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D7.1 Methodological Framework Guidance Document on Radiation Protection Education & Training (Draft Version)

Lead partner:	IPC
Author(s):	Graciano Paulo (IPC), Shane Foley (UCD), Joana Santos (IPC), Francisco Alves (IPC), João Paulo Figueiredo (IPC), Christoph Hoeschen (OvGU), Guy Frija (UP), John Damilakis (UoC), Katrine Riklund (UmU), Jonas Andersson (UmU), Ursula Nestle (UKLFR), Johnathan McNulty (UCD), Louise Rainford (UCD), Klaus Bacher (UGent)
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Abbreviations

BSS	Basic Safety Standards Directive
CIPRAM	Ibero-American Conference on Radiation Protection in Medicine
CPD	continued professional development
DoReMi	Low Dose Research towards Multidisciplinary Integration

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E&T	Education and training
EANM	European Association of Nuclear Medicine
EC	European Commission
ECTS	European Credit Transfer and Accumulation System
EFOMP	European Federation of Organizations for Medical Physics
EFRS	European Federation of Radiographer Societies
ENETRAP	European Network on Education and Training in Radiological Protection
ESR	European Society of Radiology
ESTRO	European Society for Radiotherapy and Oncology
EU	European Union
EURADOS	European Radiation Dosimetry Group
EURAMED	European Alliance for Medical Radiation Protection Research
HERCA	Heads of the European Radiological Protection Competent Authorities
IAEA	International Atomic Energy Agency
KSC	knowledge, skills, and competences
LLL	life-long learning
MELODI	Multidisciplinary European Low Dose Initiative
MPE	Medical Physics Expert
Rocc-n-roll	Roadmap interlinking to health and digitisation aspects
RP	Radiation Protection
RP&RAM	Radiation Protection and Radiation Application in Medicine
RPE	Radiation Protection Expert
RPO	Radiation Protection Officer
SRA	Strategic research agendas
WP	Work Package

Disclaimer

The opinions stated in this report reflect the opinions of the authors and not the opinion of the European Commission.

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1. Introduction

The Radiation Protection (RP) education and training (E&T) legal requirements for health professionals were defined when the first Euratom legislation for radiation protection was adopted [1]. The fast development of radiation applications in medicine increased the need for robust and updated RP E&T and several studies were promoted to characterise health professionals' radiation protection education and training[2–4].

Low Dose Research towards Multidisciplinary Integration (DoReMi) was funded by Euratom under the EU 7th Framework Programme to coordinate the EU research into risks from low-dose ionizing radiation. A DoReMi work package (WP) was dedicated to RP E&T, introducing research scientists to new topic areas and technologies. The program of education and training from DoReMi provided a significant contribution to the low-dose radiation research community and has been further developed and extended in the following Euratom-funded project OPERRA and the European Joint Programme CONCERT[5]. Other European platforms like Multidisciplinary European Low Dose Initiative (MELODI) and European Radiation Dosimetry Group (EURADOS) decided to cooperate to promote the integration and the efficiency of European RP research as well as to bring forward scientific E&T in the field of RP in medicine[6].

The European Alliance for Medical Radiation Protection Research (EURAMED) project European Medical application and Radiation protection Concept: strategic research agenda and Roadmap interlinking to health and digitisation aspects (rocc-n-roll) aims to propose an integrated and coordinated European approach to research and innovation in medical applications of ionising radiation and related radiation protection based on stakeholder consensus and existing activities in the field (incl. existing strategic research agendas, SRAs of radiation protection platforms, EC health and digitisation programmes, EURATOM-funded projects, SAMIRA initiative). The SRA will promote an interlinked approach with the overarching roadmap of the European radiation protection platforms as currently under development within the CONCERT EJP project within the health sector. An interlink document will show the links with the different research fields and contributing platforms and networks. To complement this aim E&T schemes for the health workforce and scientists to increase Europe's research capacity are crucial[7].

Several societies including the European Association of Nuclear Medicine (EANM), European Federation of Organizations for Medical Physics (EFOMP), European Federation of Radiographer Societies (EFRS), European Society of Radiology (ESR) and the European Society for Radiotherapy and Oncology (ESTRO), identified the most urgent and necessary five research areas of common strategic research agenda for RP, including concerns the metrics and the education of the staff and researchers[6].

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Concerns with RP E&T were already present by the European Commission (EC) with the inception of project Medical Radiation Protection Education and Training. A study on the implementation of the Medical Exposure Directive's requirements within the European Union (MEDRAPET), that aimed to improve the implementation of the Medical Exposure Directive provisions related to radiation protection education and training of medical professionals in the EU. This project resulted in the European Commission report Radiation Protection n. 175 (RP 175) that provides learning objectives compatible with the European Qualifications Framework (EQF), organised in knowledge, skills, and competences (KSC) and identified for all healthcare professions[1].

Other projects focus on the integration and harmonisation of the existing RP E&T is the European Network on Education and Training in Radiological Protection (ENETRAP). The ENETRAP III report indicated that effective RP E&T is a central element that helps to prevent the expertise decline and maintain and update the RP workforce. ENETRAP III added new and innovative topics to existing E&T approaches in RP. It further developed the European RP reference training scheme with additional specialised modules for Radiation Protection Experts[8].

More recently with the transposition of the European Basic Safety Standards (BSSD) Directive 59/2013, member states were required to promote and define RP E&T for health professionals employed in various fields. However, despite the existence of the RP 175 guidance document and legislation several studies revealed a large variation on health professionals RP E&T[9–11]. In order to promote radiation protection best practices, BSSD included the Radiation Protection Expert (RPE) and the Radiation Protection Officer (RPO) roles[12]. Based on BSSD requirements the Heads of the European Radiological Protection Competent Authorities (HERCA) created a recommendation to guide the implementation of the RPE and RPO requirements that includes KSC for both roles and refresher training[13].

Despite all the projects and guidelines mentioned before, the lack of harmonisation on RP E&T is a consensus and some of the weaknesses are reported. As for example the ones defined on a report of the Ibero-American Conference on Radiation Protection in Medicine (CIPRAM), established after a discussion to analyse problems and solutions on RP E&T for the health professional[14].

Also, the International Atomic Energy Agency (IAEA) published a report that defined a methodology for establishing a national strategy for education and training in radiation, transport, and waste safety[15]. More Recently IAEA also has identified strengths, common weaknesses and possible solutions and actions for improving radiation protection education and training of health professionals. The article presents a strong consensus for the need of international guidance on education and training in radiation protection and safety for health

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professionals and the requirement of an international description of minimum standards of initial and ongoing competence and qualification in radiation protection for relevant professional groups, considering the available recommendations at international and regional levels[16].

Under the EURAMED rocc-n-roll project, WP7 objectives are to design and pilot a dedicated E&T framework for health professionals and researchers to support Europe to achieve the integration aspects and common approaches and to carry out the research following the EURAMED rocc-n-roll SRA and roadmap and help the different communities understand each other, allow relevant clinical studies to be performed, and foster the transfer of research results and innovation into products and clinical practice.

A specific aim of WP7 was to analyse the existing RP E&T capabilities in the EU and identify the needs, problems, and challenges for each health profession in relation to the use of ionising radiation in medicine and related RP E&T. To fulfil this aim, a characterisation of the implementation status, at national level, of the requirements regarding E&T defined in the BSSD was also performed[1,12].

A small majority of the respondents indicated that RP topics are a part of undergraduate curricula in all courses for their profession and country (55%), however hands-on practical training is not included according to 30% of the respondents.

Significant differences were found per area of practice or research. While most "Dental Imaging" professionals reported having hands-on training during undergraduate curricula (64%), professionals in "Radiotherapy" (55%), "Medical Imaging and Radiotherapy" (52%) and "Nuclear Medicine" (46%), have chosen "Yes, in some".

The area of practice or research with the largest variation of responses was "Diagnostic Radiology" with 26% for "Yes, in some", 38% for "Yes, in all" and 36% for "No".

