Online teaching of radiation protection to health professionals: Lessons learned

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ABSTRACT

The study examines the online teaching of radiation protection to health professionals. Training in Radiological Protection is considered a basic requirement for radiology professionals and students in Health Sciences. Over the past 22 years, various educational materials, including videos and teaching resources, have been produced following the Guidelines on education and training in radiological protection for medical exposures of the European Commission. These materials have been utilized in various online learning modalities. The objective of this work is to assess the impact of this study on student training. To achieve this, different data collection processes have been carried out, according to the period, and have been analyzed. The results of this training have been analyzed through diverse methods, demonstrating adequate acquisition of basic theoretical contents and a positive acceptance of this methodology by the 6,518 students examined. However, the need to create original specialized materials and resources, the increase in the teacher's workload, and the lack of institutional recognition of the teacher's effort limit its development. On the other hand, it can also be concluded that the acquisition of practical skills by the student is a weakness of the online learning system that requires the incorporation of the teacher in a face-to-face or traditional manner in the delivery of these specialized practical contents. This study allows for a better utilization of the available tools in the training of students in this subject.

Keywords: *E-learning, Medical students, Postgraduate education, Radiology education, Radioprotection, Undergraduate education, Virtual lectures.*

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Highlights of this paper

- Over the past few years, online teaching has been incorporated into radiology and radiological protection education.
- The success of online training requires the use of appropriate educational resources.
- It has been possible to analyse the obtained results and the satisfaction level of students who have been trained in radiological protection through different modalities.

1. INTRODUCTION

Specialized training in Radiation Protection is considered a basic requirement for radiology professionals and students of Allied Health Sciences and has remained a priority line of training in the European Union since the publication of the Guidelines on education and training in radiation protection for medical exposures, the ERPET (European Radiation Protection Education and Training)Program (European Commission, 2002). In our university, an interdepartmental project grant awarded by the Spanish Ministry of Education and Science(Resolution of January 27, 1998) enabled the creation of novel and specialized teaching materials for a Radiological Protection ERPET based program. These have been published as manuals and practical teaching guides and are used by undergraduates (Technical and Vocational Training Technicians (Certificate II), specializing in radiodiagnosis, nuclear medicine, and radiotherapy) and in different university health science degree programs; these materials were hitherto non-existent in the Spanish educational system. The objective was to provide the student with scientifically up-to-date and didactically enjoyable material in their mother tongue. For this, the concepts of quality criteria in radiodiagnosis, radiation dose, and radioprotection and their implications had to be adequately presented, facilitating learning through the use of the computer and distance learning (e-learning) following the guidelines of the ERPET program of the European Union (European Commission, 2002). Since 2000, these materials have been used and adapted to conduct different editions of annual tele-learning courses (e-learning), through the Internet, which constituted the basis of the first national course on Radiation Protection and Quality Assurance in Radiodiagnosis in Spain. Subsequently, these contents were incorporated into the official study plans of different university degrees in Health Sciences (Medicine, Dentistry, and Nursing), complying with the recommendations of the Ministry of Education and Spanish universities for 15 years (2007- 2022). Additionally, these online courses and their materials have been used to obtain official accreditation, a mandatory legal requirement in Spain, to operate and/or regulate radiodiagnostic facilities for medical, veterinary, dental, and podiatric diagnostic purposes. These courses were approved by the Nuclear Safety Council of Spain and sponsored by the International Atomic Energy Agency (IAEA) as a Train the Trainers course to raise national experts in Guatemala (Instruction IS-17 of January 30, 2008).

During the last few years, e-learning has increased and has become an integral component of education in radiology and radiation protection. The demand for innovative and interactive resources has increased, and the suitability of this type of teaching compared to the traditional way of teaching has come to be considered (Belfi & Jordan, 2022; Carriero et al., 2011; Konstantinidis, Apostolakis, & Karaiskos, 2022; Pinto, Brunese, Pinto, Acampora, & Romano, 2011; Zafar, Safdar, & Zafar, 2014; Zitzmann, Matthisson, Ohla, & Joda, 2020).

The initial hypothesis in incorporating these "online" educational systems is to provide the student, within each of the different academic programs to which they belong, with an update of knowledge in radiological protection in a pleasant and entertaining manner, through interactive teaching methods. The objective of this study is to describe

the original digital resources required to conduct courses in radiation protection, the technical means necessary for their delivery in an online learning environment, the analysis, and the degree of student satisfaction, as well as the processes of adaptation to the educational needs of the student over a period of 22 consecutive years of online teaching.

2. MATERIALS AND METHODS

Three different time periods were identified during this study:

2.1. Initial Period (2000 – 2006)

Seven annual editions of educational promotion courses on "Radiation Protection and Quality Assurance in Radiodiagnosis. E-learning courses" were conducted. These e-learning courses were organized by the Clinical and Experimental Radiology Research Group, and a total of 1362 students completed official enrollment at the University of Murcia. The course was "on-line", and conducted through the Internet, where students were advised through synchronous and asynchronous tutorials that permit monitoring of students, as well as a self-evaluation process and another evaluation process of the student by the teacher. The Internet was used for work, following the standards of the HTML (Hypertext Markup Language) format to develop a web access portal that was placed as an independent server. The server used was a simple Veriton series computer (Acer Computer Iberic, Spain), equipped with a Pentium IV processor (Intel Corporation, California), 256 MB (MegaByte) of RAM (Random Access Memory), and a 40 GB (GygaByte) hard drive, equipped with Windows XP ("experience point") operating system (Microsoft Corporation, Redmond, Washington), and an 800x600 color monitor (Acer Computer Iberic, Spain). The equipment was connected to the LAN (local area network) network of the University of Murcia, dependent on RedIRIS (Integrated Routing and Intelligent Switching), the Spanish R&D (research and development) network that provides Internet access to official Spanish centers, through which the server has access to Internet. ATICA ("Área de Tecnologías de la Información y las Comunicaciones Aplicadas", Computer Service of the University of Murcia), provided us with the DNS (Domain Name System) or domain name http://radiologia.um.es that redirects all network requests from that address directly to our server.

