Faculty of Life and Health Sciences of Ulster University

Education of Therapeutic Radiographers in the European Union: competencies, professional mobility and patient care

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I confirm that the word count of this thesis is less than 100,000 words

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ABSTRACT

Introduction: Radiography education varies across Europe, potentially leading to variation in competency levels and patient care. This is relevant for European Union (EU) countries, given the free movement of professionals across member states. This study aimed to assess Radiotherapy (RT) education across the EU and its impact on competency, patient care, and professional mobility, focusing on TRs working in the linear accelerator (linac).

Methods: An explanatory, sequential, multiphase mixed-method design was used, following philosophical principles of pragmatism. Document analyses were conducted to identify professional regulations across EU, patterns of recognition of qualifications between member states, and competencies of TRs working on the linac. These results informed the survey design investigating course characteristics and competency levels across Europe. Interviews with European stakeholders further explored the survey results, assessing the impact of education characteristics on professional mobility, competency levels, and patient care.

Results: Education regulation vary considerably between member states, affecting graduates' competencies and patient care. Competency levels on the linac depend on academic level, use of international guidelines in course design, amount of RT-specific training, number of specialisms in the programme, programme duration, use of simulation, availability of academic staff with RT expertise, and teaching methods, among other non-education factors. However, when learning outcomes (competencies) are regulated, all other factors must be adjusted to achieve these objectives. In certain countries, specific course characteristics, such as low academic level and short programmes, or the lack of professional regulation, hinder the recognition of graduates' qualifications abroad.

Conclusion: RT education varies considerably across Europe due to the variation in national regulation. Regulation of the learning outcomes and academic level guarantees adequate competency, irrespective of the education model used. Standardisation across Europe could harmonise care and facilitate professional mobility. Irrespective of regulations, education institutions can improve competencies by considering the factors above when designing programmes.

ABREVIATIONS AND GLOSSARY

This list of abbreviations and glossary includes the main terms used in this dissertation and their explanation in the context of this study. Further discussion of some of the most relevant terms may also be found across the dissertation.

ASRT: American Society of Radiologic Technologists

BoK: Body of Knowledge – Set of concepts, skills and activities that constitute the professional domain.

CINAHL: Cumulative Index to Nursing and Allied Health – A library database hosted by EBSCO.

Competency: Ability to apply knowledge and skills into practise (based on EQF guidelines). Competency can be developed at various levels, with corresponding levels of autonomy and responsibility.

CPD: Continuous Professional Development

DR: Diagnostic Radiographer – Title used to refer to radiographers who practise in the MI specialism. In most cases this title includes the NM specialism, however, in specific cases these two specialisms may be separated. Refer to NMT.

EANM: European Association of Nuclear Medicine

EC: European Commission

ECTS: European Credit Transfer and Accumulation System

EFRS: European Federation of Radiography Societies

EHEA: European Higher Education Area

EI: Education institution

EP: Electrophysiology – In very few European countries, electrophysiology is a specialism of radiography. This branch of the profession performs electrophysiology exams such as electrocardiograms and electroencephalograms.

EQF: European Qualifications Framework – Framework aimed at defining the KSC for the different academic levels allowing for comparison of level between member states. The levels vary between EQF1 (lowest level at primary school level) and EQF8 (PhD).

ERG: Erasmus Radiography Group

ERIC: Educational Resources Information Centre – A literature database hosted by EBSCO and ProQuest.

ESCO: European Skills/Competencies, qualifications, and Occupations – A European database of occupations and corresponding qualifications and competencies

ESTRO: European Society of Radiotherapy and Oncology

EU: European Union

Graduate: In the context of this dissertation, it refers to a person who successfully completes a course programme irrespective of the academic level.

HCPC: Health and Care Professions Council

HE: Higher education

HEI: Higher education institution

IAEA: International Atomic Energy Agency

ISRRT: International Society of Radiographers and Radiological Technologists

KSC: Knowledge, Skills and Competencies – The three domains of learning outcomes defined by Recommendation of the European Parliament and of the Council on the establishment of the EQF for lifelong learning.

Linac: Linear accelerator – equipment capable of producing high energy photon and electron beams used to treat a variety of pathologies, mostly cancer.

MI: Medical Imaging – Field of medicine and science that uses different imaging modalities (such as X-rays and ultrasound) to image the human body. In the context of this study, it also refers to the Radiography specialism, which focuses on these fields of medicine and science.

MRI: Magnetic Resonance Imaging

NM: Nuclear Medicine – Field of medicine and science that uses unsealed radionuclides to image the human body or treat diseases. In the context of this study, it also refers to the Radiography specialism, which focuses on these fields of medicine and science.

NMT: Nuclear Medicine Technologist – Title used to refer radiographers who practise in the NM specialism.

RPD: Regulated Professions Database – Database set up by the EC that provides information on regulated professions across the EU as well as statistics and contacts with the aim of facilitate movement of professionals.

RTT: Radiation Therapist – Widely used title for professionals working in RT. Please refer to RT.

RT: Radiotherapy – Field of medicine and science that uses high-energy ionising radiation to treat a variety of pathologies (mostly malignant). The radiotherapy process encompasses all steps from planning, treatment, and follow-up. In the context of this study, it also refers to the Radiography specialism focussing on these fields of medicine and science.

Radiographer: Title overarching all professionals in the different specialisms of radiography (MI, RT, NM, and EP), irrespective if they are able to practise one or multiple specialisms.

Radiography: Profession that includes health allied professionals who practise RT, MI, and NM. It also refers to the science that studies these healthcare areas. In few countries it also includes EP.

Specialism: Branch of the radiography profession. The most common specialisms are RT and MI. However, depending on the context, other specialisms may apply, such as NM and EP.

TR: Therapeutic radiographer - Title used in some countries, including the UK, and by professional associations to refer to the radiographer practising RT. Other titles that can be found: “radiation therapist”, “radiotherapist”, “therapeutic radiographer”, “radiotherapy technologist” among others. These professionals may also be referred to as “radiographer”.

UK: United Kingdom

DECLARATION

I confirm that the content of this thesis is my own work and it has not been submitted, in part or whole, to any other university of institution. I declare that with effect from the date of which the thesis is deposited in Ulster University.

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CHAPTER 1. INTRODUCTION

Across the European Union (EU), it has been estimated that, in 2020, 2.7 million new cancer cases were diagnosed, and 1.3 million deaths occurred due to this disease (Joint Research Centre, 2021). This epidemiological data exposes the pressure caused by such disease on healthcare services. Considering that Radiotherapy (RT) is used in about 50% of cancer cases (Barton et al., 2014), this led to high demand for this treatment modality. The increase in patient throughput also led to concerns about the quality of care, requiring planning ahead to ensure a competent workforce (Ferlay et al., 2018).

A key member of this workforce is the therapeutic radiographer (TR). The most common roles of the TR include delivering radiation to a target region in the body, pre-treatment procedures (such as image acquisition and the planning of RT treatments), patient care, amongst many other roles, performed as part of a multidisciplinary team. All these roles are necessary to provide the patient with the best outcomes (Society of Radiographers, 2018a). Despite the variety of roles performed by TRs, this work focuses on the competencies of TRs delivering radiation to cancer patients using the linear accelerator (linac), which is the role performed by most TRs. This role is of high importance since accuracy in radiation delivery is vital to obtain the desired outcome. If treatment is not adequately administered, it may increase side effects and decrease tumour control (ICRP, 2000).

This study also aims to have a European picture of these professionals; however, the profession varies considerably between countries. In many European countries, TRs are an independent profession, in other countries, they fall under the general title of radiographers, which consists of two main specialisms: Medical Imaging (MI) and

Radiotherapy (RT) (EFRS, 2011; Society of Radiographers, 2020). In this study, the title “therapeutic radiographer” (TR) refers to those practising RT only and “diagnostic radiographer” (DR) was used for professionals practising MI only. The terms “radiography” and “radiographer” were used as overarching terms that include all specialisms. A detailed exploration of the radiography profession can be found in section 2.2, “The Radiography profession” and the specific roles of therapeutic radiographers are described in section 2.2.1, “The therapeutic radiographer (TR)”.

Through education, TRs would be better positioned to provide and deliver care now and in the future (Booth and Manning, 2006; Colyer, 2007; May et al., 2008; Niemi and Paasivaara, 2007; Smith and Reeves, 2009). However, radiographers’ education is not standardised across the EU and each member state has its own regulations. This variation in education includes different specialisms, academic levels (vocationally or in universities), course durations, workloads, and curricula. These educational differences result in variation of roles and responsibilities taken by TRs across Europe (EFRS, 2010; HENRE, 2008a; Janaszczyk and Bogusz-Czerniewicz, 2011; McNulty et al., 2016). Given the consequences of the misadministration of RT treatments, TRs have a huge responsibility, making proper education essential for adequate patient care (Baeza, 2012). Thus, the primary motivation for this research is to improve education so that patient treatment is not compromised by low competency levels of TRs working on the linac.

Various attempts have been made to standardise radiographers’ education across Europe (HENRE, 2008a, 2008b); however, this was never achieved. Some studies acknowledge the variation but do not identify the barriers to harmonisation (Janaszczyk and Bogusz-Czerniewicz, 2011; McNulty et al., 2016). The immense variation in education across countries may be a barrier for reform since aligning long-established education structures across many countries with so many differences would be a challenge. Additionally, the education reform would impact the profession, adding difficulty to the process. However, understanding the barriers requires additional research.

A clear picture of the regulation of the profession across EU member-states is not available. Despite the existence of international benchmarking documents identifying the standards of practice of these professionals, there was still a dearth of understanding of which competencies are effectively developed across European educational institutions.

Despite these educational differences between member-states, the free movement of radiography professionals occurs across Europe due to the recognition of qualifications, as established between EU member states (European Parliament and European Council, 2013, 2005, 2004). These European measures shifted the paradigm from individual national job markets to a European-wide market, as radiographers can be practising in a different country from the country they trained. Due to the lack of research into radiographers' mobility, its impact on patient safety is unknown. As such, further research of this mobility phenomenon was deemed essential.

1.1 RESEARCH AIM AND QUESTIONS

This study aimed to explore the *implications of the different education characteristics across the EU on TRs' competencies, professional mobility, and patient care*. Therefore, the fundamental research question of this study was: "How do education characteristics (and other education-related factors) affect competency level, professional mobility and patient care?". This will provide stakeholders, such as universities, regulators, professional associations, and the RT community in general, with a toolset that may be used to improve education, competency, mobility, and quality of care.

A multiphase design was used to achieve this aim (section 3.2 “Research Method – explanatory sequential multiphase mixed method”). Specific sub-questions were vital to guide the research in each phase. It is important to emphasise that these research questions were not research endpoints but checkpoints to ensure that each phase achieved its goal. The initial phases aimed to provide information necessary for the following phases, ultimately answering the research question above in the last phase through accumulation of knowledge across the phases. The phases, sub-questions and findings’ chapters are listed below:

Phase 1 (Document Analysis) research sub-questions:

i. What are the requirements to practise as a TR across EU member states? (Chapter 4).
ii. What are the patterns of recognition of qualifications of radiographers across the EU, and which countries encounter difficulties to obtain recognition abroad? (Chapter 5).
iii. Which are the competencies of TRs working on the linac identified in white and grey literature? (Chapter 6).

Phase 2 (Survey) research sub-questions (Chapter 7):

iv. What are the characteristics of TRs’ education programmes across the EU?
v. What are the competency levels of EU graduates with regards to linac tasks?
vi. Do education programme characteristics affect these competency levels?

Phase 3 (Cross case study – stakeholders’ interviews) research sub-questions are related to the stakeholders' perceptions regarding (Chapter 8):

vii. Why are some competencies less developed across Europe?
viii. Are these competencies essential, and at what level should they be developed?

ix. What is the impact of TRs' education and competency levels on professional mobility and patient care and safety?

1.2 SCOPE OF THE STUDY

The scope of this study was to describe the education of TRs in Europe in the current (2015-2021) international market. Radiography is a very complex profession that comprises many roles (EFRS, 2011). Therefore, to allow an in-depth understanding of the phenomenon, this research focused on a single role: the TR working on the linac, whose primary role is to administer the RT treatment, mainly to cancer patients. However, the competencies to perform this role are not limited to the treatment delivery; they encompass a complex set of competencies that allow the professionals to provide patients with the best outcomes such as communication, patient care, critical thinking, and research, among many others. This role was chosen given the researcher's expertise in RT, since this is the role undertaken by most TRs, and because it is highly significant in maintaining patients' safety, giving this study an enormous potential to impact the professional community and patients' outcomes.

