments in curricula of medical ionizing radiation sciences. From our perspective, VR can become a valuable pedagogical tool for those curricula, helping the connection of theory with clinical practice and enhancing the confidence of students.

Key words — Education, medical radiation sciences, simulation, virtual reality.

I. INTRODUCTION

Education in medical ionizing radiation sciences involves a series of academic theories and clinical practices. Students in radiography, radiation therapy, medical physics and the medical students acquire the necessary theoretical knowledge, such as radiation physics, imaging and therapeutic principles and techniques, anatomy, patient positioning, radiation management and safety and image interpretation, in the physical classroom. During clinical placements, those students apply the theoretical knowledge to practice, acquire clinical skills and achieve the required competencies for professional practice. Clinical placements take place under the supervision of qualified healthcare professionals in the clinical context, including observation of the department’s workflow and interaction with peers and other healthcare professionals.

In recent years, virtual reality (VR) has changed the game in healthcare. VR or virtual learning environments (VLE) have emerged, as a new method of delivering hands-on training in medical, nursing, and allied health professions education [1]. VR is the use of proper software and hardware to create a screen-based virtual world representation or an immersive virtual simulated learning environment (SLE). Learners use either a screen-based user interface or head-mounted display (HMD) equipment, which places them inside a computer-generated imaginary world. Thus, they can engage with the virtual environment and interact with virtual characters and elements, like in the real world. VR offers several benefits for educators and learners. Different VR scenarios can be incorporated in VR software, offering to the learner a variety of tasks to complete [2]. It is a cost-effective way of training, offering the benefits of on-demand training and repetition. Another benefit of VR is that offers a safe and risk-free training environment both for learners and patients. In medical ionizing radiation sciences, a safe and risk-free VLE is an important training component, considering the risks from exposure of staff and patients to ionizing radiation during clinical practice [3].

As technological advances overwhelm everyday practice in the medical ionizing radiation field, it is important for students to learn while engaging with technology in a safe environment, without the risk of radiation exposure. VR can benefit students to consolidate theoretical knowledge and preparing them for clinical settings. The aim of this paper is to review the literature for VR applications in medical ionizing radiation sciences and summarize the existing quantitative evidence, emphasizing the significance of the incorporation of VR as a pedagogical tool in undergraduate curricula. According to our findings, this is the first systematic review of the literature, which includes students of medical ionizing radiation sciences.

II. METHODS

A. Research Question

We conducted this literature review to answer the question; what is the impact of VR on learning outcomes for the students in medical ionizing radiation sciences and how do they perceive the application of VR?
B. Search Strategy

We performed literature research in PubMed and Epistemonkos electronic databases for the years from 2012 until the present. We used the keywords “virtual reality”, “education”, “medical radiation”, “medical imaging” “radiology”, “radiography”, “radiation therapy”, “radiation oncology”, “medical physics” and “nuclear medicine” in different combinations. For the further literature review, we used the same keyword combinations for manual search in ResearchGate electronic repository. The combinations of keywords are shown in Table I.

<table>
<thead>
<tr>
<th>TABLE I: SEARCH STRATEGY IN ELECTRONIC DATABASES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Search</td>
</tr>
<tr>
<td>#1   virtual reality AND “education” AND “medical radiation”</td>
</tr>
<tr>
<td>#2   virtual reality AND “education” AND “medical imaging”</td>
</tr>
<tr>
<td>#3   virtual reality AND “education” AND “radiology”</td>
</tr>
<tr>
<td>#4   virtual reality AND “education” AND “radiography”</td>
</tr>
<tr>
<td>#5   virtual reality AND “education” AND “radiation therapy”</td>
</tr>
<tr>
<td>#6   virtual reality AND “education” AND “radiation oncology”</td>
</tr>
<tr>
<td>#7   virtual reality AND “education” AND “nuclear medicine”</td>
</tr>
<tr>
<td>#8   virtual reality AND “education” AND “medical physics”</td>
</tr>
</tbody>
</table>

The bibliographic records were imported in Zotero references management software and duplicates were removed [4]. After removing the duplicates, the remained records were screened in two phases, according to PRISMA guidelines for systematic reviews [5]. During the first phase, we screened the titles and abstracts of the records and removed the records, which were irrelevant to the subject of the review. During the second phase, we applied specific eligibility criteria and screened the remaining full-text articles.