In this way, access is easy from any computer connected to the Internet and allows one to work independently. For the software that served the web pages, we used the Apache distribution (Apache Software Foundation) version 2.0, locating the contents in HTML format that we designed within the server. The W3c(World Wide Web Consortium) proposed HTML language standards in HTML version 4.01 for the development of the access portal's content. All of these allowed us to teach the first tele-teaching course in Radiological Protection and Quality Assurance in Radiodiagnosis that has been developed at a national level through the Internet and that was developed thanks to a specific subsidy from the Nuclear Safety Council in its call I+D+I of 2001. The course offered two possibilities in its first edition: the possibility of physical presence for enrolled students who came from the Faculty of Medicine of the University of Murcia and exclusively virtual for all external university students. For the second edition, the course was exclusively virtual, through the Internet. The course has accreditations from the Educational Promotion Course of the University of Murcia and the Regional Scientific-Health Interest granted by the Department of Health of the Autonomous Community of the Region of Murcia (Spain). At the beginning and end of each edition of the course, a survey is conducted with students and teachers to assess its developments and determine possible modifications and additions required for inclusion in the next edition. Content evaluation is done through seven online exercises that permit certification of the courses. Figure 1 shows the current entry page for

the Teleteaching Course, which can be freely accessed on the following webpage (https://webs.um.es/mab/miwiki/doku.php?id=docencia).

2.2. Consolidation Period (2007 – 2022)

Since 2007 to the present, the contents of these materials have been incorporated into the official curricula of respective degrees (medicine, dentistry, and nursing), and the institutional Virtual Classroom of the University of Murcia has been used, which is the virtual teaching platform (e-learning) through which teachers and students have various telematic tools that facilitate the development of teaching and learning processes. At the same time, it provides other tools of a general nature that facilitate more flexible communication and allow access to the information and digital resources of the subjects. This virtual classroom is based on the Sakai e-learning platform. Sakai is Collaboration and Learning Environment (CLE) distributed as free and open software under the Educational Community license (https://www.sakailms.org/). These course contents have been followed so far by 4832 students in the various editions and grades. In medicine and nursing, the contents taught online account for approximately 50% of each subject (theoretical contents of radiation protection are offered in e-learning, while the rest of the medical radiology contents are taught in a traditional way). In dentistry, 100% of the contents are taught through e-learning.

In all courses, a knowledge survey exercise was conducted at the beginning of the course assessment, which assisted us in determining the student's previous knowledge. Results obtained were compared with the answers to the same exercise carried out at the end of the course. The exercise of evaluation remained the same, although the student was not privy to this information. Similarly, the degree of student satisfaction in each of the subjects taught in the assessment has been obtained voluntarily and anonymously. These student satisfaction surveys have been independently analyzed by the Quality Unit of the Office of the Vice President for Coordination and Quality of the University of Murcia (https://www.um.es/en/web/unica/unidad).

2.3. Specialization Period (2015 – 2022)

Since 2015, these materials have been used for postgraduate training of professionals in medicine, veterinary medicine, dentistry and nursing that need official accreditation to operate or direct radiodiagnostic facilities. The contents of these courses are officially regulated (Instruction IS-17 of January 30, 2008) and coincide with the ERPET programme of the European Commission. The Nuclear Safety Council of Spain has approved the 25-hour course workload. Practical activities must always be carried out in person. Four weeks prior to the official completion of the course, virtual access to the contents began, for which the institutional e-learning Virtual Classroom of the University of Murcia (Sakai Platform) was used to complement the theoretical components of the course. Twelve different specialized courses were mounted, which allowed 324 students to access official accreditation after passing the course requirements. Although it is not necessary to have the approval of the ethics committee, since it is not experimental research and all surveys and data were anonymous, complying with current legislation, it is available, as the ethics committee for experimentation at the University of Murcia granted approval for the project "Teaching experiences in medical imaging with biomedical engineering students in the virtual world Second Life" (decision number 158-2021-H), of which this work is part.

3. METHODOLOGY

During the initial (2000-2006) and consolidation (2015-2022) periods, students voluntarily completed a questionnaire (anonymously) both before and after undergoing the training course. The questionnaire asked them

about their personal and professional status (age, gender, years of practice, and prior education), their knowledge of physical parameters affecting dose and biological response to ionizing radiation, as well as their training in image processing and storage and current legislation on radiation protection (and its application). The questionnaire comprised 60 questions. Other authors consider achieving a level of 62.5% of the total score satisfactory (Absi, Drage, Thomas, Nash, & Newcombe, 2006; Martínez-Beneyto, Camacho-Alonso, Alcaraz-Baños, López-Jornet, & Perez-Lajarin, 2008). In our case, the acceptable level was set at 63% or higher. The results were analyzed using the statistical software SPSS® version 12.00 for Microsoft Windows (SPSS, Inc., Chicago, IL, USA). A significance level of $p < .01$ was accepted, with a 95% confidence level when comparing the results obtained before and after the course. The study of different parameters was conducted using Student's t-test for quantitative variables less than 2. One-way analysis of variance (ANOVA) was employed to assess the homogeneity of more than 2 quantitative variables. Post hoc analysis included Tukey's HSD (Honestly Significant Difference) test when a significant F-ratio from the ANOVA indicated a difference between groups.