The majority (62%) of respondents rated E&T in RP in undergraduate curricula as "very good" or "adequate". However, 28% of respondents considered it "insufficient", and some reported that no RP topics were included (6%). Statistically significant differences were identified per area of practice or research. All reported professional areas, excepting "Radiotherapy" presented high levels of satisfaction on this subject, with more than 60% of responses categorised as "very good" or "adequate". Almost half of the Radiotherapy respondents (46%) rated E&T in RP as either insufficient or none.

Most respondents (66%) had hands-on practical training included during their residency/internship. However, respondents from "Diagnostic Radiology" (29%) and "Nuclear Medicine" (33%) indicated that no such training was included in their residency/internship. A

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small majority of the respondents (54%) rated RP E&T during residency/internship as "adequate". For Radiographers, the most frequent responses were "adequate" (48%) and "insufficient" (32%).

The need for mandatory RP E&T courses after entering a profession, as part of continuing professional development (CPD) was evaluated, with most respondents (68%) indicating that RP E&T CPD courses are mandatory. Differences were found per profession, where most respondents indicated that such CPD courses are mandatory CPD (values higher than 60%). However, a considerable number of "Other physicians" (60%), "Medical physicists" (37%), "Radiographers" (35%) and "Nuclear Medicine physicians" (33%) reported to not have mandatory CPD courses within RP E&T.

The periodicity of CPD was analysed based on the options "annually", "every 2-3 years", "every 4-5 years" and "every 6 or more years". The majority of the other professions indicated their CPD as every 4 to 5 years, for example: "Radiation Protection Expert" (67%), "Regulator" (60%), "Radiation Oncologist" (59%), "Medical Physicist" (52%), "Radiopharmacist" (50%), "Other Physician" (50%), Dentist (47%), "Nuclear Medicine Physician" (45%), "Radiologist" (44%) and "Radiographer" (38%). Only 34% of the respondent's performed a CPD programme with hands-on practical training included.

A list of 17 statements were presented to respondents to rate as "*no problem*", "*minor problem*", "*moderate problem*" or "*serious problem*". The top five "*serious problems*" identified by the respondents were:

1) Lack of professionals with sufficient RP E&T (35%);
2) Lack of adequate treatment protocols for paediatric patients (34%);
3) Lack of adequate imaging protocols for paediatric patients (34%);
4) Lack of practical aspects in current E&T in RP for health professionals (32%);
5) Lack of mandatory continuing E&T in RP for health professionals (31%).

The statements most frequently classified as "*no problem*" were:

1) Lack of RP recommendations and guidelines (32%);
2) Difficulties and/or limitations with regard to quality control of medical imaging & radiotherapy equipment (30%);
3) Lack of compliance with up-to-date Diagnostic Reference Levels (26%);
4) Lack of regulatory requirements for RP E&T programs for medical staff (25%);
5) Lack of availability of dose reduction technologies in equipment (25%).

The survey results revealed different RP E&T experiences and perceptions of problems and possibilities across Europe. It is important to underline that 12% of the respondents to this survey report the absence of RP topics as part of undergraduate curricula for their profession

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and country. Around 28% of the respondents that had undergraduate RP E&T classified the topic as insufficiently addressed and 6% as not included. The results revealed a heterogeneity of compliance with RP 175 and the BSSD. Different perceptions of the possible RP E&T problems and lack of legislation implementation were identified per area of practice/research and EU regions. The SWOT analysis of the results/impact of Medical Radiation Protection Education & Training aspects developed under previous EU framework programmes and EU-funded projects revealed:

❖ STRENGTHS

1. Ten-year history of collaboration across Europe via various radiation protection research platforms (MELODI, EURADOS and more recently EURAMED) and research projects and partnerships (DoReMi, OPERA, CONCERT);
2. Recognised importance of education and training (E&T) within EU project calls, with specific financial support to organise and manage E&T as part of EU-funded research projects;
3. Assessment of training needs already completed (ENETRAP 2005, RP175);
4. Strategic research agendas of radiation protection platforms have been produced and disseminated and include E&T elements;
5. Existing guidelines for E&T in RP for health professionals (EU, RP 175);
6. Euratom regulation and National Competent Authorities in existence for many years;
7. Some continued financial support for E&T, even in initiatives not specifically targeting the medical field (e.g. ENEN+);
8. Established Network and experience of organising European common training and initiatives on Education and Training in Radiological Protection in Europe (e.g. ENETRAP);
9. E&T initiatives support/encourage European mobility among students/trainees in the field of RP.

❖ WEAKNESSES

1. Lack of hands-on training courses
2. Lack of profession-specific training
3. Lack of proper understanding of the importance of RP in medicine
4. Lack of novel training methods e.g. blended learning incorporating simulation/online options; bite-sized learning
5. Lack of recognition and/or professional accreditation in some countries
6. Lack of standards on how to "train the trainers" to ensure that they can teach effectively
7. Lack of long duration courses with comprehensive coverage of RP topics
8. Lack of standardisation regarding content and scope of RP topics
9. Lack of proper and updated evidence-based E&T materials
10. Lack of guidance on how to best train for RP topics.

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❖ OPPORTUNITIES

1. Many recommendations have been made in the course of previous programmes, however, much of this work is between 10-15 years old. Opportunity to systematically review all recommendations and to propose up-to-date recommendations based on the findings of the review.
2. To focus RP E&T on the needs of the current, and future, clinical workforce (including consideration of different areas of practice and different professions and the need to build knowledge, skills, and competences, directly related to benefit-risk communication with patients and the public).
3. To focus RP E&T on the needs of the current, and future, medical radiation protection researchers (outside the clinical departments and including pre-clinical research).
4. To propose a sustainable and harmonised model for RP E&T (many past programmes have not succeeded in producing sustainable outcomes).
5. European-level accreditation or endorsement of a recommended, gold standard model of RP E&T by EURAMED and/or the professional societies EANM, EFOMP, EFRS, ESR, ESTRO.
6. To identify differences in contents and regulations of RP E&T in EU member states and to propose a European standard for mandatory E&T course contents and certification based on consensus.
7. To stress the importance of well-trained future generations of RP experts with sufficient knowledge, skills, and competences, to cover future needs of E&T.
8. To develop and deliver European-level online training programmes targeting all relevant professional groups to increase accessibility.
9. To develop RP E&T during the undergraduate course programs.

❖ THREATS

1. The awareness of the paramount importance of E&T in Radiation Protection and Radiation Application in Medicine (RP&RAM) for health professionals remains present inside a small community or group only.
2. Lack of time/space or interest by higher education institutions to include E&T in RP&RAM in the curricula of health professions, especially for clinical disciplines.
3. Some National Health Authorities are only focused on the inclusion of the requirement of E&T in RP&RAM and new technological developments in national legislation and do not care about their real application in the clinical setting and do not ensure their inclusion in life-long learning (LLL) for all health professionals involved in the application of ionising radiation.
4. Lack of awareness by hospital managers of the importance of E&T in RP&RAM.
5. Clinical researchers who include medical imaging procedures in their studies are not aware of the importance and need of E&T in RP.

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6. An evident gap between the health and research and the EURATOM communities (EURATOM with low engagement with clinical areas and the health community with low engagement with the EURATOM field).
7. Lack of awareness amongst health professionals regarding the huge heterogeneity in the medical imaging procedures that patients are exposed to across EU countries.
8. Considering the low impact of E&T in RP&RAM documents published as outputs of previous EU-funded projects, social media and self-learning tools play an increasing role among health professionals, bringing with it a lack of quality control of the contents available.
9. National scientific and professional societies do not attach sufficient importance to E&T in RP&RAM and new technological achievements, and do not include them in LLL programs.
10. Lack of incentives regarding role development in RP&RAM, leading to health professionals not interested in these topics and in understanding new applications and developments in the field.
11. Considering that all EU projects until now were focused on/oriented to E&T of Radiation Protection Officer (RPO), Radiation Protection Expert (RPE) and Medical Physics Expert (MPE), the health professionals' community got the impression that E&T in RP&RAM is only relevant for those groups

Based on the results of the SWOT analyses and the European E&T RO survey, EURAMED rocc-n-roll WP7 developed this education and training framework for health professionals and researchers, based on an analysis of the current education and training capabilities and needs assessment, to equip Europe to achieve these integration aspects and common approaches and to carry out the research following the EURAMED rocc-n-roll SRA and roadmap.