C. Eligibility Criteria

We applied specific criteria according to the PICO strategy [6], to assess the eligibility of the full-text articles:

Population: studies including students in radiography and radiation therapy, medical physics, and undergraduate medical students.

Intervention: studies investigating the impact of a VLE or an immersive SLE on students of the previous categories.

Comparison: studies assessing the impact or comparing the effectiveness of a VLE or an immersive SLE with traditional clinical practice.

Outcomes: studies with quantitative recorded outcomes on the attitude, perceived satisfaction, acquisition and enhancement of knowledge, confidence, and skills.

D. Selection of Studies

Studies fulfilling the previous eligibility criteria were included in the review. The reasons for full-text articles exclusion during the application of eligibility criteria were studies that are not written in the English language, technical articles, and other reviews. Studies that investigate the application of a VLE or an immersive SLE among health care professionals instead of students were excluded. Thus, we excluded studies with resident doctors and other health care professionals. Also, we excluded studies, which investigate the application of a VLE or an immersive SLE in ultrasound and magnetic resonance imaging training (non-ionizing radiation imaging modalities).

E. Quality Assessment of Included Studies

Due to the heterogeneity of study methodologies, the Mixed Methods Appraisal Tool (MMAT) was used to assess the quality of the eligible studies. MMAT permits assessment of the methodological quality in qualitative research, randomized controlled trials, non-randomized studies, quantitative descriptive studies, and mixed methods studies [7].

F. Data Extraction and Synthesis

We extracted and recorded information from included studies in Table II. The studies’ characteristics included the authors, year of publication, location of study, VR approach used as intervention, participants, the objective, and the outcomes of the study. Because of the heterogeneity of study designs, educational intervention designs and outcomes across included studies, the results were reported descriptively.

III. RESULTS

A. Study Selection Process

In total, 607 bibliographic records were found through the search in the PubMed database, 17 records from the Epistemonkos database and 8 records were manually selected from the ResearchGate electronic repository. After the removal of duplicates, a total of 618 studies remained. After screening titles and abstracts, 538 records were excluded. The full text of the remaining 80 studies was assessed for eligibility, and 65 more studies were excluded as they did not meet the eligibility criteria. The remaining 15 studies were included in the review. The study selection process is outlined in Fig. 1. The characteristics of the included studies [8–22] are recorded in Table II.

![Fig. 1. PRISMA flowchart.](image-url)

Despite we reviewed the literature for the last decade, the 15 articles included in the review are published in 2015 and henceforth. This fact shows the growing trend of the incorporation of VR and virtual simulation in the educational process of medical ionizing radiation sciences
TABLE II: SUMMARY OF STUDIES CHARACTERISTICS