The study focused on EU countries because of the mutual recognition of qualifications between member states (European Parliament and European Council, 2005, 2013a). Since the UK was part of the EU at the beginning of this project (2015), it was not excluded after Brexit. Even though the UK no longer benefits from the facilitated recognition of qualifications between member states, professional mobility can still occur between the EU and the UK; therefore, the results are still relevant. All data was collected before Brexit or during the beginning of the transition period, reflecting their status as an EU member-state (Table 1.1).

Table 1.1 – European Union countries (2015)

EU countries	
Austria	Italy
Belgium	Latvia
Bulgaria	Lithuania
Croatia	Luxembourg
Republic of Cyprus	Malta
Czech Republic	Netherlands
Denmark	Poland
Estonia	Portugal
Finland	Romania
France	Slovakia
Germany	Slovenia
Greece	Spain
Hungary	Sweden
Ireland	UK*

*The UK withdrew from the EU on the 31st of January 2020 at 23:00 (GMT)

1.3 THESIS STRUCTURE

This research comprises a literature review (Chapter 2) and a methodology chapter (Chapter 3) to support the three data collection phases. The results have been published or submitted to peer-reviewed journals that address the subject of the study: radiography education. These papers are integral to this thesis and the results were incorporated into the dissertation.

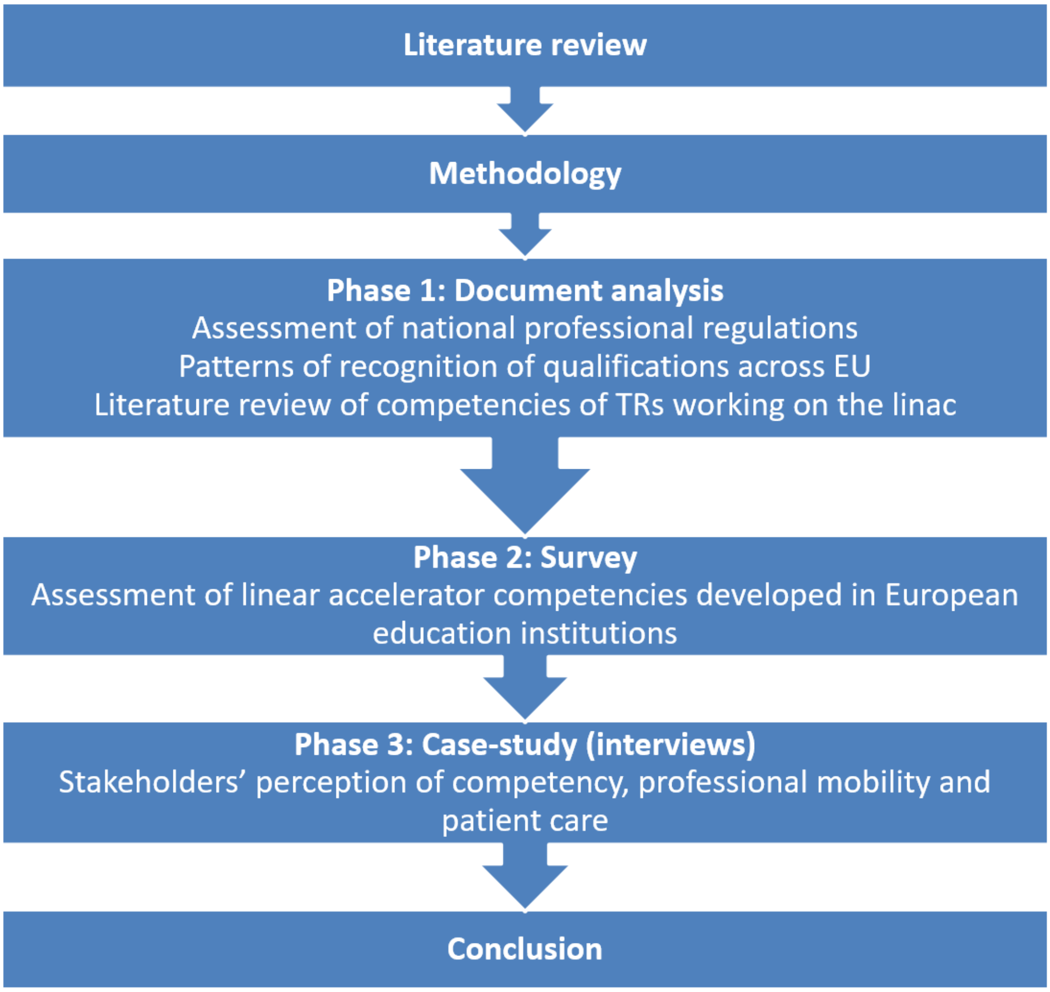


Figure 1.1 – Structure of the thesis

During phase 1, the requirements to practise radiography in European countries were investigated. This data was crucial since national regulations establish the qualifications required to obtain recognition in the destination country, according to the mutual recognition of qualifications directive (2005/36/EC directive). In addition, this also allows identifying differences between the education requirements of EU member states, which may hinder TRs' movement.

The patterns of movement were also studied by analysing the data published by the European Commission on the recognition of qualifications between member states. This data provided a picture of the professional mobility of these professionals across Europe. In addition, this study identified countries of origin from where radiographers struggled to obtain recognition.

Lastly, in this first phase, a systematic search and analysis of the literature were performed to identify the competencies of the TRs working on the linac. This list may be helpful for decision-makers designing courses or professional regulations. All three studies in this phase were used to inform the subsequent phases of the study.

In Phase 2, a survey was distributed to education institutions (EIs) across the EU. It aimed to evaluate graduates' competency level regarding tasks of linac TRs. The survey results allowed an understanding of the competency level of graduates across the EU and identification of factors influencing this level.

The last phase of data collection (phase 3) encompassed interviews with stakeholders from countries with deviant course characteristics (identified from the survey) and stakeholders' with different perspectives (educators, students, local and migrant TRs, professional body representatives and managers) to collect their perceptions regarding education characteristics, competency level, professional mobility, and patient care.

Conclusions were drawn as the phases of the study progressed. At the end of the study, there was a good understanding of the differences in national regulations, education programme characteristics, competency level of graduates in tasks related to the linac, professional mobility, and quality of care (including patient safety) across the EU. Most importantly, the factors which impacted competency, quality of care and professional mobility were identified, providing decision-makers with tools to identify and improve potential weaknesses in education programmes.

CHAPTER 2. LITERATURE REVIEW

This narrative literature review aims to establish the *status quo* of the radiography profession and education, expose the underpinning knowledge relevant for this dissertation, and inform the methodology. This chapter discusses the therapeutic radiography profession, the professional education across Europe, and the movement and recognition of qualifications.

This chapter starts with a description of the radiography profession, with emphasis on the professionals practising on the linac, allowing the reader to understand the importance of these professionals and their impact on patients' wellbeing and treatment outcomes. In the context of this thesis, the term "patient" refers to healthcare service users undergoing RT, mainly cancer patients.

Literature was analysed to determine the current educational structure in Europe, taking into consideration the pre-existing traditions of member states and the EU's vision for the future. In addition, EU regulations regarding education, recognition of qualifications, and professional mobility were also examined. All these subjects have a significant impact on radiographers' education across the EU.

Throughout this chapter, the continuous critical analysis of the literature identified areas of lack of knowledge, highlighting strengths and weaknesses of the literature and guiding the researcher about the methodology to be applied to close these gaps. The concept map in Figure 2.1 depicts the structure of this narrative literature review.

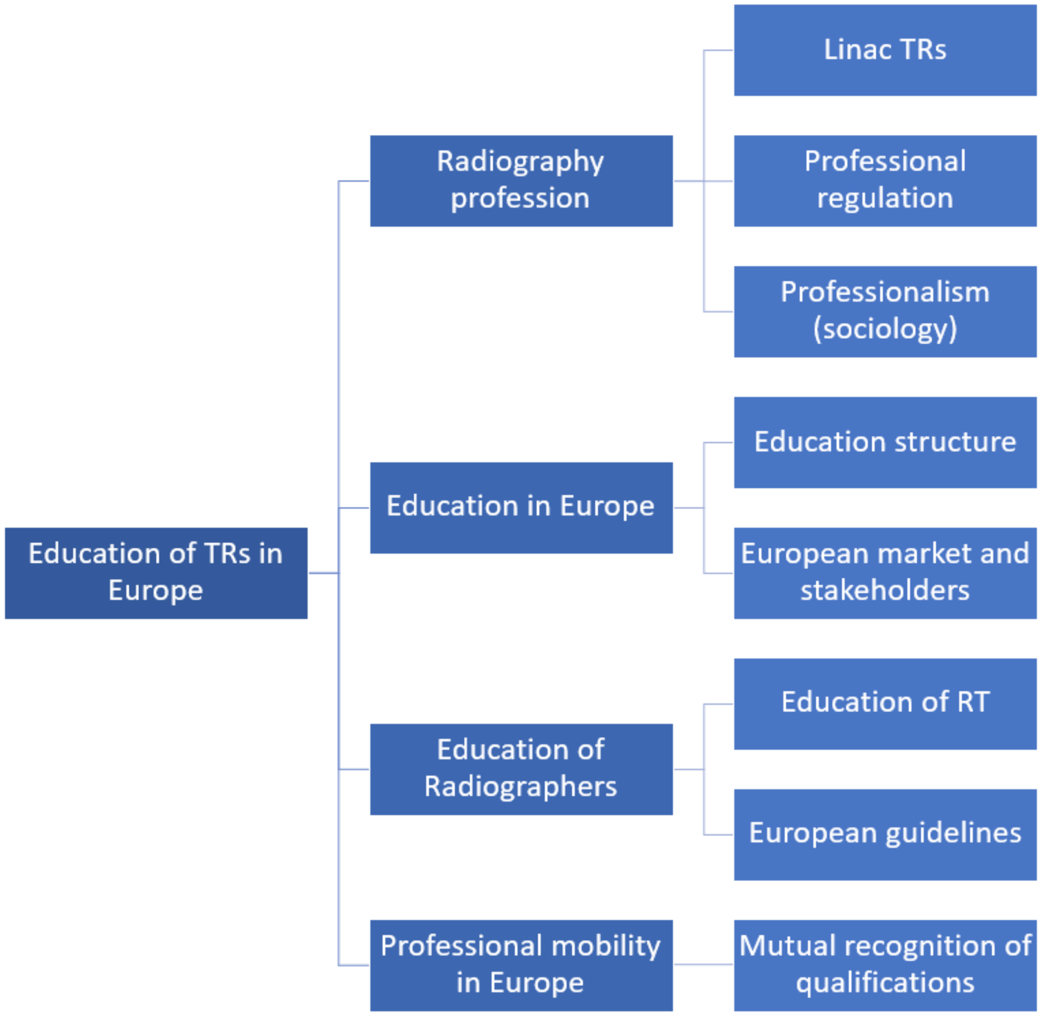


Figure 2.1 – Narrative literature review structure

2.1 LITERATURE SEARCH STRATEGY FOR THE NARRATIVE REVIEW

A separate document analysis of the literature was performed to identify the competencies of TRs working in the linear accelerator. This document analysis was based on a systematic literature search, not included in this chapter. Its methodology is described in section 3.2.1, “Document analysis (Phase 1)”, and the findings are detailed in Chapter 6, “Results of the Systematic Search and Analysis of the literature to identify the Competencies of therapeutic radiographers working in the linear accelerator."

The narrative literature review in this chapter was based on a search of literature related to radiotherapy education across Europe, followed by literature snowballing; these publications were the backbone of this review.

The search was performed using Academic search complete, CINAHL Plus (Cumulative Index to Nursing and Allied Health Plus), Medline, PubMed, ScienceDirect, ProQuest Education Journals, Education Research Abstracts (Taylor & Francis Online) and ERIC (Educational Resources Information Center) databases. A combination of the following keywords was used to search the databases: “education”, “training”, “radiography”, “radiotherapy”, “radiographer”, “Europe”, “European Union”. Related keywords and synonyms were used to prevent missing relevant literature.

The literature search included only English publications, and it was limited to the last 20 years due to the constant changes in professional education while ensuring that the time frame was long enough to include enough relevant publications. Through snowballing, publications older than 20 years and grey literature were included when appropriate. A literature search was repeated in March 2021 to identify essential publications released between the initial search and the end of this project. The same keywords and databases were used, but the search was done only on the abstract. Snowballing was not performed since the aim was to ensure that recent key literature was included. Figure 2.2 shows the literature search process for both searches.