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2. Teaching and learning methodology

2.1 Educational Theory (Adult learning approaches)

The SWOT analysis performed by WP7 of EURAMED rocc-n-roll identified the opportunities in relation to radiation protection education and training regarding the needs of the current, and future, clinical workforce. This included consideration of different areas of practice and different professions as well as the need to build knowledge, skills, and competences, directly related to benefit-risk communication with patients and the public. The lack of profession specific training was an identified weakness as indicated above. Importantly, the opportunity to include the needs of the current, and future medical radiation protection researchers outside the clinical departments and inclusive of pre-clinical research. Additionally, whilst radiation protection training is required for those working with ionising radiation there is also a need to review radiation protection training requirements at undergraduate level for programmes training those involved in ionising radiation usage. A third cohort requiring training are those who “train” and the SWOT analysis identified a current weakness in “Training trainers” and the need to ensure that there are sufficient trainers within the training network. Educational theories related to adult learners and for those who train state require consideration as the quality of training is reliant upon the trainer. The trainers’ ability to attend training sessions balanced with busy professional careers requires consideration and the need to recognise the training activity as either part of their routine responsibilities or as expert trainers performing extra work activity external to their daily work.

2.1.1 Directed and Independent Learning

SWOT analysis identified opportunities to develop and deliver European-level online training programmes targeting all relevant professional groups to increase accessibility however the current lack of novel training methods e.g., blended learning incorporating simulation/online options; bite-sized learning were deemed weaknesses and requires redress. Amongst the recommendations identified in the SWOT analysis were bite-sized approach, modular offerings, and the availability of pre-reading material. Micro modular offerings for postgraduate training are becoming increasingly common and have been found to be welcomed by trainers and trainees. One advantage of discreet learning objects is that the updating of teaching material overtime can be efficiently achieved. Furthermore, the importance of self-reflection forms an important part of professional development[17].

Hands-on opportunities in training were highlighted in the SWOT analysis as an important factor in radiation protection training at local training sites, in particular training within the clinical environment and competency fulfilment[18].

Additionally, the SWOT analysis indicated consideration was required to achieve a sustainable and harmonised model of training and education in radiation protection. Harmonisation being

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important to facilitate Recognition and/or professional accreditation across countries and to support standardisation of practices across professional disciplines[19].

2.1.2 Optimising engagement

Optimising learner engagement across a large diversity of life experiences, cultural backgrounds, and everyday demands on them is difficult to achieve and relevant to a high-pressure clinical environment when time is limited and when multiple professions require consideration when planning radiation protection education[20]. How do we engage these professionals, stimulate the interest of the learners, motivate them, and ensure they feel their contributions matter? The SWOT analysis identified threats associated with a lack of importance placed upon radiation protection by many stakeholders including health care professionals, researchers, and hospital managers. Additionally, access to learning materials requires consideration and the incorporation of on-line learning options has become more routinely available in recent years[21–23].

2.1.3 Inclusiveness

An important aspect of educational programmes is their ability to ensure inclusiveness, this is particularly relevant for radiation protection education which spans so many professions. Learners learn in multiple methods and one method of teaching will suit some but not all of them [24]. The principles of Universal Design for Learning (UDL) are extremely important to all forms of education and training. These principles include consideration of possible learning disabilities some trainees may have such as dyslexia or dyspraxia. In addition to taught modules UDL considers how best to assess trainees which may at times include the option for assessment choice aligned to the trainee strengths. There is an increasing awareness of UDL, and this should be incorporated in all curricula design processes[25–28].

2.2 Practical approach (hands-on; simulation; use of specialized tools/software)

As pointed out by Chickering & Gamson (1987), learning is not a spectator sport, …(learners) must talk about what they are learning, write about it, apply it…', hence the current focus on student centred learning, in particular that learners are actively engaged rather than passive recipients of information. This indeed stems from constructivist theory, in which learners create or construct their own understanding, often additionally including collaborative and cooperative learning (social constructivism)[29]. Active learning approaches promote skill development as well as higher order thinking skills through a range of activities that stimulate the learner and have been shown to increase learner performance[30,31].

With this in mind RP course designers should incorporate active learning strategies within radiation protection education and training in line with pedagogical principles. This can take a

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range of formats and activities from classroom based to practical hands-on training in clinical settings or technology-based tools. As recommended by the ICRP 113 (2009)[32], RP training should be related to specific jobs and roles so that clinicians can relate to their own situations and practical training should be in a similar environment to that in which learners will be practicing. Therefore, course designers should ensure inclusion of practical activities in RP, which can be done in clinical environments with familiar equipment and practices to maximise adoption and implementation of learning into routine practice. Alternatively teaching technologies continue to develop at pace and the use of clinical simulation is increasing in frequency for competency-based training and may thus present a useful alternative option in particular where access to clinical settings is limited or learner numbers are particularly high such as with online remote asynchronous training. Recent technological advances such as the use of simulation software (virtual reality, simulation software, etc.) can obviate the need for clinical access while maximising the number of learners engaging in particular training in a safe setting, often with quality user specific feedback being provided. Current literature reports high learner satisfaction and approval of such technology[33,34]. Although such simulation tools are not yet widely available and come at a financial cost, alternative open-source versions also exist which can be easily adopted and incorporated into learning programmes[35].

Finally, when designing RP training courses, it is recommended that course designers consider the ICRP 113[32]recommendation that practical exercises and sessions should last 1-2 hours for the simplest training programmes or 20-40% of the total time scheduled in more extensive courses.

2.3 Teaching Content Design

In the design of training material, the teaching content needs to be carefully considered. The SWOT analysis identified that significant work had preceded the EURAMED rocc-roll project, however, the material would require updating. The SWOT analysis also identified the need to determine differences in contents and regulations of education and training in radiation protection training across EU member states so a European standard for mandatory education and training course contents and certification could be based on consensus. The importance of collaboration between educators and regulators was highlighted in the SWOT/TOWS analysis to enable recognition of training activities across different professions and jurisdictions.

2.4 Assessment Strategies

Assessment is key to the learning process and often drives learning in education[36], and while assessment is a vital tool to evidence specific learning achievements at given points of time, and may indeed be mandated to evidence professional learning, it is also a valuable method of providing feedback (i.e., using assessment for learning) and to help learners to self-regulate

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and critically evaluate their own performance (i.e. using assessment as learning)[37]. Therefore, program designers need to consider all three uses of assessment to maximise its value for learners.

Various principles regarding assessment have already been elucidated in educational publications such as validity, reliability, effectiveness, equity, practicality, transparency, and attribution[38]. Evidence shows[39] that assessment is most effective when used to engage students in learning that is productive and when assessment for learning is placed at the centre of the program design.

There are a wide range of assessment methods available each with their distinct benefits and practical uses. Obviously, the specific appropriateness of each will also vary in accordance with the method of learning used, whether delivered asynchronously on-line, in a blended manner or if evaluating competencies in the clinical environment. However, program designers should be mindful of universal design for learning principles[40] and provide learners with a variety of assessment options to engage and challenge learners while facilitating students with different strengths to demonstrate their KSC in ways that are inclusive[41]. Prior to choosing a specific assessment type, program designers should give thought to the aforementioned assessment principles and additionally with online assessment methods should carefully consider approaches to technology enhanced feedback as well as academic integrity[42].

As feedback from assessment is an important factor to drive further learning, feedback strategies should be considered during initial program design and the most appropriate methods chosen to maximise learner engagement with same. Program designers should be aware of good practices in making feedback more effective which should include that feedback be goal referenced, tangible and transparent, actionable, user-friendly, timely and ongoing[43], planning from the offset how feedback will be provided to learners.