<table>
<thead>
<tr>
<th>Study, country</th>
<th>VR approach</th>
<th>Participants (n)</th>
<th>Objective</th>
<th>Study outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nishi et al. [8]</td>
<td>Web-based VR/AR (WebAR/WebVR)</td>
<td>Radiography students (n=35)</td>
<td>Effectiveness of VR/AR visualization of scattered radiation for education</td>
<td>High rate of correct answers both in VR and AR students’ group, improved confidence in radiation protection</td>
</tr>
<tr>
<td>O’Connor et al. [9]</td>
<td>3D VR simulation equipment</td>
<td>Radiography students (n=83)</td>
<td>Students feedback for 3D VR simulation in radiographic practice</td>
<td>Students felt more confident in their radiographic technique after using the tool, enjoyed this experience and they would recommend it</td>
</tr>
<tr>
<td>Fujibuchi [10]</td>
<td>VR Animation (ParaView)</td>
<td>Medical students (n=25)</td>
<td>Effectiveness of VR visualization of scattered radiation for education</td>
<td>The tool helped students to understand the radiation distribution</td>
</tr>
<tr>
<td>Sapkaroski et al. [12]</td>
<td>Virtual SLE software</td>
<td>Radiography students (n=76)</td>
<td>Effectiveness of VR simulation vs clinical role-play scenario</td>
<td>No significant difference between two groups</td>
</tr>
<tr>
<td>Gunn et al. Australia [13]</td>
<td>VR CT simulation software</td>
<td>MI &amp; RT students (n=66)</td>
<td>Effectiveness of virtual simulation in computed tomography</td>
<td>Benefit of repetition by VR simulation</td>
</tr>
<tr>
<td>Taubert et al. UK [14]</td>
<td>VR videos using VR headsets</td>
<td>Medical students (n=72)</td>
<td>Delivery of radiotherapy treatment and palliative care experience</td>
<td>Significantly high scores for concentration and learning adequacy with VR, which is highly recommended</td>
</tr>
<tr>
<td>Sapkaroski et al. [15]</td>
<td>Virtual SLE software</td>
<td>Radiography students (n=76)</td>
<td>Effectiveness of VR simulation vs clinical role-play scenario</td>
<td>Improvement in three practical aspects of radiography practice for VR students’ group</td>
</tr>
<tr>
<td>Lorenzo-Alvarez et al. [16]</td>
<td>Second Life virtual 3D world platform</td>
<td>Medical students (n=156)</td>
<td>Effectiveness of 3D VR classroom vs real world classroom</td>
<td>No significant difference between two learning groups</td>
</tr>
<tr>
<td>Lorenzo-Alvarez et al. [18]</td>
<td>Second Life virtual 3D world platform</td>
<td>Medical students (n=46)</td>
<td>Delivery of theoretical and case-based virtual radiological education</td>
<td>The students highly rated the course, the initiative, the participation and the overall perception</td>
</tr>
<tr>
<td>Leong et al. New Zealand [19]</td>
<td>VERT</td>
<td>RT students (n=20)</td>
<td>Comparison of VERT vs standard teaching module</td>
<td>Improved perceived comprehension and confidence in VERT module</td>
</tr>
<tr>
<td>Jimenez et al. Australia [20]</td>
<td>VERT</td>
<td>RT &amp; MP students (n=15)</td>
<td>Interprofessional workshop in radiation planning and treatment</td>
<td>No significant differences in pre- and post- intervention</td>
</tr>
<tr>
<td>Gunn et al. Australia [21]</td>
<td>Virtual SLE software</td>
<td>Medical imaging students (n=45)</td>
<td>Effectiveness of VR simulation vs clinical role-play scenario</td>
<td>High satisfaction with VERT for both of groups</td>
</tr>
<tr>
<td>Bridge et al. Australia [22]</td>
<td>VR CT + VERT</td>
<td>Radiography students (n=111)</td>
<td>Impact evaluation of VR simulation on students and academics</td>
<td>Skill level improvement of VR simulation over traditional learning method</td>
</tr>
</tbody>
</table>

The single qualitative study [22] is of moderate methodological quality because there is insufficient information to identify the data collection procedures. 13 studies are identified as quantitative. 3 of them are classified as randomized controlled trials (RCT), 4 as descriptive studies and the rest 6 as non-randomized studies. One RCT shows moderate evidence of bias, because it is unclear if there are complete outcome data and if the assessors were blinded [16]. The other 2 RCTs show low evidence of bias, subsequently, they are of good methodological quality [12], [15].

during the last years. Six studies are reported in Australian schools of health and biomedical sciences [12], [13], [15], [20]–[22].

B. Quality assessment of included studies

The MMAT algorithm was utilized, to classify the included studies into the proper study category. Fig. 2 outlines the classification of the 15 studies, according to the MMAT algorithm [23]. For each included study, we rated the five criteria of the chosen category. Further information for the detailed criteria ratings of each study can be found in the appendix.

DOI: http://dx.doi.org/10.24018/ejeng.2022.1.CIE2959
Fig. 2. Classification of included studies.

One out of 6 quantitative non-randomized studies show high evidence of bias, due to exclusion of some outcome data, reduction in cohort sizes and lack of training method evaluation [21]. The rest 5 studies are of good methodological quality [8], [12], [17], [18], [20].

1 out of 4 quantitative descriptive studies is of moderate methodological quality [9]. The other three studies are of poor methodological quality, due to negative or unclear statements for appropriate measures and statistical analysis [10], [11], [14].