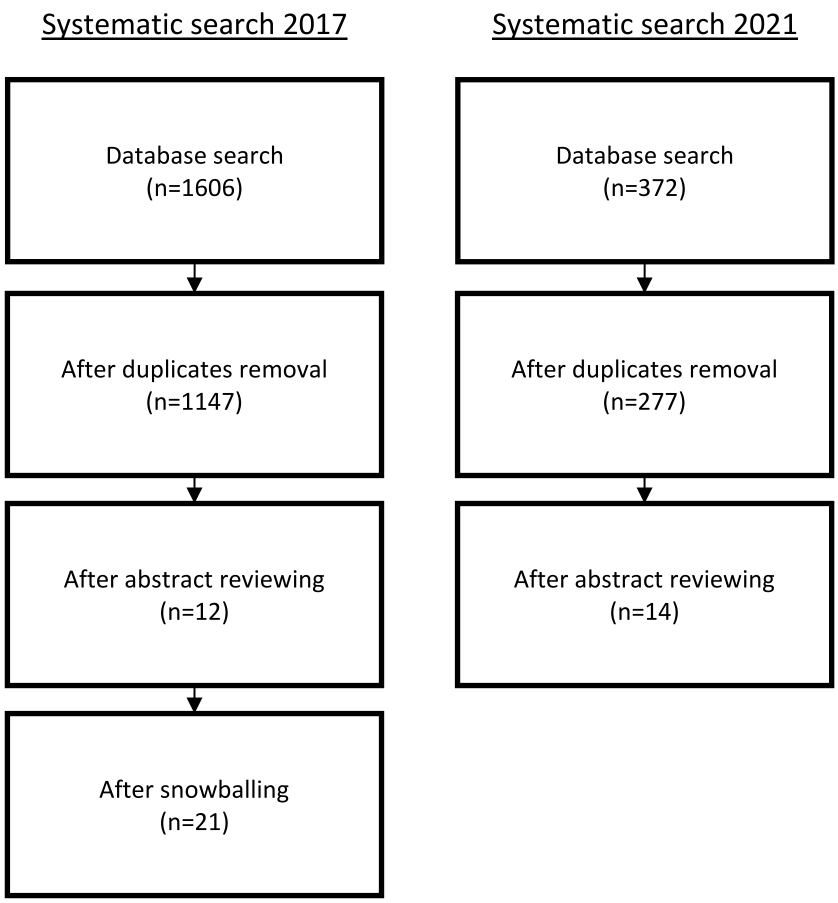


Figure 2.2 – Literature search and selection process

This literature search was complemented by additional searches performed to address specific subjects arising from the analyses of the previous literature. Subjects such as competency-based education or professionals' mobility, among others, required targeted searches. The same databases were used, but the additional keywords were used to address the topics in question, including "movement", "competencies", "learning outcomes", "courses", and "curricula".

The analysis of the literature search highlighted a lack of research on radiography education (Akimoto et al., 2009). This knowledge gap was even more evident for RT education. However, a considerable increase in publications was observed between the 2017 and the 2021's literature searches.

2.1.1 Types of literature

Most of the literature focusing on the education of TRs was descriptive in nature. While some of the publications found in the literature search had a robust collection of data and could be considered "research literature", the majority were considered "practice literature", as defined by Wallace and Wray (2011). In "practice literature", experts in the field make observations or opinions about the subject, and the results are based on a limited amount of data and are not considered as strong as "research literature". The high number of opinion-based publications is because the subject being studied is broad, political, and subjective. Most papers about radiography education were published by European professional organisations such as the European Society of Radiotherapy and Oncology (ESTRO) and the European Federation of Radiography Societies (EFRS) or by researchers linked with these organisations.

Policy literature significantly contributed to the literature analysed, given the role of national and European regulations, guidelines, and recommendations on education. Policy literature can be based on research; however, documents were often considered "practice literature" given the lack of data supporting the findings (Wallace and Wray, 2011).

Research from other professions and contexts was included in this literature review with extensive inclusion of literature pertaining to diagnostic radiographers due to their closeness to therapeutic radiography. However, due to the specific characteristics of the TR profession, this literature was limited to the topics where the researcher did not find specific literature to reduce the risk of erroneous extrapolations while allowing to draw hypotheses to evaluate if these phenomena apply to TRs. Nevertheless, the lack of evidence in some areas further strengthened the need for the current study.

2.2 THE RADIOGRAPHY PROFESSION

Radiography practice is over one hundred years old, beginning just after discovering the X-rays (Röntgen, 1896, 1896a), with debate about the radiographer's role in MI and RT since the beginning (Niemi and Paasivaara, 2007). Radiography is constantly and rapidly changing along with technology advances, with radiographers at the vanguard of the developments (Ahonen, 2009; England et al., 2017; May et al., 2008; Niemi and Paasivaara, 2007; Smith and Reeves, 2009).

Although, initially, radiographers and radiologists had overlapping roles, financial and societal pressure for specialisation resulted in radiography and radiology becoming separate professions. Radiography being further divided into the many specialisms, such as diagnostic radiographers and therapeutic radiographers, which can be regulated as independent professions or as a single profession (Decker and Iphofen, 2005; European Commission, n.d. b, n.d. a; European Society of Radiology, 2010; James et al., 2012; Larkin, 1978; Price, 2001).

Since professional regulation is decided at the national level and not the European level (European Parliament and European Council, 2005), the definition of the radiography-related professions, the roles undertaken and how these specialisms are divided vary considerably. Radiography regulation is discussed in more detail in section "2.2.2 Regulation of radiography".

In the context of this dissertation, submitted to Ulster University in the UK, "radiographers" was defined as the healthcare professionals that use ionising and non-ionising radiation to perform MI and RT procedures, which is also a definition applied across Europe (EFRS, 2011; Society of Radiographers, 2020). Therefore, "radiographers" is an overarching term that covers both specialisms, while those who only practise MI were referred to as "Diagnostic Radiographers" (DRs), and those who only practise RT were named "Therapeutic Radiographers" (TRs). This distinction is necessary because, in this work, some sections addressed only therapeutic radiographers (such as the survey and interviews); but, in other instances, the available data referred to radiographers in general, without data available for separate specialisms (such as the national regulations or the data regarding the recognition of qualifications, in some countries).

The DRs' most prominent roles are to acquire diagnostic imaging using multiple modalities such as X-rays, computed tomography, or ultrasound, among other roles. In comparison, TRs are professionals responsible for planning and administering radiation with a therapeutic intent (Society of Radiographers, 2018a, 2020). These definitions are illustrative of the main differences between the two specialisms but are an extreme over-simplification of the actual roles of these professionals. In both specialisms, patient care, research, education, among others, are essential roles beyond the technical aspects of the profession (Andersson et al., 2017; England and McNulty, 2020; Malamateniou, 2009; Society of Radiographers, 2020). The TRs' roles will be further discussed below (2.2.1 The therapeutic radiographer (TR)) with a detailed explanation of their role on the linac (2.2.1.1 The role of the radiographer practising on the linac), which is the focus of this study.

The increase in demand for MI and RT procedures and expanding radiographers' scope of practice has dramatically influenced the profession (Andersson et al., 2017). For example, the increase in demand and lack of radiologists promoted DRs to perform new roles such as reporting. At the same time, an opposite trend was also observed with recruitment and retention issues in many countries (McNulty et al., 2021) and functions such as mammography and emergency medical imaging transferred to other professions and occupations, such as nurses or assistants (Andersson et al., 2017). The need for adequate career planning and the importance of proper training before role transference becomes evident.

McNulty et al. (2021) showed that radiography has high employability and the market needs radiographers, reinforcing the importance of training new professionals while investing in retention strategies, such as better working conditions. Public awareness of the profession is also essential to guarantee the financial investment necessary to ensure the education and retention of these professionals (Andersson et al., 2017).

Radiography as a science is not yet fully established but is expanding. The knowledge acquisition in this field is often technical, and more effort is needed to reinforce the status of radiography as a science (Metsälä and Fridell, 2018). Nevertheless, an increase in radiography-led research is on the rise, and "this sustained commitment to research will see the profession develop to new heights" (England and Thompson, 2019, p. S1). These same authors identified research as a vital part of radiographers' practice and noted the dramatic improvement in radiographer-led research published, cited, and presented at international conferences.

Radiography professionals may also choose an academic career. However, academics are a small percentage of the total workforce, with very few Philosophy Doctorates (PhD) holders, who often focus on teaching activities. The majority of the academic radiographers in the UK are young professionals, holders of Master's of Science (MSc) degrees, with mostly/only lecturing tasks, and who joined the profession after some years of clinical practice (Knapp et al., 2017). The lack of research time, even in academia, reflects the underdeveloped research profile of radiography. The requirement of previous clinical experience to take academic posts reinforces the vocational framework of radiographers' education instead of a more academic profile.

Nevertheless, a constant improvement to the radiographers' professional and educational paradigm occurs due to efforts from multiple entities, such as professional associations, regulators, Education Institutions (EIs), radiographers, and governments. An improvement in the professional profile and standards of practice resulted from an evolution in technology that required competent professionals in ever more demanding roles (Coffey et al., 2018). However, this is only possible if high-quality education is offered (McNulty et al., 2021, 2017). The professional evolution was reflected in the upgrade of radiography to the "Professionals" classification in the European Skills/Competencies, qualifications and Occupations (ESCO) from the previous classification as "Technicians and Associate Professionals" (ESCO, 2020). While "Technicians and Associate Professionals" apply evidence into practice and undertaking technical work, "Professionals" are also expected to develop the existing knowledge. Despite many efforts, many countries still characterise radiography as a technical occupation.

Understanding the radiography profession is an essential background to understand the education of radiographers in general and of TRs specifically. As such, this chapter explains the roles of radiographers, dwelling on the roles of TRs and of TRs working in the linear accelerator in the next section. It also explores the professional regulation since it is strongly linked with the education regulation (section 2.2.2 "Regulation of radiography across Europe"). Lastly, the meaning of "profession" from a sociological point of view was essential to the rationale of this study but also for the discussion of the results (section 2.2.3 "Professionalism (from a sociological perspective)").

2.2.1 The therapeutic radiographer (TR)

In the context of this study, TR refers to the radiographer that practises RT, where ionising radiation is used to treat many pathologies, primarily cancer (Macmillan Cancer Support, 2012). Radiotherapist (RTT) is also a widely used title in the European Union to refer to these professionals among many other titles as discussed in section "2.2.4 Title of radiographer".

Since most radiology and RT departments are separated and have dedicated staff, it became rare for one professional to perform both specialisms (Paterson, 1954). Therefore, even though education is joint in many countries, most professionals end up practising only one of the specialisms.

The high specialisation required led to the split of the profession in the UK and many other countries. This was due to the separate knowledge, responsibilities, and authority between the diagnostic and the TRs, raising the need for titles that reflect these two roles better. Another factor was the lack of access to RT centres to train radiographers, leading to professionals across the UK with the same title but who had different levels of RT competency (Paterson, 1954).

Therapeutic radiography is not a recognised profession in most European countries. According to Coffey and Rosenblatt (2018), the therapeutic radiography profession is often not defined by national regulation, or these are of "suboptimal quality": without professional or educational requirements adequately defined. The RT specialism is often regulated as part of other professions, mostly with MI but also nursing and other professions, hindering the specialisation development necessary for good practice (Coffey et al., 2018; Coffey and Rosenblatt, 2018).

The TR is part of a multidisciplinary team that includes clinical oncologists, medical physicists, nurses, engineers, and other professionals. This team is necessary due to the complexity of RT treatments, and these professionals work together to provide the patients with the best possible outcome (Vaandering et al., 2018). TRs are generally the most represented profession in an RT department (Society of Radiographers, 2018a).

The roles of the TR are often divided into pre-treatment procedures, radiation delivery and post-treatment procedures. This may include promoting healthy habits and cancer awareness, obtaining patients' informed consent, deciding patient setup and immobilisation, acquiring radiologic images for planning, planning of the RT treatment, quality assurance of RT equipment, verification of patient setup before irradiation, irradiation of the patient, patient assessment and management during and after treatment, research and education, among others (Society of Radiographers, 2018b).

While errors in clinical practice are rare, they may lead to severe consequences for the patients, often irreversible (Coffey and Rosenblatt, 2018; Fraass, 2008; Knöös, 2017).

Given that RT is received by around 50% of cancer patients (Coffey and Rosenblatt, 2018) and the high levels of accuracy needed to provide safe treatment to so many people, research about TRs' education is of great importance.

In the IAEA's report (2016) regarding accuracy in RT, the importance of the TRs is evident since these professionals are involved in all steps of the RT process (Figure 2.3). Many RT adverse events may be caused by an inadequate educational background or lack of specialised RT competencies (Coffey and Rosenblatt, 2018; Holmberg, 2007). Furthermore, it is widely accepted that "radiotherapy not only has to be safe but has to be delivered according to the highest standards" (Vaandering et al., 2018, p. 162), which requires high levels of specialisation.