From 2006 to the present (consolidation period, from 2007 to 2022), where these contents were included as compulsory subjects in the Medicine, Dentistry, and Nursing degrees, the quality and satisfaction reports of the students on the teaching of the subjects were conducted by the Quality Unit of the Vice President for Coordination and Quality of the University of Murcia through biannual surveys. This was done to find out the level of student satisfaction with the teaching activities, the subjects, and the corresponding degree awarded, comparing them with the rest of the studies at this university. The surveys were collected anonymously and voluntarily by independent and specialized personnel from the Quality Unit of the University of Murcia among enrolled students using a Likert Scale where 1 corresponds to "poor" and 5 to "excellent." A certain minimum of responses must necessarily be collected to be considered valid, although these varyaccording to sample size. Data analysis was performed by the Quality Unit of the University of Murcia, which requires a Cronbach's alpha coefficient (odd-and even procedure) of .98 and a Guttman coefficient of .98 as internal consistency analysis.

4. RESULTS

Until now, 6518 students have taken this course in different editions with official registration from the University of Murcia. Since its first edition (2000), there have been different modifications in its development, fundamentally induced by the development of Internet connections (telephony, modem, ADSL-Asimetric Digital Subscriber Line, LAN-Local Area Network), the possibilities of using the computer and Internet by students, and the possibilities of increasing down-loads of videos and executable programs, chats, or forums through the servers of the University of Murcia. Updates and modifications in the development of the different editions were important and mainly motivated by the rapid technological and social developments.

4.1. Initial Period (2000 – 2006)

The degree of computer usage has changed significantly since this study began. For instance, the percentage of students with a computer at home increased from 40% in 2000 (with only 30% having email and minimal internet access) to 92% in 2006 (with a significant increase in the use and knowledge of computer applications).

An example of this period is the results of the fourth edition, corresponding to the academic year 2004-2005: The course was followed by 222 students, 52 of whom were university graduates (doctors, dentists, physicists, chemists, biologists, and engineers), 12 university diplomas (nurses and physiotherapists), 9 radiodiagnostic specialist technicians, and 6 nursing assistants. But, in addition, together with them, the undergraduate students, there were 143 students who came from 10 different countries: 5 European countries (Spain, Finland, Italy,

Belgium, and France) and 5 Latin American countries (Argentina, Cuba, and Colombia with 3 students each; Mexico with 2, and Paraguay with 1 student).The students who followed the course in Spain came from 8 provinces: Vizcaya, Palma de Mallorca, Badajoz, Albacete, Seville, Alicante, Madrid, and Murcia. Only 3 students were able to successfully complete the continuous assessment tests necessary to obtain the final course diploma, mainly due to their inability to access the Internet and follow the developments of the course. Statistical analysis on access to the server revealed that the students followed the course with greater preference in the time slot between 6 and 7 pm (27%), with Wednesday being the day of the week with the highest number of acce sses (30%). The total number of visits (inputs to the server) during this edition amounted to 12002 entries recorded by our own server. From the server statistics, it stands out that access to multimedia content is accepted by the students, since the number of downloads of materials in Windows Media format (videos) was similar to the number of downloads of files (pdfs and Word) that contained directly assessable theoretical topics. The access error statistics demonstrated the good reliability of the system since the error messages were 90% of the student's failures when entering the password to access the system. The reliability of the network and infrastructure of the University of Murcia is acceptable, since at no time was the course server inaccessible, except during official maintenance by authorities of the University of Murcia, which was made to coincide with the hours of least access for the students, according to the traffic samples obtained from the statistics of our server. Seven partial evaluation and one final evaluations exercise of the course contents previously defined as "evaluable" were carried out. Answers obtained from teacher questionnaires, show that the students dedicated between 2 and 11hour of study per week to this course during the 14 weeks of the course, with an average of 7.0 ± 1.7 hours of study per week. Eighty-five percent (85%) of the theoretical contents of the course, written explanations, free publications offered, and images and videos used in the course were rated as good (level 4) or excellent (level 5) on a 1 to 5 Likert scale. The usefulness of the exposed links has been rated as excellent (level 5) by 80% of the respondents and the usefulness of the blocks of practical activities was mostly considered acceptable (level 3).

For 97% of the students, their first "on-line" course was conducted through the Internet and fundamentally highlighted the freedom to choose timetables, ease of access, and ease of follow-up. The most frequent criticisms were directed at the need to have access to computers (15%) and Internet connections (12%), especially for students outside their habitual residence; as well as the long periods of internal maintenance of the university network system that made it impossible to access the course servers (5%). 90% of the students described their experience taking the course as useful, innovative, and necessary.

They consider that the incorporation of these educational systems will be important in their next professional development. However, nearly 10% of the students were clearly against the teaching and learning procedure for different reasons; the need to study alone or in isolation despite the available forums and chats, aversion to using the computer, difficulties of Internet connectivity, absence of a face-to-face master class given by the teacher, impersonal relationship situations, and little motivation for the student's activity. Almost 1% of these students completely rejected this mode of teaching.

Table 1 shows the results of the grades obtained in the 2004-2005 edition of the course, in which significant differences were determined between the initial and final exams of the course, indicating a significant increase in the content learned by the students upon completion.

No significant differences were determined in the general qualifications obtained between this and the other editions of the course conducted within this initial period.

Table 1. Initial period: Percentage of correct answers of interested students and personnel interested in participation in the educational promotion courses before and at the end of the course (2004-5).