2.5 Monitoring and evaluation of training

The need for robust quality procedures was repeatedly recorded in the SWOT analysis process of WP7. Higher education institutions typically have embedded quality processes in place for their teaching and learning practices, which includes both internal and external review and in particular regular learner feedback to ensure programs continue to be learner centric and constantly evolve to meet educational requirements. This is often conducted using standardised surveys to facilitate comparison between course offerings and time periods. However, such programs are usually designed according to local expertise, national requirements and to meet stakeholder/user interests resulting in a very heterogenous delivery between institutions both within and across Member States. Additionally, quality procedures are not so routine within smaller educational programs, in particular those delivering professional training or CPD activities, which are often delivered in a more informal

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environment or at a more local level and may be once off events or involve different educators for each iteration.

This is particularly relevant to the implementation of radiation protection education and training, where the EURAMED survey respondents recommended a European level lead accreditation process. While the European Credit Transfer and Accumulation System (ECTS) is already in place across Europe to facilitate transparency and comparability of education as well as recognition of learning, this is specific to higher education and there is currently no standard available for the harmonisation of the content of RP education and training. Creating such a standard or accreditation process would undoubtedly further promote quality of education and training by creating minimum requirements and importantly promote standardisation in this domain.

Such a process would require a collaboration of multiple key stakeholders, including educational institutions, professional societies, individual experts, and national regulators and thus would not be a simple or short process. However, introduction of an accreditation system, if even on a pilot voluntary basis, could reap significant benefits and would particularly be of interest to RP 'champions'. How accreditation and evaluation of training opportunities is progressed requires further research and debate but there already exists many templates in this domain at higher educational level/professional level and at European level[32].

3. Course structure

This chapter describes the recommended radiation protection education and training programme content for health professionals and researchers alike, but not in the specifics of the "train the trainers" part.

The radiation protection education and training programmes need to be developed mindful that various professionals will have greater or lesser involvement with medical exposures, so while all radiation users need to have minimum core competencies in radiation protection, this will vary substantially for example between medical physicists who might also have responsibilities as trainers of other health professionals in RP, to nurses and other healthcare workers not directly involved in the use of ionising radiation, but who need to be aware of ionising radiation risks as radiation is used within their clinical area.

3.1 Education and training principles

Both the ICRP in Publication 113[32] and the European Commission via Radiation Protection No. 175[1], previously set out basic recommendations for education and training in radiological protection and key principles from this are summarised below:

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a. RP training starts at entry level to professions and for those more directly involved in the use of ionising radiation, the education process should continue throughout their professional life as the collective knowledge of the subject develops. It should include specific training on related RP aspects as new equipment or techniques are introduced into a centre.
b. Training for healthcare professionals in RP should be related to their specific jobs and roles. A key component in the success of any training programme is to convince the engaged personnel about the importance of the principle of optimisation in RP so that they implement it in their routine practice. In order to achieve this, the training material must be relevant and presented in a manner that the clinicians can relate to their own situation.
c. A training programme in RP for healthcare professionals has to be oriented towards the type of training to which the target audience is accustomed. Practical training should be in a similar environment to that in which the participants will be practising.
d. It is essential that courses on RP for medical professionals are perceived as relevant and necessary, and only require a limited time commitment so that individuals can be persuaded of the advantages of attending.
e. Priority topics to be included in the training will depend on the involvement of the different professionals in medical exposures. For example, some operational aspects are important for radiologists and nuclear medicine specialists, but these are not relevant for referrers. However, most medical specialists will require knowledge of basic topics such as radiation hazards and risks. Interventional operators must be aware that deterministic/tissue effects have to be avoided by managing the doses to patients (and personnel) in such a way that they are kept well below the threshold values.
f. It is recognised that the division of tasks between professionals varies in different countries. Thus, training requirements will vary depending on the roles of individuals, and the amount of education and training should be determined by an assessment of the need and identification of specific training objectives.
g. Practical exercises and practical sessions should be included in the RP training programmes for those directly involved in procedures. A practical session in a clinical installation lasting at least 1–2 hours is recommended for the simplest training programmes, while 20–40% of the total time scheduled may be devoted to practical exercises in more extensive courses.
h. RP training should be updated when there is a significant change in radiology technique or radiation risk, and at intervals not exceeding 36 months.

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i. Medical physicists working in RP should have the highest level of training in RP as they have additional responsibilities as trainers in RP for other staff.

3.1.1 Core Learning

Learning outcomes for relevant health professionals listed as either radiation workers or non-radiation workers have already been identified as part of the Medrapet project[1], which lists core radiation protection topics for radiation workers (dentists, medical physicists, radiation oncologists, radiologists, radiographers, physicians,) as well as for non-radiation workers (referrers, nurses), see Table 1 below.

Table 1. Core radiation protection topics identified by RP175

1. Atomic structure, X-ray production and interaction of radiation
2. Nuclear structure and radioactivity
3. Radiological quantities and units
4. Physical characteristics of X-ray systems
5. Fundamentals of radiation detection
6. Fundamentals of radiobiology, biological effects of radiation
7. Risks of cancer and hereditary disease and effective dose
8. Risks of deterministic / tissue effects
9. General principles of radiation protection
10. Operational radiation protection
11.Particular patient radiation protection aspects
12. Particular staff radiation protection aspects
13. Typical doses from diagnostic procedures
14. Risks from foetal exposure to ionising radiation
15. Quality control and quality assurance in radiation protection
16. National regulations and international standards
17. Dose management of pregnant patients
18. Dose management of pregnant staff
19. The process of justification of imaging examinations
20. Management of accidents/unintentional exposures

In light of the time passed since this publication (2014)[1], a further targeted literature review was conducted of relevant European professional literature in particular of more recent professional societies curricula specifically in radiation protection educational content. This included review of the following documents:

- **EANM** benchmark document on Technologists competencies (2017)[44] and the EANM European nuclear medicine guide (2020)[45].
- **EFOMP** European Guidelines on Medical Physics Expert, RP No 174 (2014)[46].
- **EFRS** Radiation Protection Officer Role Descriptor (2020)[47].

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- **ESR** European training curriculum for radiology (Level I + II, training Years 1-3 and 4-5) - Edition March (2020)[48] .
- **ESTRO** Core Curriculum for Radiation Oncologists/Radiotherapists 4th Edition (2019)[49]and ESTRO Core Curriculum for RTTs (Radiation Therapists) – 3rd edition (2019)[50].

and in particular focused on more recent developments in radiation protection which may necessitate updating of the RP175 core topic list. Resulting from this targeted literature review, a small number (n=4) of additional topics were identified which were not clearly previously included and thus could be added to the core list identified in the above table, in particular in light of recent technological evolution and also legislative requirements.

Table 2. Supplementary core radiation protection topics identified

1. Ionising radiation benefit risk communication
2. Proficiency in use of both hardware and software regarding radiation protection applications
3. Protons in radiation therapy
4. Ethical aspects of radiation protection

It was agreed that topics 2 and 3 above could be included within a number of the RP175 core topics, namely Topics 10 and 11, however that topics 1 and 4 should be added as supplementary stand-alone core topics to be included, given their importance.

3.1.2 Elaboration of core radiation protection topics

To assist education providers when designing radiation protection education and training courses, the RP175 [1] core topics were further elaborated on (Table 3) to provide additional details as to recommended content within each topic. While this list is not exhaustive, it is intended to provide additional clarity and details as to the material that should be covered in basic training courses and should be discipline specific (radiology, nuclear medicine, radiation therapy).

Table 3 Elaboration of core radiation protection topics taken from RP175

1 Atomic structure, X-ray production and interaction of radiation	should include but not limited to an overview of atomic structures and sub-atomic particles, properties of radiation, radiation types: characteristic & braking, factors which affect quality & intensity of radiation produced. Interaction of radiation (x-rays, gamma, protons, etc.) with matter,
2 Nuclear structure and radioactivity	should include but not limited to the structure of the atom, the location, relative charge, and atomic mass of the sub-atomic particles, atomic number, the Bohr structure, isotopes and radioactive decay types and properties.
3 Radiological quantities and units	should include but not limited to units of radiation exposure and dose and their associated units including consideration of organ dose, effective dose, equivalent dose. In addition, radiation dose descriptors from different imaging and treatment modalities including their units and measurements should be detailed as required.