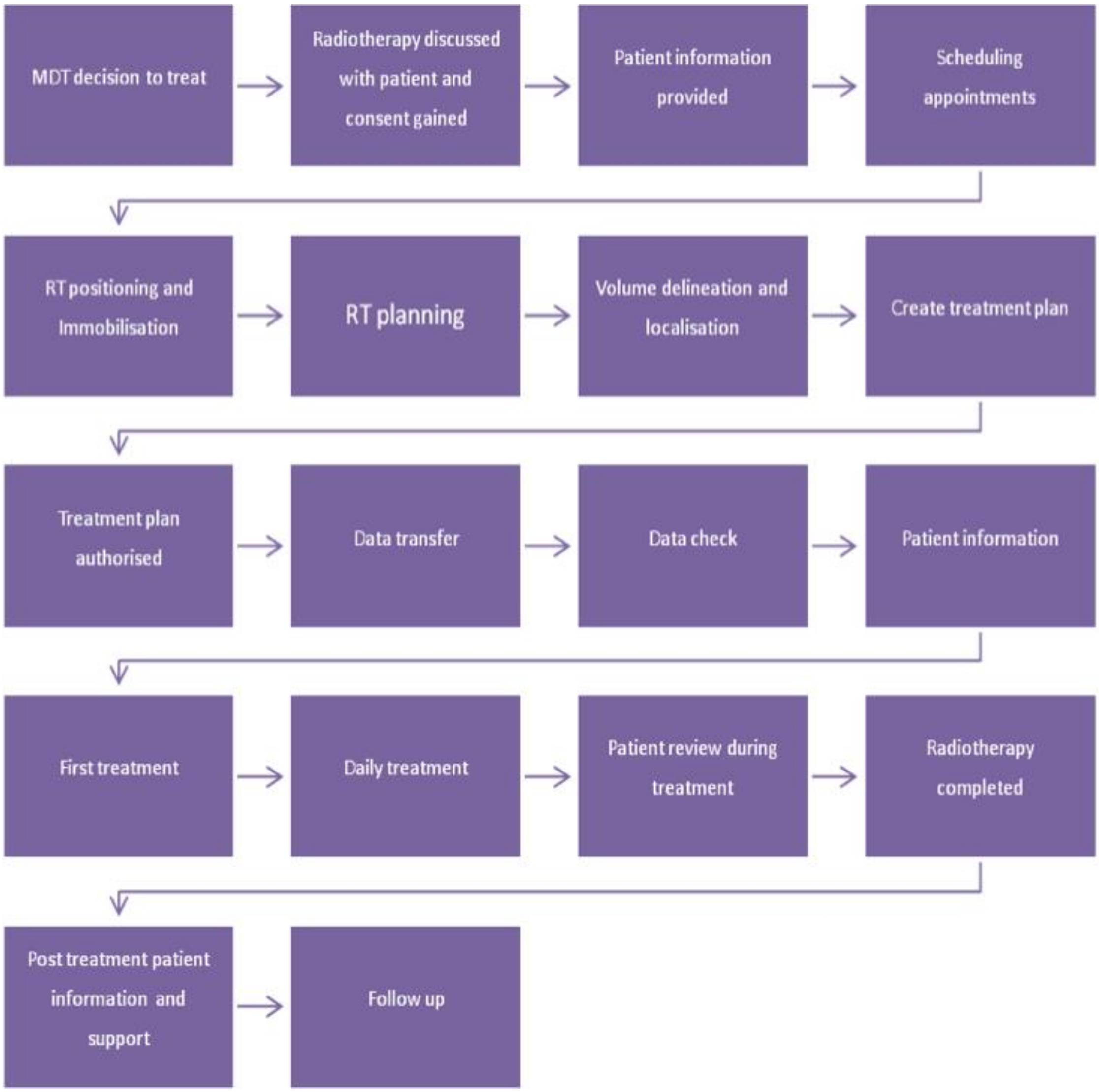


Figure 2.3 – Flowchart of a standard RT process (Society of Radiographers, 2018a)

The full range of competencies required for TRs is vast. It is for this reason that this research focused on the radiographers practising on the linac.

2.2.1.1 The role of the radiographer practising on the linac

Standard RT treatments, delivered by TRs, begin with identifying the patient, assessing their fitness for treatment, and obtaining their consent to treatment. If any patient preparation is required, such as taking radio-sensitising pharmaceuticals or drinking water to fill their bladder, the patient is instructed to do so. When ready, the patient lays down on the treatment couch with the immobilisation systems prepared by the TRs.

The patient is then set up into the treatment position using localisation references on the patient's surface and a laser system, which determines the centre of the linac. Based on these references, the patient is then immobilised in the treatment position according to the plan (Figure 2.4).

Figure 2.4 – Patient setup for RT treatment (Memorial Sloan Kettering Cancer Center, 2021)

To ensure that the patient is in the correct position, radiological images are often acquired and compared with the planned position; if necessary, corrections may be applied to move the patient to a position as close as possible to the planned. If an acceptable setup is reached, the treatment is administrated. This process is repeated in every treatment fraction (Figure 2.5) (University Hospitals of Derby and Burton NHS Foundation Trust, 2018).

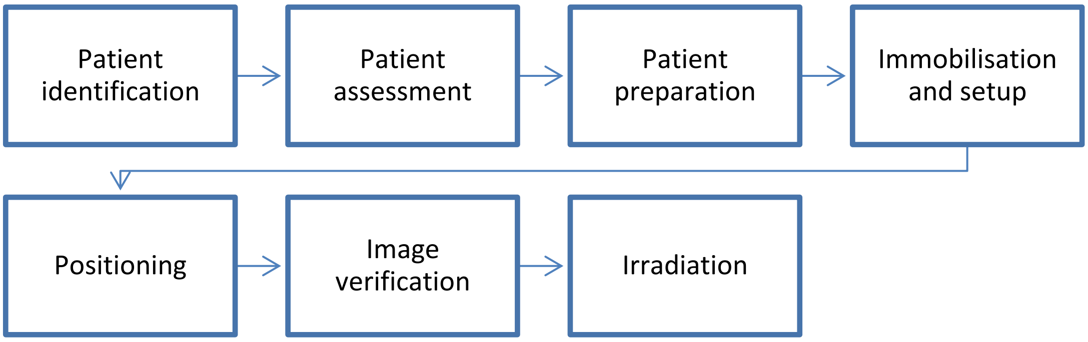


FIGURE 2.5 – COMMON PROCESS OF AN RT TREATMENT IN A LINAC

Errors in any of these steps will cause the treatment to be delivered inaccurately, resulting in a lower dose to the tumour that increases the risk of recurrence, and a higher dose to the normal tissues that increase the risk of side effects, reducing the quality of life (Baeza, 2012; ICRP, 2000).

In addition to these essential skills to administer radiation, the role of TRs working on the linac includes other tasks critical to ensuring that treatments are administered accurately. These tasks are often performed in parallel with those discussed above. They may include assessing patients' evolution in the treatment, managing eventual side-effects of the radiation or other concerns, quality assurance of the linac, radiation protection checks, quality assurance of image systems and immobilisation equipment, research, and education of patients, other TRs and other professionals, among other tasks (EFRS, 2018; ESTRO, 2014).

In general, a team of two to four TRs participate in the linac tasks. IAEA (2008) recommends at least one TR per 12.5 patients on the linac, while the remaining roles of the radiographer require much lower staff numbers: one TR in treatment planning is recommended per 300 patients, in simulation is one TR per 500 patients, and in the mould room is one TR per 600 patients. This IAEA document is more than 12 years old, and these values may need updating. However, the ratio between radiographers in different tasks is still dominated by linac roles. Although this is a common role of TRs, it is a vital role for treatment success and patients' safety.

2.2.2 Regulation of radiography across Europe

"Professional regulation" consists of the mechanisms applied by a relevant authority to govern the standards of practice and entry requirements of a specific profession. These mechanisms often include policies issued by a national government or an independent regulatory body to ensure service quality, public safety, and ethical practice (Adams, 2020). Professional regulations are critical for this study because they often define the education required to access the profession.

Radiography is regulated at the national level; however, national professional regulation varies between member states due to various financial, political and technological factors creating a heterogeneous regulation of radiography across the EU (Decker and Iphofen, 2005; European Society of Radiology, 2010; James et al., 2012; Larkin, 1978; Price, 2001). Since educational programmes are designed to fulfil the requirements to practise locally and not internationally (Society of Radiographers, 2013), the variation in the education may result in professionals with different skills and competencies in each country (EFRS, 2010; HENRE, 2008a; Janaszczyk and Bogusz-Czerniewicz, 2011). This contrasts with other health professionals, such as dentists and nurses, who have education frameworks regulated at the European level (European Parliament and European Council, 2005). One of the most evident differences is that radiography may be regulated as a single profession or have the different specialisms regulated as independent professions (Cowling, 2008; European Commission, n.d. a, n.d. b).

Specifically for RT, Coffey et al. (2018) argued that TRs lack professional recognition in some countries, leading to a lack of government commitment to regulate the profession, compromising good education and practices. The lack of adequate regulation leads to poor education, often framing TRs and radiographers as technical occupations rather than professions (Coffey et al., 2018; McNulty et al., 2016; Sá dos Reis et al., 2018).

These differences in national regulation translate into different competencies being developed across the EU, potentially hindering professional mobility and compromising patient safety when movement occurs. However, there is no published literature evaluating the regulation of radiography at a European level.

2.2.3 Professionalism (from a sociological perspective)

"Professionalism" in the context of this study refers to sociological phenomena related to professions and professionals. Considering the impact that health care professions have on society, understanding professionalism is paramount.

Diverse authors identified essential features of professionalism, all of them relevant to the radiography profession. These concepts are strongly linked to each other and are summarised in Table 2.1.

Table 2.1 – Professions and professionalism concepts.

Concept	Definition	Essential in distinguishing profession from occupation?	Application to this study	References
Body of Knowledge (BoK)	Set of concepts, skills and activities that constitute the professional domain.	Yes, as it enables autonomy and authority. Different professions have different BoKs.	Defined at national level with variation across the EU. Lack of literature on who defines it in each country. Professionals develop the BoK through education. Research is essential to advance the BoK of the profession.	(Cruess et al., 2004; Hughes, 1984; Jackson, 2010; McNulty et al., 2021)
Autonomy and responsibility	Ability to perform tasks independently and with accountability. Ability to self-regulate, defining and developing the profession's BoK.	Yes. Lack of autonomy and accountability reflects a technical/assistant occupation.	Depending on the country, radiographers are autonomous and accountable for a wide range of tasks in MI and RT. Radiography may not be self-regulating in many countries. Autonomous research is underdeveloped, compromising the development of BoK	(de La Cámara Egea, 2013; England and Thompson, 2019; Freidson, 1994; Metsälä and Fridell, 2018; Yielder and Davis, 2009)
Dominance	Dominance is the process where one profession executes an instruction given by a dominant profession.	No. However, a dominant profession may remove autonomy from another.	Radiography is dominated by the medical profession in some countries, compromising autonomy.	(Andersson et al., 2017; Coffey and Rosenblatt, 2018; Rueschemeyer, 1986; Yielder and Davis, 2009)
Authority and legitimacy	Legitimacy is the recognition of authority by society and other professions to perform the tasks.	No, it applies to all occupations.	Radiographers have the authority to perform various tasks in MI and RT. Lack of literature on who provides the legitimacy to practise the profession across Europe.	(Adams, 2008; Freidson, 1994)
Code of ethics	The professionals apply a code that ensures competence, integrity, morality, altruism, and the promotion of the public good	Yes	There is evidence of variation in the code of ethics of radiographers between EU countries.	(Yielder and Davis, 2009)

Authority and legitimacy are considered non-essential features of a profession; their presence will not distinguish professions from occupations. It is also possible for a profession not to dominate any other profession or occupation. Alternatively, a BoK, autonomy and responsibility are essential to distinguish between profession and occupation (Hughes, 1984; Jackson, 2010). A profession must possess a body of knowledge (BoK) that allows its holder to perform the required tasks they are authorised to execute (England and McNulty, 2020; Johnson, 1972).

In the context of professionalism, dominance is the process where a profession gives orders and dominates the executor, who lacks autonomy (Freidson, 1994; Rueschemeyer, 1986). Coffey and Rosenblatt (2018) argued that this dominance over TRs still observed in many countries, resulting in low professional status, bounding them to perform practical tasks only, leading to a disinvestment in the profession and education. However, dominance is a dynamic phenomenon that can be stopped by changing the dominated profession's attitude. Better education improves the professional status and provides the required skills to take roles beyond technical tasks (Yielder and Davis, 2009). Other studies agreed that radiographers worldwide may lack autonomy due to dominance by the medical profession (Andersson et al., 2017; Yielder and Davis, 2009). However, higher levels of independence have been achieved, at least in some countries like Sweden (Andersson et al., 2017).