Sections	Before correct answer (%)	After correct answer (%)
Physics of ionizing radiation	10.3±0.5	70.2±5.4*
Risk of ionising radiation (Radiobiology)	25.7±3.6	89.0±6.1*
Radiation doses in dental radiography	12.3±1.6	80.4±7.4*
Factors affecting doses-equipment to exposure factors	7.1±1.9	80.7±6.7*
Principles of radiation protection practical measures	12.8±2.5	95.3±4.1*
Statutory requirements	35.4±3.8	98.7±1.2
Quality assurance	9.1±2.1	80.7±7.5*
General qualification	19.4±2.05	88.6±4.1*

Note: *$p < 0.01$.

Also, 42% of the students demanded a greater quantity of specialized videos in line with those already made and an increase in computer programs and interactive CD-ROMs (compact disc read-only memory), and images to complement the content offered. 12% of the students also requested an increase in forums or chats between groups of students that will allow interactive work in small groups to complement the only enabled chat. Ninety percent (90%) of the students from the University of Murcia consider that this course is an excellent idea for free student mobility, harmonized international credit recognition (harmonized equivalence scale), and useful preparation materials for subjects in the area of radiology and physical medicine.

The questionnaires made for the teachers show the three most important difficulties in the development of this type of teaching.

Firstly, the need to prepare original or freely accessible audiovisual materials and resources prior to the completion of these courses, which must be presented (texts, videos, presentations, and computer programs) as digitized resources and available on the computer media (90%). The lack of readily available free educational resources and the strict legislation that forbids the dissemination of such materials via the Internet make the situation worse(100%).

Secondly, the time necessary for the teacher to acquire sufficient computer knowledge to fully address the content of the course and also to allow them to adequately attend to the students is insufficient. The 14-week course was identified as inadequate time to maintain synchronous and asynchronous connections with structured individual tutorials, which requires a huge amount of teacher time, all contributing to loss of time to have a personal quality relationship with the student (98.5%).

Thirdly, the entire teaching staff also points to the low institutional appreciation of the university's academic authorities of this type of activity which is not taken into account in academic staff promotion. For this reason, they are involved in this project in the belief that the system allows evident improvements compared to the traditional system but that it is carried out exclusively due to personal interest based on voluntary participation in this type of project.

According to the survey carried out on teachers, the theoretical contents and collaborative and multimedia-based activities are well conducted and accepted by the students (93.2%).

However, the specialized practical activities (quality control tests, interpretation of radiological images, defects, and most frequent technical errors) of importance in professional education and training, are not adequately achieved with this type of training and are considered insufficient to obtain adequate learning of practical techniques and skills (89.5%).

4.2. Consolidation Period (2007 – 2022)

Technological developments and the incorporation of the contents into modern e-learning platforms such as the one used in this study (Sakai) have made connectivity and access problems sporadic. The student's ability to use the computer, Internet connection, and work online is already the prevailing condition. The use of the quality services of the University of Murcia made it possible to establish a degree of satisfaction in the students in the different aspects of the teaching and learning processes officially taught at different degrees of the University of Murcia. The contents comprise all the contents taught (for the Dentistry degree), or 50% of the contents of the corresponding subjects (Nursing and Medicine), co-existing with the other 50% of the subjects that were taught in a traditional face-to-face manner.

Table 2 shows the degree of student satisfaction with the teaching activity of the four subjects taught in the e-learning modality in the different academic years taken as a reference following the Likert scale 1-5. During this academic period, four subjects were taught every year: degree in nursing (subjects:biophysics, radiology and physical medicine); medical degree (subjects:radiology and physical medicine); dentistry degree (subject director of dental radiodiagnosis facilities); medical degree (subject medical physics). Different academic years were selected to show the results in each subject.

No statistically significant differences were determined for each of the subjects taught in the different academic years analyzed. The results of 2019-20 academic year corresponding to the mandatory confinement caused by the COVID-19 pandemic have been excluded from the study.

At the beginning of each course, the student representatives for each one of the subjects were called upon to choose their preferred teaching modality for practical aspects of the subjects (laboratory and hospital activities). In all cases, the chosen form was the traditional face-to-face method with the possibility of accessing the course contents previously prepared for use in e-learning.

Figure 1 also shows the degree of student satisfaction with the teaching activity of the four subjects taught in e-learning modality, allowing its comparison with the degree of student satisfaction with the subjects traditionally taught by the rest of the department's professors, and regular university degree programs following the Likert scale 1-5.