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4 Physical characteristics of X-ray systems	should include but not limited to X-ray tube components, cathode functions; thermionic emission, anode functions, electron interactions at the target, inherent and additional filtration, electricity requirements and factors that influence the quantity and quality of x-rays photons produced.
5 Fundamentals of radiation detection	should include but not limited to methods of detecting and measuring gamma and x-ray radiation including gas filled detectors (ionisation chambers), scintillators, solid state detectors and their associated advantages and disadvantages, for both patient and occupationally exposed worker dosimetry. The difficulties in measuring patient doses accurately, the role of radiation dose estimation via mathematical simulation in particular relevant to organ doses and resulting risks, the impact of patient size on radiation dose.
6 Fundamentals of radiobiology, biological effects of radiation	should include but not limited to ionizing radiation biological effects and risks from cellular to human level, the factors that affect the dose-effect relationship, relative biological effectiveness (x-ray photons, gamma rays, protons, etc.), acute and late effects from ionizing radiation, cellular repair mechanisms, radiosensitivity, fractionation, free radical influence, adaptive response.
7 Risks of cancer and hereditary disease and effective dose	should include but not limited to models of radiation risk including the linear no threshold model, basis for current cancer risk from radiation, individual radiosensitivity, epidemiology of radiation induced diseases, genetic radiation risks.
8 Risks of tissue reactions (previously deterministic effects)	should include but not limited to the type of effects produced and the related dose levels associated as well as the follow-up strategies to clinically deal with those effects, Definition of trigger levels and respective values as defined by international organizations and the levels of occupational exposure that can lead to tissue effects, such as the risk of cataracts.
9 General principles of radiation protection	should include but not limited to the rationale for radiation protection, understanding of radiation sources, acute and late effects of radiation including tissue effects and stochastic effects, patient, staff and public radiation protection, justification and optimisation principles including ALARA, selection of equipment and appropriate radiation dose optimising tools.
10 Operational radiation protection	should include but not limited to practical implementation of justification and optimisation principles, use of evidence based referral guidelines, use of diagnostic reference levels (DRLs), application of the inverse square law, limitation of exposure in particular via beam size limitation,, control of incidents involving ionising radiation, shielding materials (both primary and secondary barriers), operator and patient protection, safety during pregnancy, local rules and procedures, the use of audit, selection of appropriate equipment, advantages and disadvantages of automatic exposure control and radiation optimising software, establishing pregnancy status on relevant females, proficiency in use of both hardware and software regarding radiation protection applications, RP for protons.
11 Particular patient radiation protection aspects	should include but not limited to radiation protection of particular groups such as paediatrics, pregnant females, recurrently imaged patients, high dose examinations, high risk patients, use of both hardware and software regarding radiation protection applications, photon and proton radiation protection aspects.
12 Particular staff radiation protection aspects	should include but not limited to radiation protection practices in diagnostic radiology, nuclear medicine and radiotherapy with consideration of time, distance and shielding principles in addition to radiation beam optimisation, and personal dosimetry as well as education and training requirements. Pros and cons of various personal protective equipment as well as operational practices should be included relevant to the specific discipline and area of work. Specific radiation protection measures required in various modalities including diagnostic imaging, interventional fluoroscopy, nuclear medicine and radiotherapy procedures. Safe handling of radioactive substances management of radioactive contamination, management of radioactive waste.
13 Typical doses from diagnostic procedures	should include but not limited to doses from common diagnostic and therapeutic procedures as well as methods of communicating this information adequately to both patients and their carers as well as other health professionals. An understanding of relevant local and national diagnostic reference levels for common examinations.

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14 Risks from foetal exposure to ionising radiation	should include but not limited to an understanding of foetal growth, radiosensitivity in particular relevant to gestational age of exposure and should be relevant to both patients and workers, epidemiology of foetal risk, methods and limitations of current foetal dose measurement methodologies.
15 Quality control and quality assurance in radiation protection	should include but not limited to requirements as well as best practice in clinical audit in particular specific to ionising radiation practices and radiation dose management, which should include surveillance of equipment as well as processes/ practices.
16 National regulations and international standards	should include but not limited to national and international legislation (e.g. Euratom Basic Safety Standards, ICRP publications), responsibilities of different professionals (e.g. practitioner, referrer, radiographer, medical physicist) dose limits for workers and public, accidental exposure / radiation incident reporting requirements, audit requirements.
17 Dose management of pregnant patients	should include but not limited to understanding of foetal growth periods and radiosensitivity, stochastic risks of childhood cancer and tissue effects, relevant national policies guidelines in minimising foetal exposure, tissue effects, monitoring of foetal dose, foetal dose prevention/minimisation strategies including identifying pregnant patients appropriately, documenting justification and benefit-risk communication as well as consent issues as appropriate.
18 Dose management of pregnant staff	should include but not limited to national legislative requirements and local operating procedures, dose limits for both staff and foetus understanding of foetal growth periods and radiosensitivity, stochastic risks of childhood cancer and tissue effects, relevant national policies guidelines in minimising foetal exposure, tissue effects, monitoring/measurement of foetal/staff dose, foetal dose prevention / minimisation strategies.
19 The process of justification of imaging examinations	should include but not limited to the roles of referrer, practitioner, radiographer and patient in the justification process, balancing benefit vs risk and understanding metrics for both, the value of evidence-based referral guidelines, the necessity for regular audit of justification processes.
20 Management of accidents/unintentional exposures	should include but not limited to national legislation and processes for reporting accidents / unintended exposures, reporting mechanisms both locally and nationally as appropriate, the importance of disseminating information from lessons learnt.
21 Ionising radiation benefit-risk communication	should include but not limited to the ability to communicate the radiation risk to the patient or their carer at an understandable level, whenever there is a significant deterministic or stochastic risk, or when the patient has a question. Additionally, to provide clear information regarding safety measures to patients undergoing nuclear medicine procedures. Similarly, to communicate with other healthcare staff in particular when discussing justification of procedures.
24 Ethical aspects in Radiation Protection	should include but not limited to history of ethics in medicine, the understanding of the application of the main core values as defined by ICRP: beneficence/non-maleficence, prudence, justice, and dignity, in addition to the procedural values that play a role in the practical implementation of the core values such as: accountability, transparency, and inclusivity [51]as well as what is known of the dose response relationship with emphasis on the associated uncertainties, consideration of specific ethical situations as well as how to communicate with patients, carers and health professionals.

3.1.3 Volume of content

Core radiation protection topics identified must be included within curricula, but the extent to which each topic is covered should be decided according to the needs of each professional group. The ICRP in Publication 113[32] previously recommended the extent to which topics could be covered by various professional groups and ranked these in terms of priority (a. low level of knowledge indicating a general awareness and understanding of principles; b) medium level

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of knowledge indicating a basic understanding of the topic, sufficient to influence practices undertaken; c) high level of detailed knowledge and understanding, sufficient to be able to educate others). Additionally, the ICRP provided a suggested number of hours of training for each relevant professional (Table 3.1 and 3.2), which could serve as a useful guide for programme designers. However, learning outcomes should always be favoured as a method of gauging learning rather than accounting for hours, given this has noted limitations depending on how learners engage with the topics.

The design of curricula should be in line with the tables provided in RP175[1] knowledge skills and competences as well as the additional topics recommended here, according to the needs of each professional group. It is further recommended that curricula are based on the European Credit Transfer system (ECTS) to facilitate transparency, recognition of studies and transfer of learning between institutions.

For those dealing directly with radiation (namely medical physicists, radiation oncologists, radiographers, radiologists, etc) it is recommended that these radiation workers complete a minimum of 20 ECTS of basic radiation protection training, as a requirement for entry into each profession. For other professional groups, the above listed core RP topics need to be included and this is recommended as requiring a minimum of 5 ECTS education / training.