In a publication regarding Spanish radiographers, the author identified that the development of competencies would provide the autonomy required to allow the profession’s development (de La Cámara Egea, 2013). In the UK, introducing the 4-tier professional career allowed radiographers to increase their competencies and autonomy as they progress. Work-shift from physicians to radiographers also increased their autonomy (Andersson et al., 2017). One important aspect of autonomy is the ability of professionals to self-regulate, that is, to define their own BoK, code of ethics, and standards of practice and education (Cruess et al., 2004; England and McNulty, 2020).

Research is also an essential feature of the radiography profession (Malamateniou, 2009) that links well with the features above. Research is vital for the autonomous development of the professions' BoK (England and McNulty, 2020). An updated BoK provides professionals with the most recent evidence necessary to perform at the highest standards. From an ethical perspective, developing new knowledge is essential to provide society with the best care possible.

Radiographers have historically relied on research performed by other professions; however, radiographer-led knowledge production has increased in recent years (England and McNulty, 2020; England and Thompson, 2019; Nixon, 2001). Advances in the BoK improve society's recognition of the profession's legitimacy to perform the tasks allocated to them since they hold advanced knowledge of the science underpinning their practice (Adams, 2008; Freidson, 1994). Nevertheless, research can only increase if graduates are educated to perform such skills, which is an essential aspect of radiography curricula (England and McNulty, 2020).

In healthcare, professionals are primarily accountable for the patients' safety and care (Gunderman and Streicher, 2012). Therefore, given the risks of the tasks performed by healthcare professionals, they require high competency levels to undertake these tasks with accountability. The European Qualifications Framework (EQF) establishes a European reference for academic levels according to different levels of responsibility and autonomy. As a result, high academic levels are essential in developing adequate competency levels to provide autonomous healthcare services. The EQF will be further discussed in the section “2.3.2 The European Qualifications Framework (EQF)”.

2.2.4 Title of radiographer

An essential feature of a profession is the title since it identifies individuals who hold similar professional features. It is important to note that the title does not make a profession, as occupations also have titles.

The word “radiographer” is not a universal term; other terms, such as “radiation technologist”, can be found. Specific titles are used for specific roles, such as “radiation therapist” or “sonographer” (EFRS, 2011; ESTRO, 2012; Thomson and Paterson, 2014). Some radiographers’ roles have not always been fully defined within organisations, and some are still debated (Ahonen, 2009; EFRS, 2011).

White literature regarding the title of radiographer in Europe is scarce, while grey literature is richer in this subject. However, European organisations published different recommendations regarding the titles applicable for radiographers (EANM, 1998; EFRS, 2011; ESTRO, 2012). This discrepancy is even more significant at a worldwide level (Cowling, 2008).

In the UK, the rise of new technology led to titles starting to appear without a clear relationship between title and roles and, until the 1920s, the titles of radiologist and radiographer were used interchangeably (Larkin, 1978). The separation of these titles occurred with the establishment of the Society of Radiographers (SoR) (Adams, 2008).

Radiographers became able to register in the Council of Professions Supplementary to Medicine Act in 1960 after this regulatory body was introduced. At this point, the profession had developed a code of conduct, a body of knowledge, and the essential education and training requirements. Simultaneously, the title of “radiographer” became protected (Adams, 2008; Decker and Iphofen, 2005).

Nowadays, new titles start to appear within and around the radiography profession. With the introduction of the four-tier service delivery model in 1999, the following titles were introduced in the UK:

- Assistant Practitioner,
- Practitioner,
- Advanced Practitioner
- Consultant Practitioner.

In this model, the minimum qualification required to practise radiography was lowered since assistant practitioners' qualifications are lower than the previous requirements, a matter of concern for Adams (2008). However, the title of radiographer in the UK does not include assistant practitioners (Adams, 2008) whose practice is limited to “clinical imaging examinations or treatment procedures in concert with, and under the supervision of, registered radiographers” (Society of Radiographers, 2012, p. 2).

“Diagnostic radiographer” and “therapeutic radiographer” and their national equivalents are common titles used across Europe and may reflect independent professions; however, as new specialisms emerge, new titles may arise. Some examples include the “Magnetic Resonance Radiographer” (Castillo et al., 2015) or the “Dosimetrist” (Buchheit et al., 2013).

Other titles started to emerge across the EU with the increased specialisation of radiographers, including “sonographer” or “ultrasonographer”. This title is currently not legally protected in the UK (Thomson and Paterson, 2014), but professionals can register voluntarily on the Public Voluntary Register of Sonographers (Society of Radiographers, 2016). According to Thomson and Paterson (2014), statutory registration and the consequent recognition of the title ensures standardisation of education, training and conduct, protecting the sonographers, patients and employers. In addition, White and McKay (2004) refer to the importance of developing a model that recognises the specialist radiographer titles to ensure that these professionals maintain the competence required to practise that specialist role, safeguarding the patient.

Similarly, Joynes (2018) found that professionals tend to develop an “intra-professional identity”, associating themselves with a sub-group of the whole profession, such as dosimetrist, sonographer, and MRI-radiographer. This results from specific BoK, autonomy and legitimacy that separates them from other colleagues in the same profession.

Ahonen (2009) established a correlation between the title of “radiographer” and the main features of the profession identified in the study: technical use of radiation, radiation protection, and patient care. A relationship between title and the professional features, including specific BoK and autonomy, was also observed in other publications (Buchheit et al., 2013; Castillo et al., 2015; Society of Radiographers, 2012; Thomson and Paterson, 2014; White and McKay, 2004), showing the importance of titles in clearly representing the roles and autonomy of the professionals.

One of the issues regarding the radiography profession at the European Union level is the lack of a standardised title. This variation in titles may be interpreted as a variation in BoK, level of autonomy or authority amongst other professional features since the society legitimises each title as a separate profession.

European professional organisations that represent radiographers also do not have a common title for the profession. The EFRS uses the title of “radiographer” and briefly defines the profession, distinguishing between “therapy radiographers” and “diagnostic radiographers” (EFRS, 2011). ESTRO “recognises all the titles for each discipline” (European Society for Radiotherapy and Oncology (ESTRO), n.d.); however, the title of “Radiation Therapist” (RTT) is used when referring to professionals executing functions in Radiotherapy (ESTRO, 2012). “Nuclear Medicine Technologist” is the title used by the European Association of Nuclear Medicine (EANM) to identify radiographers in the specific field of Nuclear Medicine (EANM, 1998). This lack of cohesion may hinder the development of a consolidated profession across Europe, limiting the recognition and status of these professionals (Coffey et al., 2018). Therefore, having a single title representing all radiographers across Europe conflicts with the need of having titles representing each specialism.

When EU radiographers obtain recognition of their qualifications in another member state, they are allowed to use the title of the destination country. This shows that they hold the necessary competencies to practise the profession in the host country and that society recognises them as professionals (legitimisation) (European Parliament and European Council, 2005). The use of the national title is only possible after comparing the applicant’s qualifications with the national requirements that vary between member-states. Understanding the national requirements to practise across the EU is imperative to understand the importance of title recognition.

2.3 EDUCATION STRUCTURE IN EUROPE

In the 1980s, education within the EU might be best characterised by divergence since the three main historical models used across European higher education institutions (HEIs) diverged considerably: the Napoleonic, Humboldtian, and the Anglo-Saxonic Model (Gellert, 1999). The aims of the traditional education models and their characteristics are summarised in Table 2.2, but a full description can be found in Appendix 1.

TABLE 2.2 – BASIC FEATURES OF THE EUROPEAN MODELS AND OBJECTIVES.

Model	Features	Main objective
Humboldtian	– Research as a major mean of learning – Teacher-student collaborative research work – Freedom of research and teaching – Government funding – Vocational education offered outside HEIs	Production of new knowledge
Napoleonic	– Focused on vocational training – Research performed outside HEIs – Strong government control – HEI have no flexibility on curricula design – Same education across every HEI in the country	Education of students to execute professions
Anglo-Saxonic	– Personality development (problem-solving skills) – Inter-disciplinarity – Market-oriented and competitive system – Two-cycle structure (under- and post-graduate) – HEI self-governance but overseen/regulated by the government	Curricula influenced by stakeholders/market

By the 1990s, convergence across the member states became visible following the signing of the Maastricht Treaty by the European Leaders (1992). Among other aspects, this treaty defined the limits for government deficit, leading to reforms aiming to cut costs and increase efficiency, including in higher education (HE) (Fanghanel, 2012; Gellert, 1999). Two other significant European policies are the Bologna declaration and the European Qualifications Framework, which will be discussed in sections “2.3.1 The Bologna Declaration” and “2.3.2 The European Qualifications Framework (EQF)”, respectively.

Amilburu (2014) considered the HE system created after the Bologna protocol as a new HE model, a sequence of the Napoleonic, Humboldtian and Anglo-Saxonic models. The new European educational model gathers characteristics previously scattered across the different traditional models (Table 2.2). In the current model, government influence varies considerably. Governments may strongly regulate curricula, similar to the Napoleonic model; provide complete freedom in curricula design to the HEI, as seen in the Humboldtian model; or something in between, where the HEI has flexibility in course design as long as they achieve the learning goals established in the professional regulation, similar to the Anglo-Saxonic model (Gellert, 1999; Sam and Sijde, 2014). Governments are still the primary funders of HEIs, but universities gained financial autonomy and were encouraged to find other funding sources, depending less on the government (Le Feuvre & Metso, 2005). The current HEI must include the points of view of other stakeholders, which is a characteristic of the Anglo-Saxonic model (Clarke and Winch, 2015; Sam and Sijde, 2014).

Current radiography courses are not as extreme as the Napoleonic or the Humboldtian model regarding knowledge production. In the current model, students are introduced to the concept of knowledge creation and develop research skills in the initial degree, further developed at higher academic levels, such as Master’s and doctoral degrees (England and Thompson, 2019; Malamateniou, 2009). Other transversal skills are also developed, preparing students for life after graduation, a characteristic of the Anglo-Saxonic model (Sam and Sijde, 2014).

In addition to the characteristics inherited from the historical models, the current education paradigm advocates for educational objectives defined in terms of learning outcomes. This shift in education paradigm is discussed in section “2.3.2.2 Learning outcomes”.

The European university also became a promoter of movement of students and professionals and collaboration between institutions, emphasising the EU aims of movement and uniformity. Evidence can be seen on the European Commission’s 2005/36/EC Directive that regulates some healthcare professions at the European level, including medicine and nursing (European Parliament and European Council, 2005). In addition, this directive establishes that the member states may agree on “Common Platforms”; i.e., they may agree on the common minimum requirements to practise a profession, removing the need for graduates to undergo compensation measures when requesting recognition of qualifications abroad if they comply with these requirements (High Level Group on the Modernisation of Higher Education, 2014). A European-wide education credit system based on the British model was also introduced to facilitate this exchange (Clarke and Winch, 2015).

Although there is a convergence in contemporary HE, country traditions and philosophies still influence education, maintaining a significant variation in education between EU countries (Gellert, 1999; Sam and Sijde, 2014). This is discussed in more detail in section “2.3.3 The impact of market, stakeholders and national tradition on education”.

Understanding the existing convergences and divergences of higher education in Europe is essential for this study. This section allows the reader to understand the overall European education setting before diving deeper into the specifics of TRs' education in section 2.4 "Education of radiographers in the European setting".

2.3.1 The Bologna Declaration

The Bologna process started during the celebration of the 800th anniversary of Sorbonne University in 1998, when the French, German, British and Italian education ministers signed the Sorbonne Declaration (Kurelić, 2009). This Declaration included the core ideas of the future Bologna Declaration: mobility of students, academics, a credit system, and a division of HE into undergraduate and postgraduate programmes (Kurelić, 2009).

The Sorbonne Joint Declaration was taken on board by 29 countries, of which 14 were non-EU. The inclusion of non-EU countries increased the programme's strength and it was partially due to the need to harmonise with the new European educational system if they wanted to be integrated into the community (European Higher Education Ministers, 1999; Kurelić, 2009). Forty-nine states are currently integrated into the European Higher Education Area (EHEA), which was created from the Bologna process (Figure 2.6) (European Higher Education Area (EHEA), 2021). Even though the Bologna Process is not fully implemented across the signatory countries, considerable progress has been made (European Higher Education Area (EHEA), 2018).