Finally, in 1 study a mixed-methods design is used [19]. We assessed this study as of moderate quality, without being possible to tell whether there are inconsistencies between the quantitative and qualitative findings and if the different components of the study adhere to the quality criteria of each tradition of the methods involved.

These findings suggest that 7 studies of good quality, 4 studies of moderate quality and 4 studies of low quality were included in this review. The studies of moderate and low quality were not excluded from the analysis, as the MMAT discourages this action.

C. VR Approaches and Tools

Two studies report a virtual SLE as a pedagogical tool, for visualizing the behavior of scattered ionizing radiation during radiological procedures. The virtual SLE was created, based on the 3D data generated by Monte-Carlo simulation and visualization using ParaView software and animations.

The Second Life 3D virtual platform is used in two studies, to represent a 3D virtual classroom. In this virtual classroom, the students had the chance to interact remotely and anonymously. 360° videos are reported in one study, to be used as the VR approach. 360° videos are recordings of the environment, using a 360° camera, which can film in every direction at once. With the use of HMD equipment or a VR headset, the users feel like they are in the recorded environment.

In 2 of the 15 studies, augmented reality (AR) is used to represent educational content in space (four dimensions, 4D). The first study reports WebAR, which was created to simulate the behavior of scattered ionizing radiation during radiological procedures. The second study reports on the Magic Mirror system. This system combines an AR projection of human anatomy with corresponding CT slices along the projected human anatomy. The users can review each CT slice, moving their hands along the AR projection.

In 9 of the 15 studies, an immersive virtual SLE is applied among the learners as a pedagogical tool. Virtual Environment for Radiotherapy Training (VERT), virtual CT simulator and 3D VR radiography simulator were used in those studies.

D. Population of Included Studies

The participants in 10 of the 15 studies are radiography, medical imaging, and radiation therapy students. In 5 of the 15 studies, the participants are medical students. 1 of the 15 studies investigate the application of VR simulation in an interdisciplinary workshop of radiation therapy and medical physics students.

E. Effectiveness of VR Approach

The outcomes of the studies recorded in Table II show that the impact of VR is rather beneficial for the students. The research by Nishi et al. [8] showed that participating students recorded high scores in the exercise questionnaire both for VR and AR modules. The research by Fujibuchi et al. [10] recorded key points of the virtual teaching material, which facilitated the understanding of radiation distribution. Thus, the students were able to acquire new knowledge and understand the invisible distribution of radiation in the workplace, while the simulation allowed them to imagine this situation, effectively connecting the theory with practice. Although the research of Sapkarosi et al. [12] showed no significant difference between a group of students with VR simulation students and a group of students with a clinical role-play scenario, it emphasized the benefit of repetition, which VR simulation offers. Repetition can help students retain and practice their skills. High scores of learning adequacy of the VR approach were recorded in two studies [14], [18]. Improvement of skills recorded in two more researches, which compared the effectiveness of VR simulation over a clinical role-play scenario [15,21]. Finally, the research by Bridge et al. emphasized time saving, as advantage for the academic staff workflow, but only in the case of introductory group teaching, and not as a replacement for individual clinical placements [22].

F. Students’ Perception on VR Approach

The feedback for each VR approach recorded in Table II, reflects the positive perception of students. In 3 of the 15 studies, an improved level of confidence in students is recorded, as a result of their exposure to a VLE or a virtual SLE [9], [13], [19]. In 4 of the 15 studies, enhanced conceptual comprehension and satisfaction after the use of VR are recorded [10], [19], [20], [22]. In 3 of 15 studies, the students declared that they would recommend the VR software they used to other students [9], [14], [18]. Finally, in 2 of the 15 studies, the students emphasized the improved overall experience, when the VR intervention was applied [11], [18]. In addition, VR is considered enjoyable and interesting, and gamification through VR can encourage students’ engagement and autonomous learning.
IV. DISCUSSION