3.1.4 Continuing Professional Development in Radiation Protection

To ensure continued improvements in radiation protection, and thus improvements in patient safety and occupational safety, all professionals working with ionising radiation should ensure that radiation protection focused CPD forms part of their lifelong learning.

Within healthcare facilities utilising ionising radiation, a holistic, multidisciplinary, and collaborative approach should be taken towards radiation protection CPD. Such CPD activities should:

a. give due consideration to the 22 subject areas referenced in Table 3 above.
b. be focussed on individual requirements based on a personal development plan.
c. be based on individual needs (e.g. an individual working exclusively with CT may not benefit from engaging with IR-focused RP CPD), local requirements (e.g. systems, procedures, protocols, case mix), national resources and priorities.
d. be accessible and offered in various formats including smaller 'bite-sized' offerings which can be taken sequentially to address individual needs.
e. give due consideration of the format e.g. online, practical (online or in-person), inclusion of assessment of new knowledge or new skills gained

CPD is an essential part of developing a radiation protection culture and thus there is an onus on healthcare professionals, employers, and professional bodies to work to establish strong radiation protection CPD structures.

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3.1.5 Teaching, Learning, and Assessment Approaches

Due consideration must additionally be given to the most appropriate modes of education/training delivery and assessment as outlined in Section 2 here and also in the SWOT analysis. Course designers should prioritise active learning strategies that are learner centric and promote deeper learning e.g. problem-based learning, hands on practical approaches rather than a solely didactic approach and thus encourage practical implementation and improved long-term retention.

4. Training timelines

This chapter discusses possible timelines for RP training in Europe which can also be used as a baseline for a changed landscape regarding training for different professionals and in different areas of practice or research. It should be seen as a guiding document but can be adjusted according to local and or national additions. The presence of RP training in undergraduate curricula, during residency or internship and the presence E&T in the continuous professional development is crucial to achieve appropriate usage and optimization of ionising radiation in healthcare.

It is stated in the Council Directive 2013/59/Euratom[12] that practitioners and the individuals involved in the practical aspects of medical radiological procedures must have adequate education, information, and theoretical and practical training for the purpose of medical radiological practices, as well as relevant competence in RP and that the member states shall establish appropriate curricula for all relevant educations.

Existing national and international guidelines, as well as recommendations from professional societies for different health professionals are key documents for setting the requirements for each professional discipline[46,48–50]. Basic recommendations for E&T in RP are described in ICRP (2009) Publication 113 and in the European Commission via Radiation Protection No. 175[1,32]. RP175 could be used as a basis to formulate and implement a European standard for mandatory RP E&T courses and certification (face to face and online learning) based on consensus to meet the needs of the various professional groups. Ethical aspects and communication strategies of RP have been added after the publication of RP175[1]. The desired content of RP E&T is described in detail in chapter 3 in this document. It is demanded in the directive that the E&T in RP is generic, and mandatory[32].

It can be summarised that the legislation of mandatory courses and training in RP differs between countries and that a harmonisation with standardised training requirements across all member states in Europe should be advantageous to increase safety and optimised usage of ionising radiation in healthcare across borders. Even if increased steering by legislation is not a desirable way forward it could be useful in some respects.

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European legal requirements are then passed over to national authorities for adoption to country specific conditions.

A complementary way to homogenise the training timelines is to achieve European level accreditation of curricula and certification of individuals and overcome the national / political challenge of accepting European-level recommendations or qualifications on radiation protection E&T. This is useful for all three levels of education and training and has to be custom made for each program or profession. It will be worthy to develop strategies bringing together national authorities, educational institutions, professional societies, safety campaigns and manufacturers to create awareness for the need of harmonisation of procedures involving RAM.

Timelines for training are discussed over a timescale, starting with underground education, followed by training during residency or internship and ending with the continuing professional development. The online survey referred to has been distributed via the EURAMED rocc-n-roll consortium and 550 colleagues from different professions have responded.

4.1 During undergraduate training

In the survey it was found that over all radiation protection topics are part of all the undergraduate curricula in approximately half of the countries. However, significant differences were found between education for different professions and between areas of practice or research. Hands-on or practical training was identified in only one quarter of all undergraduate curricula and one third stated that it is not included. Most of the undergraduate training in dental imaging education and approximately half of the education in radiotherapy and medical imaging reported practical training in their curricula. More than half (61%) rated education and training in radiation protection as very good or adequate. Less than one third reported the quality as insufficient.

In accordance with BSSD[12] and RP175[1] all health professionals must have E&T in RP, but the content and timelines differ between different programs. It has been identified that there is a lack of harmonisation between the content and the timeline of E&T in RP between different undergraduate programmes and between countries. An initiative to harmonise at a proper level is needed. Undergraduate training in disciplines using ionising radiation covers many educational programmes and the content and timeline must be aligned with respective programmes. It is well known that the need for E&T in RP differs significantly between different professionals but everybody in healthcare needs a foundation of knowledge in RP. The content and the timeline have to be described in the curricula and appropriate for each educational program.

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A practical recommendation to implement E&T in RP during undergraduate training for all health professionals that emerged from the SWOT analysis performed under this project, is to encourage collaboration between regulators, higher education institutions and professional societies, to ensure existing regulations[12] regarding E&T are implemented in Member States.

The inclusion of E&T RP during undergraduate training may vary from the inclusion of specific disciplines in the course program or by including RP topics in other disciplines, as long it is guaranteed that the respective KSC for each health professional are obtained.

4.2 During residency or internship

More than half of the participants of the EURAMED rocc-n-roll survey responded that radiation protection training is part of all residency or internship programmes and the responses were similar between different professions and between countries. Approximately one third reported that no hands-on training was done during residency or internship and differences between professionals were identified. No significant differences between countries and professions were identified. The E&T was scored as adequate in more than half of the responses and one fifth scored it as very good.

Even if the quality of existing training overall is of high quality the prevalence of training is too low. The situation that only half of the residents and internships report training is not sufficient. If training is needed for half of the group, the situation should develop in the direction of giving all during residency or internship this education. It is important to combine theoretical with hands-on training and the training must be in line with the practical work with usage of methods using ionising radiation. When starting the work at a department using ionising radiation an introductory education should be mandatory. The development of a hands-on training program through healthcare facilities following national or European guidelines could minimise the cross-border heterogeneity both during residency and internship but also during the continuous professional development.

The need for E&T in RP spans from basic knowledge to advanced level and the work in the actual professional or research area sets the demands. The timeline should be set so the training precedes the real working life activities during residency or internship. The content of E&T in RP should align with the real work to come.

4.3 During continuous professional development

In the questionnaire two thirds reported that repeated radiation protection education is mandatory. In this group significant differences were found between different professions. In the group “other physicians” as many as almost two thirds reported repeated education and training as not mandatory and more than half (60%) of the physicists also reported not to have

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mandatory repeated education. Approximately one third of the nuclear medicine physicians and the radiographers reported not to have mandatory repeated education and training.

Regarding the frequency of repetition intervals between one and six or more years was reported, with significant differences between professionals and area of practice or research. Half of the radiologists and nuclear medicine specialists have mandatory courses annually or every second to third year while professionals in radiotherapy and radiotherapy reported longer intervals of four to five years. This was consistent over countries. Even if the mandatory interval differed most of the responders reported that they had attended a radiation protection course during the last three years. These courses are mostly theoretical and only one third contained hands-on training. The differences between countries are significant and more than half of the courses in continuous professional development in Northern Europa contain hands-on training.

In some countries regulatory requirements set the standard and timeline for medical staff even if there are differences between Radiology and Radiotherapy, but in some countries, legislation is missing.

Building on the initial, formal, education and training in radiation protection for health professionals, it is essential that systems are established to facilitate CPD on a regular basis. This is an essential requirement for lifelong learning and the maintenance of knowledge, skills, and competence in radiation protection, which are aligned with the latest developments. CPD may be mandated at local or national levels for many health professionals, however, individuals should also be aware of the importance of CPD as part of their personal and professional development. Where CPD is not mandated, professional bodies/societies, employers, and the individual health professionals, hold responsibility for making sure CPD is accessible, encouraged, and supported.