Figure 2.6 – Map of the EHEA (2021)

The Sorbonne Joint Declaration was followed by the signing of the Bologna Declaration in 1999 which established the initial six objectives of the Bologna process, however, four other objectives were added in the Prague and Berlin Summits (European Higher Education Ministers, 2001, 1999; Ministers responsible for Higher Education, 2003; Reinalda, 2008). The 10 objectives of the Bologna process are as follows:

- Easily readable degrees, allowing comparison between them.
- The division between undergraduate and postgraduate cycles.
- Creation of the European Credit Transfer and Accumulation System (ECTS).
- Mobility of students and academics.
- Co-operation regarding quality assurance of the courses.
- Promotion of HE at a European level.
- Lifelong learning.
- Involvement of students and institutions.
- Enhancement of the attractiveness of the European HE.
- Development of doctoral programmes through the collaboration between the EHEA and the European Research Area.

Following the Bologna process, education converged from a national system to a European system through multiple actions. These included direct actions such as mandatory restructuring programmes into two cycles and the inclusion of the ECTS, while indirect actions included collaborations between institutions or student exchanges that further promote uniformity. The measures were similar for all courses, including radiography.

The Anglo-Saxonic two-cycle system was considered more structured than other models and allowed a quicker entry of graduates into the job market by reducing the duration of the first cycle to three years (Kurelić, 2009; Lorenz, 2006; Sam and Sijde, 2014). The first cycle is often the academic level that gives access to the profession, including for TRs (Cowling, 2008). As such, essential RT knowledge to access the profession must be included in the undergraduate programme, providing students with the necessary skills to practise while developing the base for them to progress to postgraduate cycles (Sam and Sijde, 2014).

In most cases, postgraduate cycles aim to prepare professionals for advanced and specialised practice (Mary Coffey and Leech, 2018). In some countries, TRs may be trained at postgraduate levels after following a nursing or diagnostic radiography undergraduate programme (Coffey et al., 2018). The current research aimed to understand the education required to practise as a TR; therefore, it mainly focused on undergraduate programmes while acknowledging that the academic level allowing access to the profession varies across Europe.

The EC believes that students' mobility encourages graduates' mobility, contributing to the EU's goal of a flexible jobs market (European Commission, 2015; High Level Group on the Modernisation of Higher Education, 2013). The greatest example of student mobility is the Erasmus+ exchange programme; this programme supports students training abroad and encourages cooperation between institutions, among other educational and research aims. The Erasmus Radiography Group (ERG) is an example of this European collaboration between universities. It offers radiography students the opportunity to experience diverse cultures of practice and expose them to experiences different from their home country (Erasmus Radiography Group, 2006).

Education uniformity promotes mobility since the training provided abroad must be similar to the home university to avoid knowledge gaps (European Higher Education Ministers, 1999; Lorenz, 2006) and facilitate recognition of qualification of graduates (European Parliament and European Council, 2005; Lorenz, 2006). However, the vice-versa is also true: mobility also promotes uniformity since the exchanges can help identify and close gaps in education for both parties involved (High Level Group on the Modernisation of Higher Education, 2013).

The harmonisation of the education model gave rise to resistance since it required significant structural changes, causing clashes between new and old degrees, between degrees from different institutions and countries; some of the reforms also contradicted the national tradition or needs, putting governments in difficult political situations (Kurelić, 2009; Le Feuvre & Metso, 2005; Lorenz, 2006). The involvement of students and institutions was intended to ease this resistance to the process and include the students' view as stakeholders (Kurelić, 2009). This study aimed to provide recommendations for change in educational practice based on the research findings. However, it is acknowledged that these recommendations may not be implemented due to this resistance to change of educational paradigms.

The addition of lifelong learning in this educational reform ensured that HEIs prepare graduates for practice but also develop their ability to progress in their learning after graduation (High Level Group on the Modernisation of Higher Education, 2013; Sam and

Sijde, 2014). It also aimed to compensate for the reduction in the duration of undergraduate degrees, transferring some content to postgraduate programmes. As such, graduates would be ready to work at an earlier stage but must continue developing their competencies throughout their careers (Kurelić, 2009). This is particularly relevant for this research about TRs' education, since it is essential to understand the competencies developed in the pre-registration programme and those developed as part of the lifelong learning to ensure patient safety. European and national entities must establish the necessary life-long learning programmes and promote adherence through incentives such as career progression and reduction of known barriers: time, human resources and cost (Committee on Health Workforce Planning, 2017).

Despite the pressure to achieve economic goals, education quality is a priority at European level. This includes promoting quality of teaching, attainment, mobility, regional development and funding and many other aspects that might influence the objectives for education in the EU (High Level Group on the Modernisation of Higher Education, 2014).

2.3.2 The European Qualifications Framework (EQF)

The European Qualifications Framework (EQF) provides descriptors for each academic level between EQF1 (primary school) and EQF8 (PhD) in three learning outcomes domains: Knowledge, Skills and Competencies (KSC) (European Parliament and European Council, 2008). These descriptors identify the levels which graduates achieve across these three domains for each EQF level, harmonising the level of competence across Europe. However, it does not replace the national qualification frameworks (European Parliament and European Council, 2008).

By presenting this framework, the EQF also promoted harmonisation in curricula design across Europe by encouraging EIs and regulators to follow the KSC format when designing their learning outcomes (section 2.3.2.2 "Learning outcomes and constructive alignment"). This harmonisation facilitates the comparison of European programmes, promoting the free movement of professionals inside the EU (European Parliament and European Council, 2008).

Given this study's European scope, the definitions of "learning outcome", "knowledge", "skills", and "competence" were based on these EQF recommendations. These definitions are as follows:

> *"'Learning outcome' means statements of what a learner knows, understands and is able to do on completion of a learning process, which are defined in terms of knowledge, skills and competence.*
>
> *"'Knowledge' means the outcome of the assimilation of information through learning. Knowledge is the body of facts, principles, theories and practices that is related to a field of work or study. In the context of the European Qualifications Framework, knowledge is described as theoretical and/or factual;*
>
> *'Skills' means the ability to apply knowledge and use know-how to complete tasks and solve problems. In the context of the European Qualifications Framework, skills are described as cognitive (involving the use of logical, intuitive and creative thinking) or practical (involving manual dexterity and the use of methods, materials, tools and instruments);*
>
> *'Competence' means the proven ability to use knowledge, skills and personal, social and/or methodological abilities, in work or study situations and in professional and personal development. In the context of the European Qualifications Framework, competence is described in terms of responsibility and autonomy." (European Parliament and European Council, 2008, p. 11).*

The levels that give access to the therapeutic radiography profession range from EQF4 (secondary education programme) to EQF7 (Master's degree). The descriptors relevant for this study can be seen in Table 2.3 (European Parliament and European Council, 2008).

Table 2.3 – EQF4 to EQF7 descriptors (European Parliament and European Council, 2008)

Dimensions \ EQF Level	Knowledge	Skills	Competence
EQF4 (Secondary educational programmes)	Factual and theoretical knowledge in broad contexts within a field of work or study	A range of cognitive and practical skills required to generate solutions to specific problems in a field of work or study	Exercise self-management within the guidelines of work or study contexts that are usually predictable, but are subject to change; supervise the routine work of others, taking some responsibility for the evaluation and improvement of work or study activities
EQF5 (short HE cycle)	Comprehensive, specialised, factual and theoretical knowledge within a field of work or study and an awareness of the boundaries of that knowledge	A comprehensive range of cognitive and practical skills required to develop creative solutions to abstract problems	Exercise management and supervision in contexts of work or study activities where there is unpredictable change; review and develop performance of self and others
EQF6 (Bachelor's degree)	Advanced knowledge of a field of work or study, involving a critical understanding of theories and principles	Advanced skills, demonstrating mastery and innovation, required to solve complex and unpredictable problems in a specialised field of work or study	Manage complex technical or professional activities or projects, taking responsibility for decision-making in unpredictable work or study contexts; take responsibility for managing professional development of individuals and groups
Level 7 (Master's degree)	Highly specialised knowledge, some of which is at the forefront of knowledge in a field of work or study, as the basis for original thinking and/or research	Specialised problem-solving skills required in research and/or innovation in order to develop new knowledge and procedures and to integrate knowledge from different fields	Manage and transform work or study contexts that are complex, unpredictable and require new strategic approaches; take responsibility for contributing to professional knowledge and practice and/or for reviewing the strategic performance of teams

The level at which the radiographers are educated influences the radiographers' roles. For example, at EQF6, radiographers are competent to perform decision-making in unpredictable situations, while at lower levels, they do not.

2.3.2.1 Competencies

This study focused on the evaluation of radiographers' competencies since competency requires applying knowledge and skills into practice; as such, analysis of competency reflects the development of these other domains. While knowledge is described as theoretical and skills as cognitive and practical, competency is strongly linked with professionalism since it reflects both responsibility and autonomy (European Parliament and European Council, 2008). The professionals are considered competent when they perform the tasks in such a way that grants autonomy. As a result, competent professionals are held accountable for the tasks performed. The level of autonomy and responsibility increases with the EQF level (European Parliament and European Council, 2008). Understanding the concepts of "responsibility" and "autonomy" was essential to recognise the importance of "competencies". These concepts are discussed in detail in the next sections.

Autonomy and responsibility are also linked with authority. Professions establish contracts with society, where society provides autonomy and self-regulation to the profession, but expects responsibility and accountability from those practising the profession – i.e. they expect competent professionals (Cruess and Cruess, 2010; Thistlethwaite and McKimm, 2015).

Johnson (1972) declared that the profession-specific BoK must be accompanied by developing competencies that can be tested. These competencies should also be included in the professional code of conduct and standards. Therefore, competencies are associated with these two other professional concepts.

Even though other concepts could have been evaluated, such as knowledge, skills, tasks, these do not reflect responsibility and autonomy, while "roles" are generic references to the functions of a professional, not being specific enough for the aim of this study. Given the association of competencies with professionalism concepts such as autonomy, responsibility, authority, and BoK and its reflection of knowledge and skills, competencies was the concept selected to be measured in this study.

2.3.2.1.1 RESPONSIBILITY

The concept of responsibility is defined as a value that the individual develops. However, the literature defines responsibility in diverse ways (Barilan, 2009; Güngör and Güzel, 2017). Professional responsibility is fundamental in healthcare to establish a relationship of trust and accountability between healthcare professionals and their patients (Mitchell and Ream, 2015).

Barilan (2009) mentions responsibility as a virtue in the medical profession, describes the evolution of the concept of responsibility and establishes four meanings of responsibility. These meanings are interlinked since responsibility can be seen as the amalgamation of these dimensions. These meanings identified by Barilan (2009) are in agreement with definitions published in other sources (Fenwick, 2016; Güngör and Güzel, 2017; Macmillan Dictionary, n.d.; Oxford Dictionaries, 2018a)

Responsibility to fulfil duties (Barilan, 2009): "a duty that you have to do because it is part of your job or position" (Macmillan Dictionary, n.d.); It refers to the relationship between role and duties, where the person takes responsibility for a task as part of the role they undertake (Barilan, 2009).

Responsibility for the actions performed (Barilan, 2009): "assume the responsibility for his own and moral subjects actions" (Güngör and Güzel, 2017, p. 169). This interpretation of responsibility indicates that individuals assume the consequences (positive or negative) of their actions – they are accountable (Fenwick, 2016).

Responsibility to commit to the reparation of unfairness, suffering and damage (Barilan, 2009): "a moral obligation to behave correctly towards or in respect of [something/someone]" (Oxford Dictionaries, 2018a, p. n.d.). Responsibility is not limited to technical expertise and accountability, but it extends to a commitment to ethical and social norms, including trustworthiness and well-being of others (the patient, for healthcare professionals) (Mitchell and Ream, 2015).

Responsible for the development of personal identity (Barilan, 2009): Güngör and Güzel (2017) indicate that the responsibility is the result of the individual's "psychological formation", emphasising that personal identity is required to attain responsibility. It cannot be an act of randomness, unawareness or due to enforcement by another individual. This refers to the need for autonomy in upholding responsibility.

Although responsibility was depicted as one of the professions' features since the beginnings of professionalism studies (Johnson, 1972), societal changes increased the emphasis on this particular attribute of professions. Healthcare practitioners are increasingly more accountable because of current social expectations and regulations (Thistlethwaite and McKimm, 2015).

2.3.2.1.2 AUTONOMY

The word autonomy comes from the Greek word "autonomos", which can be divided into "auto" (self) and "nomos" (laws), resulting in the meaning of having his own laws or, as stated in the Oxford dictionary (2018b): "The right or condition of self-government". More specific for the healthcare worker is the concepts of "professional autonomy" and "clinical autonomy", which can be defined as the freedom to identify patients' needs and use the necessary resources to meet those needs (Johnson et al., 1995).

Lucie Kelly, during her exploration of the dimensions of professional nursing, identified that the relative independence and control of their own policies and activities during their practice is one of the characteristics of the nursing profession, emphasising that autonomy is not an attribute exclusive to the medical profession (Kelly, 1981). As understood by the word "relative", clinical autonomy might not be complete since all practitioners must collaborate to achieve better patient care, effectiveness, and efficiency of the healthcare systems (Thistlethwaite and McKimm, 2015).