A variety of VR approaches was recorded, including immersive virtual simulation and AR, screen-based VR, and 360° VR videos. Immersive technologies facilitate the engagement of the learner with an imaginary world, offering to the learner the advantage to interact with the virtual environment. Consequently, immersive technologies can help the development of practical skills of students, such as patient positioning during an x-ray. In the case of radiography students, 3D immersive virtual simulation is considered a valuable pedagogical tool [9]. According to Taubert et al. the advantage of immersive VR is the lack of real-world distractions, which happen when the learner uses a laptop, a tablet or a mobile phone [14]. On the other hand, screen-based VR can facilitate the comprehension and perception of imperceptible phenomena in space, such as the distribution of scattered ionizing radiation during radiological procedures [8], [10]. 360° videos can be used to put the learner inside a virtual environment, to offer a learning experience. However, this method does not offer to the user the advantage of interaction with the virtual environment [1]. Blurry or incorrectly adjusted visuals, tight headset strap and user’s extended immobility can cause discomfort, nausea, and fatigue [14].

Some VR training packages can deliver clinical scenarios, using dedicated equipment, a small space, and an easy and quick setup. In cases where HMD equipment is needed, a variety of HMD options is commercially available, making it simple to obtain one and connect it to a personal computer or laptop. Regarding some commercially available VR software packages, teaching staff and students do not need extra training to use them, as these are intuitive and easy to use [9], [12], [15], [21]. On the other hand, other VR contexts may require the guidance, coaching and observation of a faculty member or team [11], [13], [19], [20], [22].

According to O’Connor et al., students can access VR remotely, taking advantage of the flexibility of time and space. Integrating simulation-based learning into everyday practice gives students the advantage of organizing a self-directed learning program at their own pace [9].

Jimenez et al. outline in their paper that collaborative learning between students of allied disciplines can promote increased awareness and knowledge about their roles as future professionals. In addition, being part of a collaborative team can facilitate the development of communication skills and encourage learners to learn with, from and about each other [20]. An established pre-clinical collaborative background could potentially be translated into enhanced professional collaboration and subsequently improved health care delivery during a professional career.

Clinical practice in medical imaging and radiation therapy premises the use of ionizing radiation for imaging or therapeutic purposes. The application of virtual simulation alongside or before clinical practice allows students to repeat imaging or therapeutic scenarios after making errors, enabling them to correct those errors, without the risk of unwanted radiation exposures on patients or the need for traditional time-consuming role-plays in a constrained clinical setting [12], [15]. This condition is extremely beneficial, as it offers psychological safety to the students and recurrence to core learning objectives, promoting increased cognitive recall. Thus, they can safely practice, improve their performance, acquire the necessary skills, and enhance their self-confidence before clinical practice [13]. According to Bridge et al. [22], the inclusion of VR simulation in the learning and teaching of CT skills for students in medical ionizing radiation sciences can enable a safe and repetitive practice. In addition, Bridge et al. highlight the link of theory with practice, the preparation before clinical practice and the workflow understanding as benefits from the implementation of a VR scenario.

Regarding efficiency, it could be assumed that the application of virtual simulation can lead to a reduction of the required hours in a clinical setting, to achieve competency. However, clinical placements are a critical component of students’ practice, to exercise in a realistic environment, get to know difficulties and barriers and develop communication skills. In addition, there is only little quantitative evidence of enhancement of clinical performance through virtual simulation [12]. O’Connor et al. also record from the students’ point of view that VR lacks realism and interaction with the patient [9]. Therefore, it is still early to support the perspective of the reduction of clinical placements.

The COVID-19 pandemic has changed the delivery of education from the preschool level to higher education. Emerging global challenges, restrictions in social gatherings, social distancing and lockdowns around the world made imperative the use of digital technologies, to support remote education [24]. In addition, clinical placements were suspended for radiography and other biomedical sciences students in many countries, to prevent the spreading of coronavirus among students and society [25]. Considering that clinical practice and real-life simulation were impossible for medical ionizing radiation sciences students under the risk of infection, virtual simulation found its position among other emerging remote learning solutions, helping students to develop their clinical skills in a COVID-free virtual environment [13].

Possible barriers in low resource settings, such as reduced workforce in the clinical environment, absence of biomedical equipment or insufficient clinical placements can delay the clinical practice of students, leading to a gap between theory and practice. In addition, real-life simulation of biomedical equipment in an educational setting is not considered a choice for schools, due to prohibitive costs and requirements in space and shielding. In these cases, VR and virtual SLEs can be deployed and supply the necessary practical knowledge to the students [26].