4.3. Specialization Period (2015 – 2022)

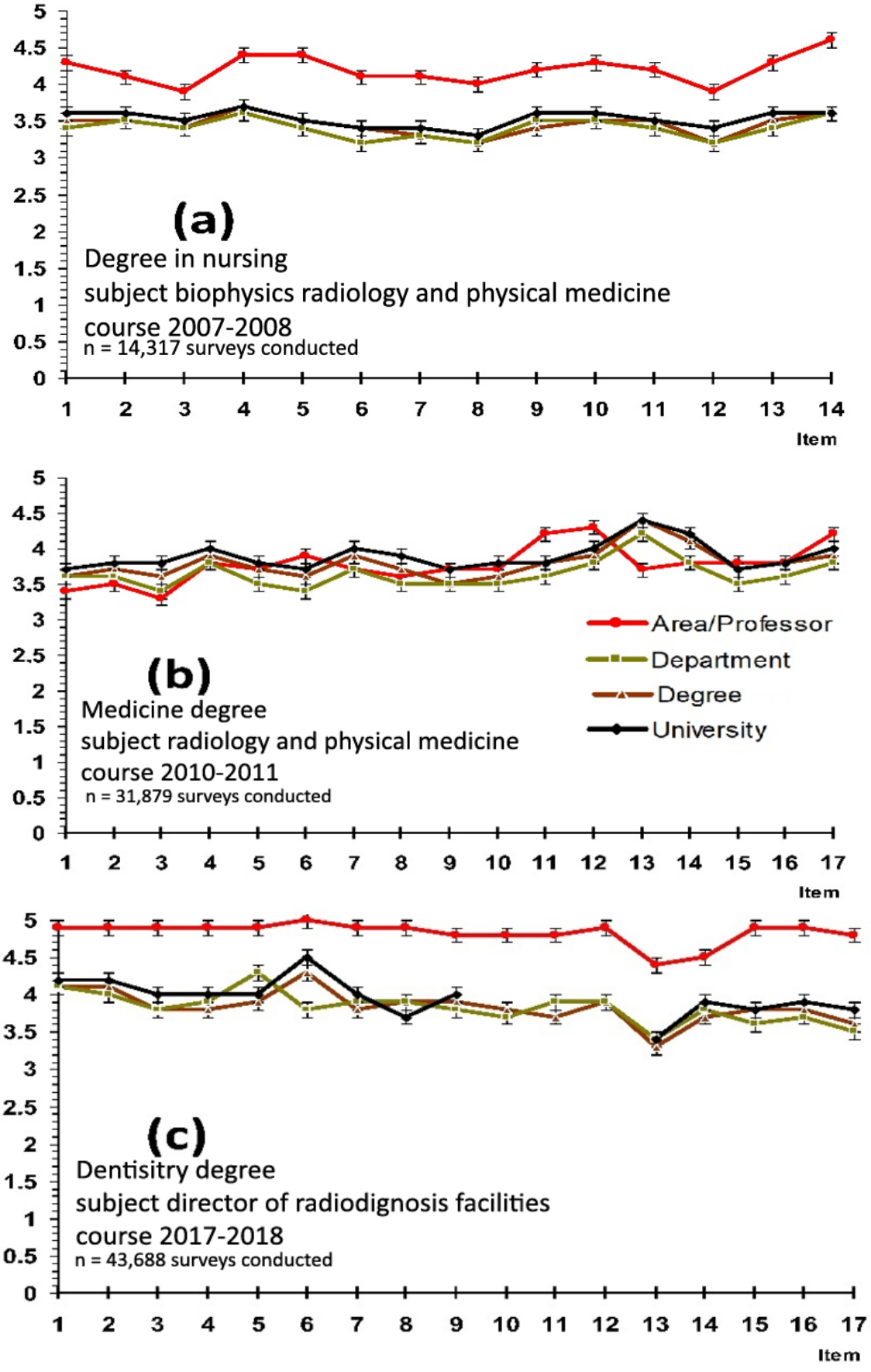
During this period, all enrolled students were working or will work immediately as operators or directors of radiodiagnostic facilities for medical purposes, so they took the course to meet a legal requirement. Table 3 displays the qualifications earned in the edition that took place during the 2016-2017 school year.

There were significant differences between the number of correct answers on the first exam and the number of correct answers ($p<.001$), indicating that the student learned a lot more after finishing it.

No significant differences were determined between the results of the qualifications general obtained in this edition with respect to those obtained in the other editions during this period of specialization.

Table 2. Consolidation period: Results of student satisfaction surveys with teaching activities of the academic staff of the university (Quality unit of the office of the vice president for coordination and quality of the university of Murcia)):((a) Degree in nursing, subject biophysics radiology and physical medicine, course 2007-2008; (b) Medical degree, subject radiology and physical medicine, course 2010-2011; (c) Dentistry degree, subject director of radiodiagnosis facilities, course 2017-2018; (d) Medical degree, medical physics, course 2021-2022 (Results are shown as mean ±standard error).

	Items	Nursing 2008 biophysics (n=74/130)	Medicine 2011 radiology (n=58/110)	Dentistry 2018 directors (n=12/24)	Medicine 2022 medical physics (n=34/106)
1.	Teacher complies with the agenda and activities (Proposed in the teaching guide) of the subject	4.3 ± 0.1	3.4 ± 0.1	4.9 ± 0.01	4.4 ± 0.1
2.	Teacher applies the evaluation criteria included in the teaching guide	4.1 ± 0.1	3.5 ± 0.1	4.9 ± 0.1	4.6 ± 0.1
3.	Theoretical and practical activities are well coordinated	3.9 ± 0.1	3.3 ± 0.1	4.9 ± 0.2	4.2 ± 0.2
4.	Activities developed by the teacher facilitate learning (Knowledge and skills)	4.4 ± 0.1	3.8 ± 0.1	4.9 ± 02	4.3 ± 0.2
5.	The explanations of the teacher help me to understand the contents of the subject	4.4 ± 0.1	3.7 ± 0.1	4.9 ± 0.1	4.4 ± 0.13
6.	The teacher has mastered the subject	4.1 ± 0.1	3.9 ± 0.1	5.0 ± 0.0	4.8 ± 0.1
7.	The teacher encourages student participation in class	4.1 ± 0.01	3.7 ± 0.1	4.9 ± 0.1	4.2 ± 0.2
8.	The teacher resolves doubts and guides correctly in the development of tasks	4.0 ± 0.1	3.6 ± 0.14	4.9 ± 0.1	4.3 ± 0.2
9.	The didactic resources used (Blackboard, audiovisual media, material on the virtual network, etc.) are useful and appropriate for classes and study	4.2 ± 0.1	3.7 ± 0.1	4.7 ± 0.2	4.0 ± 0.2
10.	In the tutorials (Both face-to-face and in the virtual classroom) I am satisfied with the help received by the teacher	4.3 ± 0.1	4.7 ± 0.1	4.8 ± 0.2	4.0 ± 0.2
11.	The teacher has managed to increase my interest in the content and skills taught in the subject	4.2± 0.1	4.3 ± 0.1	4.8 ± 0.2	3.7 ± 0.2
12.	Generally, assess the work done by the teacher, considering all the above aspects	3.9 ± 0.1	4.4 ± 0.1	4.9 ± 0.1	4.2 ± 0.1
13.	To plan the subject it is useful for me to consult the teaching guide	4.3± 0.1	3.7± 0.1	4.3± 0.4	3.2± 0.1
14.	The subject does not repeat the contents of other subjects	4.6 ± 0.1	3.8± 0.1	4.5± 02	4.2± 0.1
15.	The planning of class activities (Date, duration, etc.) is adequate to meet the objectives of the subject.		3.8± 0.1	4.9± 0.2	3.7± 0.1
16.	The bibliography used by the teacher is adequate (Understandable, updated, complete) to prepare the subject		3.8± 0.1	4.9± 0.1	3.3± 0.1
17.	The evaluation system seems appropriate to assess the learning and knowledge of students		4.2± 0.1	4.8± 0.2	3.5± 0.1