The extent of CPD will vary according to many factors including previous education, available local technology, local expertise etc, but should in as much as possible be practical and hands on, using local equipment. No minimum requirement is specified here although the BSSD[12] requires that such training be repeated at 'appropriate intervals' and documented (Article 14) and in the special case of the clinical use of new techniques, training is provided on these techniques and the relevant radiation protection requirements (Article 18 (3)). The EURAMED survey revealed that CPD course hours and subjects for healthcare professionals are sometimes predefined by local legislation. In some cases, regulation might even limit the accredited subjects of a CPD program to radiation protection of patients and carers/comforters. As a result, important topics like staff radiation protection might be excluded from CPD programs in these countries. There is evidence of different requirements for CPD in different countries but whatever the design of CPD, it should include all relevant aspects of staff and patient RP.

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It can be concluded that repeated training is needed for professionals using ionising radiation in health care and taking the behaviour in Europe into consideration, an interval of 3-4 years seems appropriate, nevertheless it should occur immediately after new techniques or dose reduction technologies (hardware or software) are implemented in the hospital. The training should be a combination of theoretical and hands-on training, adapted to the specific needs of the clinical workforce. The existing EU guidance documents on E&T in RP could be used as a tool to engage/empower national health professional societies to achieve implementation of CPD E&T in RP.

5. Train the trainers

This chapter describes the recommended actions identified to train and support trainers in RP, within pertinent lifelong learning programmes for healthcare professionals, and related needs. These recommendations are based on the existing literature[52], European guidance documents[1,15,53] , as well as two novel papers prepared within the EURAMED rocc-n-roll project[54,55].

The goal of this chapter is to underline the primary outcome, which is to achieve healthcare professionals with appropriate knowledge regarding RP, and how to find, maintain, continuously develop, and support the trainers needed for this task. This means that the daily practices of healthcare professionals, when using ionising radiation, are quality-minded and safe, i.e., similarly to the expectations on all other aspects of patient safety and work environment regulations in Europe.

Some initiatives at European level shows that implementing the concept of teamwork, in the field of E&T in RP, integrating medial doctors, radiographers and medical physicists, significantly contributes to increase the radiation protection culture in medical imaging and radiotherapy departments (e.g. Eurosafe imaging campaign). However, literature identifies a lack of implementation of this concept in daily clinical practice, such as “the need for multidisciplinary approach to E&T that incorporate a team of educators with RP expertise from a range of professions/disciplines”[56]. This lack of effective teamwork between professionals across medical disciplines has been identified as a common weakness in developing KSC of health professionals related to RP[16].

Also, the survey made under EURAMED Rocc-n-roll project has identified, under the top 5 serious problems: “the lack of professionals with sufficient E&T in RP” and lack of mandatory CPD in RP for health professionals.

To fulfil the fundamental radiation safety legislative demands, e.g., justification, optimisation, and dose limits[12] it is of paramount importance the implementation of CPD programs for health professionals involved in the use of ionizing radiation in medical field.

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Considering the exponential technological growth in the field of medical imaging and radiotherapy, both hardware and software driven, with considerable potential for patient and staff dose reduction, high-quality training programs with evidence-based education is of extreme importance to have competent health professionals in the field of RP. It is in this aspect that trainers play an essential role and indirectly determine the health care quality delivered to the patients[57].

5.1 Education and Training of Trainers

It is important to clarify what is meant by training the trainers for RP. Formally, training may be considered as what is done to achieve the necessary knowledge about how to perform practical work, while education is mostly about theory. However, in many contexts, these words are often used interchangeably[58].

Every trainer needs two different sets of knowledge and skills. First, they must know what subject they are teaching (content-related expertise), secondly, they must know how to convey this information (instruction expertise). However, in practice, this is not always the case, as there can be trainers with very high content-related expertise, but with low capacity of applying the adequate teaching methodologies or have the communication skills to engage others in the learning process.

A better approach, than separating different aspects of RP training, is a collaboration between educators and trainers from various disciplines, e.g., medical doctors, radiographers, and medical physicists for training of staff. With this approach, the rationale for RP can be explained from a physical perspective together with clinical needs and requirements.

5.2 Identifying and Recruiting Trainers

A good trainer needs specific attributes, besides being knowledgeable in the field of RP, such as being skilful in passing their knowledge in a simple and effective way, adapting the teaching methodology to each specific audience. The trainer must have positive attributes[57] such as:

1. Character:

- Approachability
- Patience
- Enthusiasm
- Encouraging/supportiveness

2. Operative:

- Willingness to let trainee to practice
- Balance between supervision and independence

3. Teaching and communication:

- Sets educational aims and objectives

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- Ability to use appropriate feedback
- Communication skills
- Time availability to train

4. Clinical:

- Capable
- Good relationships with the health care team

In addition, trainers should be well respected reflective and open to receive feedback. After identifying trainers with such attributes, the next step is to develop a train-the trainer (TTT) course as a strategy to improve training performance and enhance the learning curves of the trainees in the field of RP[59]. The TTT is a framework for training the trainers, empowering them to train others in RP.

The TTT course should focus on fundamental educational concepts and teaching practices and should be designed based on two essential subject matters: a) learner-centred coaching with the ability to adapt tempo and content according to the trainee's personalised learning objectives and level of skills; b) instructions on providing real-time, constructive feedback and debriefing after a training exercise. In each phase, reflection is considered an integral part and includes self-reflection, peer's opinions, and concurrent expert feedback[57].

5.3 Strategies and Goals for Continuous Professional Development of Trainers

European strategy and guidance documentation has repeatedly underlined the importance of CPD. The Council Resolution on a strategic framework for European cooperation in education and training towards the European Education Area and beyond (2021-2030) has the following strong recommendations[52]:

- At EU level, the vision for quality in education and training makes mastering key competences, including basic skills, fundamental bases for future success, supported by highly qualified and motivated teachers and trainers, as well as other educational staff. As set out in the Council Recommendation of 22 May 2018 on key competences for lifelong learning[60].
- As an essential element of lifelong learning and an important means of enhancing personal development, employability and adaptability, mobility for learners, teachers, teacher trainers and staff should continue to be expanded as a key element of EU cooperation and a tool to enhance quality and inclusion in education and training and promote multilingualism in the EU. It is important to strive for a balance in the mobility flows in order to stimulate optimal brain circulation and to monitor it, including through graduate tracking.

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The same document[52] ,under section Strategic priority 3: Enhancing competences and motivation in the education profession, has the following recommendations:

1. Teachers, trainers, educational and pedagogical staff and education and training leaders, at all levels, are at the heart of education and training. To support innovation, inclusion, quality and achievement in education and training, educators must be highly competent and motivated, which requires a range of professional learning opportunities and support throughout their careers.

2. More than ever, attention needs to be paid to the well-being of teachers, trainers and educational staff in education and training systems, which is an important factor also for the quality of education and training, as it affects not only teacher satisfaction but also the quality of teaching.

3. Furthermore, the pivotal role of education and training leadership should be taken into account when developing favourable environments and conditions for the development of competences and motivation of teachers, trainers and educational staff, thus ensuring that education and training institutions operate as learning organisations. Initiatives such as the European Teachers Academies, which will be launched through the Erasmus+ programme, will facilitate networking, knowledge sharing and mobility among institutions providing teachers and trainers with learning opportunities at all phases of teachers' and trainers' careers, sharing of best practices and innovative pedagogies, allowing for mutual learning at a European scale.

And finally, from this report[52], the following concrete issues and actions are proposed for teachers and trainers with regard to CPD:

I. Strengthening the recruitment and selection of the best and most suitable candidates for the teaching and pedagogical profession at all levels and in all types of education and training.

II. Raising the attractiveness and the status of the teaching and pedagogical profession, by its revalorization in social and also in financial terms, including through the foreseen European Innovative Teaching Award.

III. Explore the possibility of developing a European guidance for the development of national career frameworks and lifelong guidance, thus supporting the career progression of school education professionals.