However, nurses' autonomy are frequently compromised by the fact that most are employed at hospitals. Here the level of autonomy is defined by the employer who frequently establishes physicians as having authority over nurses by defining that specific tasks can only be done under authorisation or supervision (Black, 2017). This phenomenon applies to radiographers who are employed in similar frameworks.

Increased autonomy is currently being granted to healthcare professionals, mostly evident in the advanced roles that both professions are currently undertaking, performing tasks that were traditionally exclusive of physicians (Andersson et al., 2017; Black, 2017; Eddy, 2008; Hardy et al., 2008; May et al., 2008). This is often a result of an education that provides them with the necessary competencies to increase their autonomy (Black, 2017).

Role development occurs at different paces, with some tasks so well established in some institutions that they are now considered a part of everyday practice. Some roles are less common either because they are only developed to compensate for specific local needs (College of Radiographers, 2003) or due to resistance by some professionals (de La Cámara Egea, 2013; White and Mckay, 2002). This role extension is directly linked with responsibility and accountability for the task, requiring proper education and training (White and Mckay, 2002). Well-established practices should be developed at the undergraduate level, while postgraduate education should cater for role extension (M Coffey and Leech, 2018; Woodford, 2006).

THE COMPLEXITY OF "COMPETENCIES"

Identifying competencies is a complex process since they include various professional domains. These can include transversal competencies that would apply to all professions (e.g., to be punctual). Some others can apply to all health care professionals (e.g., protect patients' dignity). However, some of them are specific to radiographers (e.g. provide appropriate radiation protection during exposure), and even fewer are specific to linac radiographers (e.g. accurately position the patient for treatment). Nonetheless, all competencies are relevant for the professional's performance and affect patient care.

As Adams et al. (2010) discussed, competencies may imply other competencies or be subdivided into components. According to these authors, peer-review competency is not explicitly identified in the American Society of Radiologic Technologists (ASRT) scope of practice (2017), but other competencies in this document imply it. For example, it states that "the therapist changes the action plan", and in order to do that, the professionals need to assess their colleagues' plan before changing it. Another example given by Gillan et al. (2015) is the responsibility of evidence-based practice that would only be achieved by performing various sub-competencies "questioning practice, evaluating ideas, critically analysing the evidence, and applying the learning achieved to future practice" (Gillan et al., 2015, pp. 430–431)

The well-established skills of the TR (e.g., positioning the patient for treatment) are evident in several, or even all, benchmarking documents and are practised in most departments. However, some are still a matter of debate and can only be found in certain benchmarking documents since not all stakeholders agreed that those are competencies of the TR. These debatable competencies are also often discussed in white papers. An example was whether the TR is responsible and autonomous in assessing verification images and subsequent decision-making (White and Kane, 2007), which are now a more established competency of TRs. This example also shows that what is considered standard also changes with time, adding complexity.

2.3.2.2 LEARNING OUTCOMES AND CONSTRUCTIVE ALIGNMENT

Educational institutions can follow two types of outcomes: “teaching objectives” and “learning outcomes”. The teaching objectives define what lecturers should teach, while the learning outcomes define what students should learn (Harden, 2002, 1999; Spady, 1988). In programmes guided by teaching objectives, learning is a by-product, not the aim (Zitterkopf, 1994).

Some authors argued that replacing knowledge objectives with learning outcomes would limit education, compromise student learning liberty, and decrease academic content (McKernan, 1993; O’Neil, 1994). These arguments have been disregarded since there is evidence that knowledge acquisition increases when learning outcomes are used (European Parliament and European Council, 2008; Harden, 1999; Tan et al., 2018). Medical doctors from programmes that were not outcome-based showed significantly lower competency levels than their counterparts (Walton, 1993).

Outcomes defined in terms of learning objectives are nowadays observed throughout Europe, such as the EQF's KSC learning outcomes framework, showing the consensus regarding the usefulness of this approach (CEDEFOP, 2016; European Centre for the Development of Vocational Training, 2017; Winterton, 2009). Learning outcomes also align with the "easily readable degrees" objectives of the Bologna declaration, facilitating the comparison of qualifications (Mary Coffey and Leech, 2018; European Higher Education Ministers, 1999; Ministers responsible for Higher Education, 2003)

Learning outcomes can be defined at several levels: institutional level, by EIs; regional or national level, by regulatory bodies or professional bodies; and international level, by international organisations. EIs often design their curriculum exclusively to meet the learning outcomes required to practice by the regulator, making regulators the entity with the most direct influence and authority on education (Harden, 2002).

The regulation of the learning outcomes required to practice the profession can be seen across Europe (Health and Care Professions Council (HCPC) (UK), 2013; Qualifications Authority (Estonia), 2014a), but not in all countries (Ministry of Health (Malta), 2003). International learning outcomes guidelines are available to EIs. However, despite their harmonisation potential at the national and international level, there is no complete implementation (European Centre for the Development of Vocational Training, 2017), possibly because these are not a legal requirement, so EIs do not have a great incentive to implement them.

Learning outcomes include the whole learning experience and influence all aspects of the learning process, as shown in Figure 2.7 (Harden, 1999; Spady, 1988). To ensure that the learning outcomes are achieved, the assessment and the learning/teaching activities must be aligned with these outcomes. This is known as *constructive alignment* (Biggs, 1996). In this model, students *construct* meaning through an *alignment* between the students' learning processes and the teachers' learning activities, which should promote the achievement of the learning outcomes. Essential to this model is also the *alignment* of assessments to effectively evaluate the achievement of the learning outcomes and not only the recall of knowledge (Biggs, 1996; Biggs and Tang, 2010). This model has been successfully applied in radiography and other healthcare courses (Biggs and Tang, 2015; Higgins et al., 2017) with positive feedback from the students (Higgins et al., 2017). Existing literature also showed that using alternative teaching activities may improve the alignment of the teaching with the learning outcomes (Bridge et al., 2020; Leong et al., 2018).

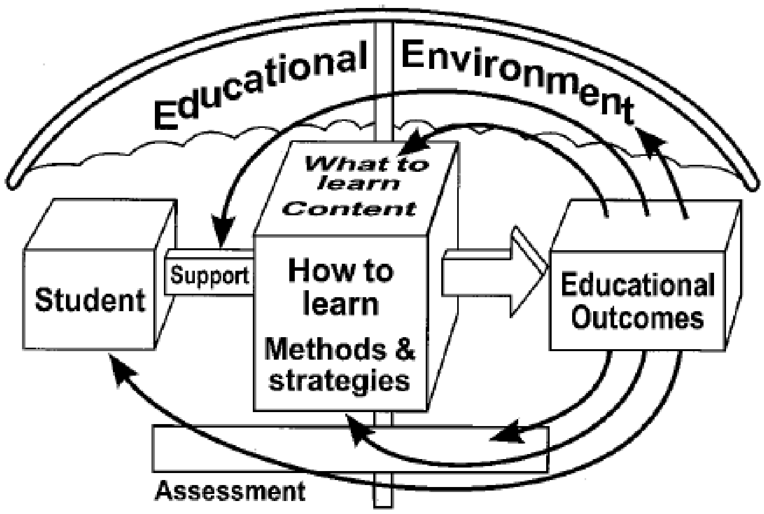


Figure 2.7 – The influence of the learning outcomes (educational outcomes) in the education structure (Harden, 1999)

In summary, the constructive alignment has the potential to improve the competency level of graduates. The first step for the development of a constructive alignment is the definition of learning outcomes. If these learning outcomes are defined in national regulations, they become mandatory for practice and therefore are included across all programmes. As such, the regulation of the learning outcomes has excellent potential to improve competency levels nationwide. International guidelines also have an immense potential to improve standards of practice and international harmonisation, but their non-binding status makes their implementation difficult.

Defining learning outcomes at the local, national or international level is extremely complex since it requires the answer for a very subjective question: "what are the required learning outcomes to become a competent professional?" (European Centre for the Development of Vocational Training, 2017; Harden, 1999; O'Neil, 1994). The answer also depends on who is answering that question, as discussed in the next section.

2.3.3 The impact of market, stakeholders and national tradition on education

In a modern society based on knowledge, the individual as a carrier of knowledge, skills and resources is a much-valued asset. The increasing need for competitiveness raised a knowledge-based economy, putting pressure on governments to develop HE systems to answer the competitive labour market (Lorenz, 2006; Sam and Sijde, 2014). Knowledge is now seen as an asset, and course designs affect the perceived value of the programme.

This is also visible in radiography since graduates put more value in developing the skills that allow them to practice at the highest standards and be competitive in the job market, rather than its ability to provide access to the profession (Beldham-Collins and Milinkovic, 2009). Employers may also pay higher salaries for specific qualifications, such a dosimetrists in the USA ("Medical Dosimetrist," 2018), making programmes that offer these skills more appealing.

The advantage of providing the population with specific competencies may be a direct financial profit. However, in healthcare, the benefit may also be non-financial such as better health of the population. One example was the inclusion of RT into the radiography course at the University of Malta, where the high costs of educating these professionals were compensated by an increase in the radiographers' workforce able to practise this specialism on the island (University of Malta, 2013). In contrast, areas of study can be closed if they do not appeal to the market (Amilburu, 2014; Lorenz, 2006).

The traditional Anglo-Saxonic model was characterised by being driven by social usefulness, measured by the willingness of the market to buy the product. Following the convergence of education structure, this characteristic was disseminated across Europe (Le Feuvre and Metso, 2005; The National Committee of Inquiry into Higher Education (UK), 1997). Another characteristic of the Anglo-Saxonic model that remained was the two-cycle framework, allowing graduates to start working sooner than in other models, satisfying the market needs for educated professionals (Lorenz, 2006).

The HE reform promoted curricula that adapt to the market needs rather than just government-imposed structures (High Level Group on the Modernisation of Higher Education, 2013). However, despite governments still having significant influence in most healthcare professions through regulation, ensuring that population needs and safety are met, the education of these professionals is influenced by various stakeholders (Le Feuvre and Metso, 2005).

2.3.3.1 STAKEHOLDERS

Given the scope of this research, stakeholders who influence education and curricula design are discussed here. The most common stakeholders that define the social usefulness of the programme are (Le Feuvre and Metso, 2005):

- **Regulatory bodies**, which may be part of the government or autonomous entities, influence the minimum requirements for the professionals to practice. These may be the only stakeholder consulted by EIs during course design since their requirements are mandatory. Regulatory agencies may have consulted stakeholders during the definition of the minimum requirements, indirectly representing other stakeholders. Professional regulation has multiple aims, including population safety, service provision quality, the efficiency of the resources, or accountability, which are often challenging to balance (Adams, 2020).
- **Employers** are often consulted during the design of education programmes, increasing the value of their programmes by offering the skills that match the market needs. In many instances, including radiography, the employer can include the government.
- **Professional bodies** define the learning outcomes expected for their members (standards of practice). These standards of practice are not a requirement to practice. However, when EIs incorporate these standards into the programmes, it ensures that best practices are taught and allows graduates to register with the professional body, improving their job competitiveness.
- The **academic staff** are crucial stakeholders because of their knowledge and input into the course programme, ensuring that the programme delivered is realistic, efficient and manageable (High Level Group on the Modernisation of Higher Education, 2013). However, they should not be the only decision-makers since their opinion regarding the curriculum design is often influenced by personal knowledge and beliefs, professional practice, individual achievement, peer influence, EI's vision, national culture, international recommendations and trends, among others (Burrell et al., 2015; Clarke and Hollingsworth, 2002).
- **Students** are considered stakeholders since they have the power to decide to enrol in a specific educational programme. Students weigh the costs of enrolling (such as fees, accommodation, time, effort) against the benefit they can retrieve from the course. Commonly, students give higher value to programmes providing greater employability, higher salaries, and academic experience. At the same time, students' needs and preferences are also considered (Ognjanovic et al., 2016). Radiography students should contribute to the curricula design to match their learning needs (Beldham-Collins and Milinkovic, 2009).
- Since they are facing the market's needs, **graduates** have a better perception of the usefulness of the course programme to deal with real-life situations (High Level Group on the Modernisation of Higher Education, 2013).

- **Funding bodies**, such as the government and other public and private organisations, can also support specific programmes by offering grants. These programmes often develop competencies that help them achieve their goals, such as competencies they require but lack in the market or skills that benefit society (Le Feuvre and Metso, 2005).
- Lastly, **service users (patients)** are stakeholders since the ultimate goal is to provide them with the best possible service, ensuring that the graduates develop competencies that match their needs (Naylor et al., 2015). Although some institutions include service users in the discussion of the curricula, they may also be represented by the government or regulatory bodies. Service users were not included in the current study since their perceptions of the competencies required by TRs was studied in a separate work package within the SAFE EUROPE project.