(a)
Degree in nursing
subject biophysics radiology and physical medicine
course 2007-2008
n = 14,317 surveys conducted
Item
(b)
Medicine degree
subject radiology and physical medicine
course 2010-2011
n = 31,879 surveys conducted
Area/Professor
Department
Degree
University
Item
(c)
Dentisitry degree
subject director of radiodignosis facilities
course 2017-2018
n = 43,688 surveys conducted
Item

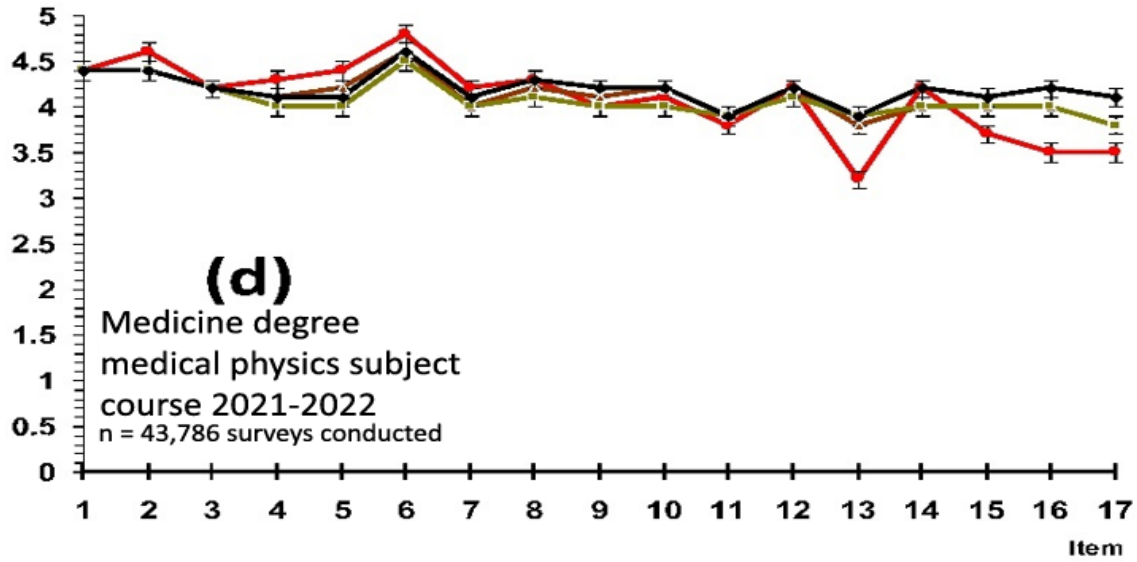


Figure 1. Consolidation period: Results of the student satisfaction surveys on the teaching activity of the subjects taught in e-learning modality comparing them with the subjects traditionally taught in person by the other professors of the department, the degree and the university: (a) Degree in nursing, subject biophysics, radiology and physical medicine, course 2007-2008; (b) Bachelor of medicine, subjects; Radiology and physical medicine, course 2010-2011; (c) Degree in dentistry, subject; director of radiodiagnosis facilities, course 2017-2018; (d) Physician title, subject; Medical physics course 2021-2022 (Results are shown likert scale 1-5 as mean ± standard error).

Table 3. Specialization period: Course aimed at professionals to achieve the official accreditation of director/Operator of radiodiagnostic facilities for medical, dental, veterinary or podiatric purposes, 2016-2017 edition.

Items	Correct answer (%)	
	Before	After
Physical characteristics of exposure to X-ray machine	23.1 ± 4.3	88.4 ± 6.2*
European union recommendations on intraoral radiology	70.2 ±.23.7±	94.2 ± 2.5*
Characteristics of aluminum filtration from X-ray equipment	22.5 ± 2.1	85.3 ± 5.9*
Characteristics of the rectangular collimator in intraoral radiology	5.2 ± 1.2	86.2 ± 1.4*
Mandatory signaling of radiation emission in radiological equipment	66.6 ± 2.3	98.3 ± 1.5*
Characteristics of personal protection working inside the radiological room	62.5 ± 4.3	97.4 ± 2.1*
Mandatory annual external audit on quality assurance	61 ± 3.9	99,5 ± 0.5*
X-ray film/Digital sensor characteristics	7.2 ± 1.2	63.5 ± 3.2*
X-ray film storage	21.4 ± 5.4	95.2 ± 2.7*
Characteristics of manual processing of radiographic film	3.2 ± 1.1	89.3 ± 3.4*
Characteristics of the automatic processing of the radiographic film	18.7 ± 2.1	92.2 ± 5.1*
Recommendations to reduce the radiation doses administered to the patient	32.5 ± 3.1	88.5 ± 3.7*
Quality assurance techniques in radiodiagnosis	2.3 ± 0.5	67.9 ± 7.4*

Note: *$p < 0.01$.