In contrast with medical ionizing radiation sciences, many virtual systems have been introduced in medical education for pre-clinical training, endoscopic and interventional procedures, surgery, and other medical fields, since 1965, when Robert Mann introduced the first virtual system, to facilitate a new training environment for orthopedic [27]. In our review, the time range of included studies reveals that the application of VR and AR tools is a relatively recent approach in the education of medical ionizing radiation sciences. This fact can be explained, considering the recent growing demand for imaging and therapeutic procedures using ionizing radiation, the growing demand for patient
safety and radiation protection and awareness during these procedures and the need for healthcare systems to recruit practice-ready healthcare professionals in case of a health crisis. The pandemic of COVID-19 and the barriers in education have been an example, which highlighted the vital role of medical ionizing radiation practitioners in the treatment of patients, as well as the necessity for practice-ready graduates to immediately enter the healthcare systems.

As a pedagogical tool, VR offers a practical experience for students. In terms of effectiveness, VR promotes increased cognitive recall, convenience in conceptual comprehension and improvement of practical skills. Despite the flexibility, repetition, safety, and student engagement the VR offers, there are no bibliographic findings to advocate for a reduction of students’ clinical placements. Nevertheless, VR can help the connection of theory with practice in a low-resource setting or during a health crisis, like the COVID-19 pandemic. The lack of realism is an issue, which is offset by clinical placements.

This paper corroborates the pre-existing knowledge of the positive impact of VR tools in the education of students in medical ionizing radiation sciences. VR tools can contribute to a comprehensive digital learning portfolio, through which the learners will be able to monitor their progress and the administrators to evaluate the system-learner interaction data and track educational needs. Partnerships and collaboration between the academic institutions and the VR industry can help the adoption of the right VR solution, according to the training needs of students, while the increasing adoption can boost the VR industry’s growth.

CONFLICT OF INTEREST

The authors declare that they do not have any conflict of interest.

APPENDIX

The supplementary information of detailed criteria ratings of each study can be found online.

REFERENCES


Kleanthis A. Konstantinidis was born in Athens, Greece on the 26th of August 1981. He completed his studies in Radiographic Science and received his bachelor’s degree from the Department of Radiography and Radiation Therapy of the School of Health and Welfare Sciences, Technological Educational Institute of Athens in 2006. He received his master’s degree on Healthcare Services Administration from the Public Health School of the University of West Attica in 2019.

He started his professional career as a Diagnostic Radiographer in private healthcare sector 14 years ago, working in computed tomography, magnetic resonance imaging and x-rays. Since 2017, he is employed as a Diagnostic Radiographer in the Diagnostic Imaging Department of KAT General Hospital of Attica. His background in research is showed in his published work in Greek and international scientific journals and conference presentations, from 2020 until present. His research interests focus on digital tools for continuing education and training of healthcare professionals and radiographers.

Mr. Konstantinidis is an active member of the Greek Society of Medical Radiological Technologists, Greek Federation of Radiographers and Hellenic Health Services Management Association. He is also member of the editorial board of the scientific journal of Greek radiographers, called “Aktinotechnologia”.

Ioannis A. Apostolakis was born in Chania, Crete on the 24th of September 1961. He holds a bachelor’s degree in Mathematics (1983), MSc in Informatics, Operational Research and Education issues (1987) and a PhD in Medical Informatics (1993) at the University of Athens, Greece.

He works, as Teaching Staff, at School of Medicine of the University of Athens. He has been a scientific researcher for several years at the Department of Clinical Therapeutics of the University of Athens. He has research and educational activities on Health Informatics and Education (1995–2022). He has taught a wide range of courses at undergraduate and postgraduate level: Health Informatics, Information Systems, Computational Statistics, e-Government, e-Democracy, Virtual Communities, Research Methodology, Teaching Computer Science, Data analysis using statistical techniques. He has worked as an IT Specialist at Ministry of Interior (1989–1995) and as Head of Informatics Program at the National School of Public Administration (1995–2005).

Dr. Apostolakis has also been a member of program committee of many International Conferences and a reviewer for journals in the area of digital transformation in health care, digital educational models and e-learning tools.