IV. Explore the possibility of developing policy tools in a form of teacher competence frameworks to increase relevance of initial teacher education programmes as well as development of continuous professional development opportunities and to provide guidance for teachers in their career progression.

V. Supporting initial education, induction and continuous professional development at all levels, especially to deal with the increased diversity of learners and their specific needs, to tackle early leaving from education and training to promote work-based learning, supporting the development of basic and advanced digital competences and innovative pedagogies, including ensuring that teacher education addresses teachers' competences to teach in digital environments.

VI. Supporting the promotion of excellence in teaching at all levels of education and training, through effective organisation of learning and structural incentives, by

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> promoting appropriate support mechanisms, infrastructure and teaching materials and research-based teacher education, as well as exploring new ways to assess the quality of teacher training.

The European Commission Radiation Protection 175 report has the following recommendations on CPD[1] :

Specifically, in order to plan and provide effective education and training, education providers should have the necessary knowledge and skills in the radiation protection aspects of the procedures carried out by the practitioners involved in the training activity[32]. Training in medical radiation protection is very challenging, considering the rapid technological developments and the complex science involved in modern imaging procedures. For this reason, the development of 'train-the-trainer' schemes is of crucial importance to provide the best possible opportunities to medical physicists and other experts involved in medical radiation protection training.

These are the recommendations from the International Atomic Energy Agency (IAEA) regarding CPD, from their report; On the development and implementation of education and training programmes, IAEA Safety Report Series Nº. 93 – A Methodology for Establishing a National Strategy for Education and Training in Radiation, Transport and Waste Safety [15]:

> Aspects to be addressed include consideration of appropriate implementation methods. For example, every identified education and training need should be matched with an appropriate methodology, such as attendance at a structured course, on the job training or distance learning. Likewise, requirements for training facilities are expected to be established when appropriate, prerequisite experience and/or qualifications for trainers specified and guidance provided on content, format and preparation of training materials.
>
> One of the most important and effective means of optimizing resources and transferring the skills necessary for building competence is the TTT approach. This is aimed at training those who will become trainers, with a cascading effect that will make available a large number of trained personnel in a reasonable time frame. The desired end point is a pool of trainers with technical competence, practical experience, and teaching and communication skills in order to allow the establishment of a sustainable and self-supporting training programme in the country.
>
> A country could consider adopting mechanisms for training the trainers with short- and long-term approaches.
>
> In the first case, the country could make use of resources available abroad, for example inviting international experts to train local trainers, or organizing scientific visits for local trainers to well established foreign institutions to enable them to gain the necessary experience. Potential local trainers could also be sent as observers or participants to specifically designed training courses organized by international organizations (e.g. the IAEA has been regularly organizing workshops for training the trainers of Radiation Protection Officers: RPOs)."

In the IAEA report, the following action is proposed with regard to training the trainers[61]:

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> Action 17. Government and education and training providers take long term actions to build national competence over time (Action 10 (b), (2)). For example, when building sustainable competence through the TTT approach, the following initiatives are expected to be considered: - Inviting international experts to train local trainers, organizing scientific visits for local trainers to well established foreign institutions to enable them to gain the necessary experience, and sending observers/participants to specifically design training courses organized by international organizations (e.g. the IAEA). The government might need to take specific actions at certain times (e.g. requesting support in the framework of the IAEA technical cooperation programme).

In the European Monitor 2020 report on Teaching and Learning in the Digital Age, the following statements are made on CPD[55]:

> However, teachers were not adequately prepared to use digital technologies in the classroom before the crisis. Investment in digital infrastructure and tools has not always been adequately accompanied by appropriate preparation of teachers. On average in the EU, fewer than half of teachers (49.1%) report that ICT was included in their formal education or training. Moreover, while a growing number of teachers participate in CPD programmes related to the use of digital technologies, this does not always translate into teaching practices.

In stark contrast to all of these strong recommendation in European guidance documents, EURAMED Rocc-n-roll WP7 found through a European survey that RP education and training is not performing as expected.

5.4 Digitalization and e-learning as Part of Teaching

Digitalization and e-learning has been a part of universities, as well as healthcare, education and training for some time. Associated with this trend are obvious opportunities for more cost-effective teaching, but downsides have also been identified, perhaps most prominently during the Covid-19 pandemic when various digital learning solutions became the norm. Nevertheless, there are definitive possibilities also for RP education and training within the new digitized world with distributed materials.

The Monitor 2020 report on Teaching and Learning in the Digital Age has some valuable insights that can be extrapolated to RP education and training[55]:

> The COVID-19 pandemic has exposed more than 100 million Europeans, who are part of the education and training community, to new realities, new ways of communicating, learning and teaching. During this difficult period, education institutions and teachers demonstrated their dedication to learners' wellbeing and continued learning, as well as their enormous capacity for flexibility, creativity and innovation. At the same time, however, the crisis shone a spotlight on existing weaknesses in our education systems. Socio-economic background is still the most important determinant of educational outcomes in

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> the EU, and the crisis is likely to have the most detrimental effect on those learners who were already in a disadvantaged position before it started.
>
> However, teachers were not adequately prepared to use digital technologies in the classroom before the crisis. Investment in digital infrastructure and tools has not always been adequately accompanied by appropriate preparation of teachers. On average in the EU, fewer than half of teachers (49.1%) report that ICT was included in their formal education or training. Moreover, while a growing number of teachers participate in CPD programmes related to the use of digital technologies, this does not always translate into teaching practices.

As concluded by the Monitor 2020 report, digitalization and e-learning is not a magic bullet that by or in itself will solve the persistent problems in European education and training. However, there are opportunities which should be employed also for RP education and training[55].

More important to maintain and develop quality in education and training could be to promote work-based learning, the development of basic and advanced digital competences and innovative pedagogies.

Further improvements to education and training within radiation protection in the medical field could be built upon the creation of networks of education institutions through the proposed Erasmus Teaching Academies, which would provide further learning opportunities for teachers. Another beneficial strategy would be to support innovation within the field and to inform national and European teacher education policy makers and organisations.

To build strong and attractive career paths within education and training, excellence in teaching at all levels should be promoted. New ways to assess quality of teacher training should be explored, promoted, and be made an incentive for staff promotion and salary. Furthermore, the possibilities and pitfalls of digitalization and e-learning must be navigated for RP aspects of teaching in Europe.

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Accreditation and certification

According to the SWOT analysis performed under this project, one of the opportunities identified is the development of a European-level accreditation gold standard model for E&T in RP, using for that purpose the existence of well-established networks between European professional societies, organized under EU platforms, such as EURAMED, supported by regulators, also organized at EU level, such as the Heads of the European Radiological Protection Competent Authorities[13].

This European-level accreditation of E&T RP programs and certification of individuals would considerably contribute to overcoming the national/political challenge of accepting qualifications from other countries, conditioning the desirable professional free movement across the European Union. Since the publication of the MEDRAPET guidelines[1] by the European Commission in 2014, it was stated: "Medical radiation protection education and training courses must be accredited by an external, independent accreditation body with the involvement and representation of the relevant specialists", which would also allow the accreditation through different educational programs if performed in combination with the European Credit Transfer System (ECTS).

Achieving this desideratum is of extreme importance as it would also contribute for the implementation of a radiation protection safety culture across Europe. And might even help for harmonising education and training on a higher level, at least allowing to fix a minimum requirement for contents of education and training as well.

The minimum requirements for accreditation of a training programme should take into account aspects related to admission policy, facilities, staff, certification programmes, educational material, teaching methods, administration and archives, course updates and course evaluation.

On other hand, certification is a process that recognises an individual medical professional who has demonstrated special knowledge and expertise in medical radiation protection and has successfully completed the education or training provided by an accredited organisation.

There is already some form of accreditation like what is provided by the Accreditation Council in Imaging (ACI), but this is not specific in radiation protection CPD, for which accreditation should be designed and controlled by the expert organisations.

Combining both, accreditation and certification of E&T in RP, is the way forward to provide better and safer healthcare to EU citizens, by decreasing the exposures to the dangers arising from the exposure to ionising radiation while keeping its great benefits in medical care.

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