The teacher survey carried out on students shows a degree of satisfaction of 4.3±0.4 on the Likert scale and a recommendation to increase practical activities (42%) and reduce the theoretical load of the course (62%).

5. DISCUSSION AND CONCLUSIONS

Numerous studies show deficiencies in the initial training in radiation protection of undergraduate students and new healthcare professionals whose activities encompass the use of ionizing radiation. This may imply an increase in radiation exposure to both patients and the radiation workers themselves, thus leading to an increased risk of radiation-induced injuries (Absi et al., 2006; Faggioni, Paolicchi, Bastiani, Guido, & Caramella, 2017; Furmaniak, Kołodziejska, & Szopiński, 2016; Georges et al., 2009; Martínez-Beneyto et al., 2008; Van Puyvelde, Clarijs, Belmans, & Coeck, 2021). Several studies have shown that things get a lot better when special education courses are added. These courses are made up of hours of continuous training to keep the knowledge and skills of professional

who use ionising radiation to treat patients and do health tests up to date (Absi et al., 2006; Faggioni et al., 2017;Furmaniak et al., 2016; Georges et al., 2009; Martínez-Beneyto et al., 2008; Van Puyvelde et al., 2021).

From the review of the literature, numerous studies showed that with the application of new technologies and e-learning, knowledge acquired by persons involved in e-learning radiation protection and the different medical specialties that involve the use of ionizing radiation is at least as good as that obtained through traditional face-to-face teaching (Absi et al., 2006; Carriero et al., 2011; Konstantinidis et al., 2022; Pinto et al., 2011; Van Puyvelde et al., 2021; Zitzmann et al., 2020). In this study, an initial situation has been established for undergraduate students with deficiency in the knowledge of radiological protection as well as professionals who have started their careers and who use ionizing radiation in their daily routine, which is in agreement with what has been described previously by numerous authors (Absi et al., 2006; Faggioni et al., 2017; Furmaniak et al., 2016; Georges et al., 2009; Van Puyvelde et al., 2021). It has been suggested that this basic knowledge in radiological protection could be taught online, with the appropriate materials, since it is a teaching modality accepted by many students (Furmaniak et al., 2016; Martínez-Beneyto et al., 2008; Van Puyvelde et al., 2021). This means that the results show that e-learning on radiation protection meets the main theoretical goals set out in the European Commission's guidelines on education and training in radiation protection for medical exposures for health science students and professionals (Absi et al., 2006; Carriero et al., 2011; European Commission, 2002; Konstantinidis et al., 2022; Pinto et al., 2011; Van Puyvelde et al., 2021; Zitzmann et al., 2020). In addition, a high degree of student satisfaction is achieved, which is sufficient motivation to achieve the objectives of the course through e-learning (Carriero et al., 2011; Van Puyvelde et al., 2021).

Five decades ago, the first studies were published claiming improvements in the radiological training of students (Frank Squire & Becker, 1975). Although significant advances have been made during this time, radiological education in different university majors has lagged considerably behind social needs (Subramaniam & Gibson, 2007). A considerable number of computer-assisted and digital teaching projects have been included in the area of radiology and radiation protection. Already in 2003, a review of published papers on computer-assisted teaching in medicine showed that 24% of the studies analysed corresponded to the field of radiology, second only to those in the field of internal medicine (34%) (Letterie, 2003). In most studies, computer-assisted teaching and e-learning have been shown to be innovative, promising, and exciting (Absi et al., 2006; Carriero et al., 2011; Letterie, 2003;Zitzmann et al., 2020). However, until just a few years ago, it was still considered necessary to confirm the superiority of this technology by conclusively demonstrating that it is not detrimental to professional education (Frank Squire & Becker, 1975; Letterie, 2003; Mahnken, Baumann, Meister, Schmitt, & Fischer, 2011; Subramaniam & Gibson, 2007; Zafar et al., 2014). After 22 years of e-learning, this study confirms the advantages of these new educational tools, including interactivity, multimedia, open systems, independence of space-time, electronic publication, access to unlimited resources, intercultural communication, multiplicity of experts, student control over their own learning, absence of discrimination, collaborative learning, reasonable cost, and "on-line" evaluation of students and teachers (Alcaraz, Chico, Saura Iniesta, Armero, & Vicente, 2004; Mahnken et al., 2011; Van Puyvelde et al., 2021). Currently, different studies consider that the use of multimedia systems and e-learning is more effective for learning than the traditional teaching method and produces an evident improvement in student performance (Absi et al., 2006; Fleetwood et al., 2000; Goodman & Blake, 1996; Konstantinidis et al., 2022; Pelayo-Alvarez, Albert-Ros, Gil-Latorre, & Gutierrez-Sigler, 2000; Van Puyvelde et al., 2021). It has even been established that the more multimedia and interactive the teaching method is, the greater the student's participation and the greater its effectiveness in the learning obtained (Goodman & Blake, 1996). In this sense, a high level of student

interest in the topics covered has been determined, as has higher fulfilment of the assigned tasks and a high demand for teacher orientation.

However, some shortcomings in this form of electronically mediated learning in radiology have been detected. The article mostly talks about the benefits of e-learning in radiology and radiological protection. It does this by looking at how satisfied students were with the type of teaching that happened before, after, or during both stages of the e-learning courses and comparing them to traditional teaching (Zafar et al., 2014). In agreement with Zafar et al. (2014), no studies have been found to specifically demonstrate an improvement in performance in practical skills., in clinical practice, or in the analysis of patient responses, as these can be difficult to assess in medical education. Pretentious learning environments can affect practical and clinical skill competencies (Zafar et al., 2014). Usually, until recently, students have always preferred traditional face-to-face training to conduct all practical and clinical activities, to the detriment of virtual learning. The interaction with patients and learning of practical skills necessary for real professional development in matters of healthcare do not allow the adoption of correct measures that will have direct impact on protection of people's health. Therefore, to complement other studies, e-learning should not completely replace the traditional face-to-face method (teacher-student). Certain aspects, such as practical skills ("know how"), must be learned in the context of practice in the real world, which can also be enhanced with the use of technologies that emulate them. For some authors, they suggest that the appropriate ways to interact with colleagues and patients cannot be realized on a computer screen (Leong, Mc Laughlin, O'Connor, O'Flynn, & Maher, 2012; Lieberman, Abramson, Volkan, & McArdle, 2002; Zafar et al., 2014).

Under our circumstances, the biggest problem hampering the development of teaching activities through the useof these new technologies is ensuring that the teacher, a specialist in his field, not only creates the texts, videos, media, and specialized resources but also sufficiently masters these techniques to be able to properly incorporate them into his teaching style (Mahnken et al., 2011). Already in 1991, it was noted that the cost of developing computer-assisted teaching systems must include the cost of the time used by the teacher for these tasks. It has further been noted that, even when the teacher has a sufficient level of experience with computer technology, the development of computer-assisted programs requires so much time and energy that it is at least equivalent to writing a book (Keane, Norman, & Vickers, 1991). Our courses have been developed on the priority line of the European Union; trying to establish communication networks between the different levels that work with ionizing radiation and obtaining different competitive aids from public institutions that allow publication of the contents taught in e-learning and also in the traditional format. After delivering the first national course on radiological protection through the year in 2000 thanks to a competitive national R+D+i project granted by the Nuclear Safety Council, representatives of the Spanish Society of Radiological Protection (SSRP), the Spanish Society of Medical Radiology (SSMR), and the Spanish Association of Radiation Oncology (SARO) came to learn about the technological infrastructure necessary to carry out these courses taught over the Internet. The necessary technical means are few, however, the creation of original digital texts, videos, and teaching resources that allow free dissemination through the Internet and ownership of intellectual property rights has so far not allowed these institutions to carry out this type of course in the e-learning mode.

In Spain, adequate recognition of this mode of teaching is not included in the evaluation criteria for the promotion of faculty members of the university to enhance their professional careers. While clinical and research results are closely monitored at the hospital level, educational and teaching results are not valued in the same way. For example, the professors who participated in the creation of e-learning context materials are aware that this will not count towards academic promotion and tenure at the university, unlike traditional teaching, research, and scholarly works. This is because there is a no teacher impact factor assigned for this mode of teaching; however,

impact factors are awarded for scholarly works produced in specialized scientific journals, and these have been included as part of the evaluation criteria for Health Sciences teachers (Resolution of December 23, 2022).

In this study, the lowest degree of satisfaction among medical students was observed among students of nursing and dentistry, which could indicate that the higher the demand for academic training, the less satisfied they perceive e-learning. In addition, the attitude of our students, who systematically choose face-to-face learning to learn practical and clinical contents as opposed to e-learning compelled us to mix teaching where e-learning, is used to teach basic theoretical content and face-to-face or traditional teaching for contents requiring practical or clinical skills. Similarly, some studies don't see e-learning as an alternative method. Instead, they see it as a way to support traditional teaching (Mahnken et al., 2011; Meckfessel et al., 2011) or to improve learning outcomes by combining it with traditional teaching to help students better understand practical information (Autti, Autti, Vehmas, Laitalainen, & Kivisaari, 2007; Leong et al., 2012; Meckfessel et al., 2011; Zafar et al., 2014).

However, these results should be considered within the limitations of this study. It is a case study of the experiences of a single academic institution, attempting to adapt e-learning with very specialized knowledge in the health sciences, incorporating it into the regulatory rigidity of some official university studies, and conducted by a limited number of university professors.

6. CONCLUSIONS

The use of adequate digital didactic material is a necessary requirement to conduct this type of teaching, which can also be used to determine the level of knowledge that can be acquired and, therefore, possibly the initial professional capacity of the students. In order to support teachers, educational institutions should make an effort to create new didactic material.

Once the training process, both university and non-university, has been completed, e-learning allows for a continuous training process where it is possible to achieve basic theoretical objectives of radiological protection and quality control programs in radiodiagnosis. However, learning aspects and specialized practical skills ("know how") are insufficient in this teaching modality. In these cases, along with the dissemination of the information carried out through remote teaching and high-quality digital procedures, it should be complemented with practical face-to-face activities that allow the acquisition of said skills in a controlled and objective manner by the teacher. Especially in those activities where insufficient technical ability might imply significant risks to third parties, as pertains to the field of health sciences.

Finally, e-learning currently requires additional efforts from teachers, as they are not adequately rewarded for their extra efforts by the different organizations that control and accredit the academic promotion processes within universities in Spain.

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