When considering the views of the different stakeholders, it is crucial to be aware that they may have different or opposite perspectives (Porter, 2010). This divergence constitutes a challenge to integrate the needs of all stakeholders into the curricula.

HEIs are considered the focal points of knowledge production, creating individuals capable of critical analysis and problem-solving, which society needs to address future challenges. As such, society must contribute to course design by involving all relevant stakeholders (High Level Group on the Modernisation of Higher Education, 2013).

> *“Recommendation 7 – Curricula should be developed and monitored through dialogue and partnerships among teaching staff, students, graduates and labour market actors, drawing on new methods of teaching and learning, so that students acquire relevant skills (...)” (High Level Group on the Modernisation of Higher Education, 2013)*

Stakeholders help the HEI keeping up with the profession's evolution resulting from changes in practice and the service users' needs. This constant adaptation is crucial in RT due to the increase in procedures and task-shift from other professions, requiring that TRs develop additional roles (Department of Health [UK], 2003; Price et al., 2002).

Harden (1999) further defended that the learning outcomes of the medical education programmes should be made public so that all the stakeholders are aware of these professionals' competencies and can continuously identify opportunities for improvement; these same can be applied to radiographers.

2.3.3.2 NATIONAL TRADITION

Historically, different educational models with different characteristics and aims (Table 2.2) were present in different countries (Table 2.4). However, in reality, each country has a variation of these three European educational models, slightly moulded by national tradition (Sam and Sijde, 2014).

TABLE 2.4 – HISTORICAL MODEL USED IN SOME EUROPEAN COUNTRIES

Napoleonic Model	Anglo-Saxonic Model	Humboldtian Model
France Spain Russia (non-EU) Romania Hungary* Italy Portugal	UK Norway (non-EU) Republic of Ireland	Germany Netherlands Czechoslovakia Hungary* Poland Sweden (non-EU) Finland

*different authors defend that Hungary used the Napoleonic or the Humboldtian Model

The Bologna process changed the HE structure to the extent that it can be considered a new education model (Amilburu, 2014). The current model includes characteristics of the different historical models, such as the adaptation to market demand (Anglo-Saxonic model), regulation of the curricula by the state (Napoleonic model) or HEIs as the main producer of new evidence (Humboldtian model). This change can be observed even in countries where the historical models were born. Therefore, the identification of the traditional models in current education is not straightforward.

The Bologna process did not define all aspects of education. Relevant aspects for the country, region and/or institution may have remained unchanged (Kurelić, 2009; Le

Feuvre and Metso, 2005; Lorenz, 2006; Sam and Sijde, 2014). As such, national traditions will perpetuate differences in European education philosophical values and educational structures, leading to variation in thelearning outcomes (High Level Group on the Modernisation of Higher Education, 2013; Le Feuvre and Metso, 2005). These traditions and philosophies apply to all education programmes, including radiographers'.

2.3.3.2.1 LANGUAGE

Language is also an important traditional aspect to consider. Although not frequently discussed at the policy level because it is a sensitive subject, it is acknowledged that language can be a barrier to the movement of students, academics and professionals but also for curriculum internationalisation (High Level Group on the Modernisation of Higher Education, 2013).

The directive 2013/55/EU, amending 2005/36/EC, included knowledge of one of the country's official languages as a new optional criterion for the recognition of qualifications between member states (European Parliament and European Council, 2013). Therefore, regulatory bodies can now request evidence of language proficiency, which may hinder professional mobility.

The acknowledgement that language can be a barrier is vital for this work. In the particular case of moving radiographers, they must communicate with patients that speak a different language, and there is not always a common language between a local patient and a foreign professional. Therefore, the amendment to the 2005/36 directive improves patients' safety.

The language also directly affects education since only those who speak the tuition language can enrol in the programmes. In addition, students only have access to experts who do speak their language. Even when student exchanges occur, students are limited to attend lectures in a language they understand. The High Level Group on the Modernisation of Higher Education (2013) recommends that two foreign languages (one of them being English) should be included in all HE courses. However, this is not mandatory, nor is it being implemented.

Another relevant point for this study is that language hinders radiographers from finding the information needed to move to another country. The researcher also experienced a language barrier during the literature search, which was limited to the languages understood by the researcher, possibly excluding relevant national publications.

2.4 EDUCATION OF RADIOGRAPHERS IN THE EUROPEAN SETTING

McNulty et al.'s paper in international radiography education starts by stating that "radiography education is the cornerstone to the profession and an essential element in helping generate competent radiographers who can practise safely and effectively" (2021, p. 1). This quote clearly conveys the rationale of the current research.

However, the education of radiographers in Europe and worldwide is characterised by disharmony (England et al., 2017; ISRRT, 2012), raising questions about competence, safety and effectiveness. Cowling (2008) identified 11 main education pathways for the profession across 144 countries. This inhomogeneity results from programmes being guided by national regulation, local departments' needs, and vague educational recommendations published to fit all settings (Cowling, 2008; McNulty et al., 2021).

There was no research comparing RT curricula of education programmes across Europe. This is probably due to the amount of data, making such a task overwhelming. In addition, different institutions and countries design their curriculum using completely different formats (e.g., based on teaching objectives vs learning objectives; knowledge vs competencies).

Consequently, summarising the education of radiographers into a single document would not be easy. In fact, this research study focused on a single role, TRs working on the linac, allowing an in-depth assessment of the topic.

The discussion in the following sections focused on the overall course structure available in the literature. Subsequently, European education guidelines and EU legislation that affects RT courses are covered. This section finishes with a discussion on the existing studies about the constant change in radiography education. These subjects were essential for the researcher to understand what was previously known about radiography/TRs' education, informing the methodology and supporting the discussion of the results.

2.4.1 Structure of radiography education programmes

The structure of the education programmes in radiography in Europe is quite varied (Bibault et al., 2018; England et al., 2017; McNulty et al., 2017, 2016; Sá dos Reis et al., 2018). The variation in structure and curricula is likely due to many factors not yet fully identified (McNulty et al., 2021).

National regulation must be followed to grant graduates access to the profession; therefore, it is probably one of the most significant factors influencing the structure and curriculum of radiography education (Sloane and Miller, 2017). However, these regulations are often based on tradition. Continuous reviewing of the regulated national standards is essential to develop radiographers' education and profession (Bibault et al., 2018; Sloane and Miller, 2017).

It is important to note that differences in education structures may not automatically indicate different competencies. These differences may also be necessary given national needs while still equipping graduates who can provide care at the highest standards (EFRS, 2019). However, programmes must develop the core competencies while being flexible and adapt to changes in practice and evidence (England and McNulty, 2020).

In McNulty et al.'s study (2016), a survey was distributed across EIs affiliated with EFRS to understand the main characteristics of the radiography educational programmes. The biggest differences were the specialisms included in the programme (diagnostic and/or radiotherapy and/or nuclear medicine), programme duration (between 3 and 4 years) and the number of hours (h) per ECTS (from 20h to 30h per ECTS). The authors highlighted how the differences in competencies hinder the movement of radiographers in Europe. Similar variation was also observed worldwide (Cowling, 2012; McNulty et al., 2021)

In contrast, 90% of the respondents in Europe and 84-94% worldwide stated that the academic level required to practise in their country is the Bachelor degree (EQF6) (Cowling, 2012; McNulty et al., 2021, 2016), which is the academic level that allows for independent practice. In addition, an increase in the use of the EQF and KSC in the definition of the learning outcomes was observed, which is a step towards more comparable outcomes (McNulty et al., 2016). However, many countries require postgraduate education, internships or exams to access either the profession or specific specialisms (McNulty et al., 2021)

The evolution of radiography education occurred as a step-by-step process, with a gradual increase in academic level: from professional courses to diploma and finally to degree, which is currently considered the standard by most countries. Some authors identified the technological advancements as the primary rationale for changing the educational structure, needing to increase the programmes' overall duration and academic level (Decker and Iphofen, 2005). While the shift from predominantly clinical training to a model supported by theory also influenced the overall course structure (Beldham-Collins and Milinkovic, 2009).

However, the Bachelor's degree (EQF6) is not yet the standard level of education in some countries (Čurić, 2018). Other structures can be found, including graduates with degrees in nursing or other areas who can practise radiography. For example, in Belgium, nursing graduates undergo a postgraduate course in one of the radiography specialisms (ISSIG, 2012a, 2012b). At the same time, levels lower than the undergraduate are sufficient to practise in certain countries, such as Spain (Centro de Estudios Sanitarios, 2015a, 2015b, 2013; ITEP, 2015). However, there is a gap in published literature discussing the profession's regulation across Europe and the impact of these educational models on competency.

Some radiography programmes focus on projection radiography (possibly with an additional modality), others develop all imaging modalities in parallel, but some programmes do not develop certain modalities, such as MRI, paediatric imaging, mammography, or radiotherapy (Caruana and Plasek, 2006; Sá dos Reis et al., 2018). Both studies showed that radiography course programmes have different structures (programme duration, ECTS and specialism) that lead to different curricula and competency levels. However, curricula differences were observed even between programmes with similar structures, showing that harmonisation of the main course characteristics may not automatically mean standardisation of curricula (Sá dos Reis et al., 2018).

Regarding education structure, it seems consensual that a theoretical radiography education followed by clinical experience is the ideal setting for developing the much-needed specialists (Andersson et al., 2017), explaining why the most common education structures across Europe include a mix of theory and practice spread across all years of the programme (England et al., 2017; McNulty et al., 2021). The clinical practice is often performed at hospitals and health centres (Naylor et al., 2016) and was considered the most crucial aspect of education by RT staff (Bibault et al., 2018). The majority of respondents to England et al.'s survey (2017) reported that more than 60 ECTS were dedicated to clinical practice. Concerningly, some countries reported less than 31 ECTS; however, these countries reported the requirement of postgraduate education or internships after graduation. Furthermore, this structure emphasises the vocational nature of radiography, leading to learning outcomes that focus on preparing graduates to perform a job (England et al., 2017). A limitation of England et al.'s (2017) methodology was the lack of anonymity which may have led to pressure to provide acceptable answers, thus influencing the findings.

Clinical practice supervision seems well established, despite variation in roles, requirements for such roles, employment frameworks and ratios of students per supervisor. However, only 32% of institutions perform Quality Assurance (QA) of clinical placements and, from those who performed it, the vast majority do it through questionnaires to students (England et al., 2017), which can arguably be considered a very limited form of QA and raising questions about the quality of the placements.

Additionally, QA of clinical placements seems to be predominantly performed only if required by professional bodies or accreditation (Price et al., 2000).

Variation in the use of clinical simulation was reported between respondents. The majority have less than 15 ECTS in skill labs, while some reported more than 26 ECTS (England et al., 2017). Other literature confirmed an increase in the use of simulation for teaching (McInerney and Druva, 2019; McNulty et al., 2021). Multi-specialism programmes tend to have a larger percentage of clinical placements using simulation (McNulty et al., 2021), possibly due to the lack of access to placements in all specialisms.

In addition, education funding also varies considerably across Europe, affecting the profession and education (England et al., 2017). Studies showed that changes in funding models in the UK were a deterrent from entering radiography (Hopkins, 2016 as cited in Knapp et al., 2017), while funding issues affect the capacity of universities to keep an adequate academic workforce (Knapp et al., 2017). These staffing issues are evident in the retirement of older staff, holders of higher qualifications, who are slowly replaced by younger staff without PhDs (Snaith et al., 2016). However, the authors suggest that this will happen over a 10-year period which may be enough time for those young academics to obtain their doctorates. The only concern was that only 14.6% of European EIs with radiography programmes offer doctorate programmes, limiting radiographers capacity to obtain higher academic grades (McNulty et al., 2016).

A tendency to harmonise education in radiography can be observed at the European level, as a consequence of the Bologna process (European Ministers Responsible for Higher Education, 2005) and other radiography-specific projects such as the Tuning project, which aimed to harmonise radiography learning outcomes across Europe

(Challen, 2008; HENRE, 2008b, 2008a). Some authors refer that HEI emphasises different aspects of radiography science, leading to differences in curriculum. However, no systematic approach to identify the details about these differences was completed (Akimoto et al., 2009; Payne and Nixon, 2001; Pratt and Adams, 2003).

The conclusions from a survey related to the educational framework for radiation protection found that knowledge regarding radiation protection was primarily obtained by radiographers during undergraduate courses (Directorate-General for Energy, 2014). Following the Bologna process, employment is expected to happen at the end of the undergraduate course; therefore, developing radiation protection knowledge at the undergraduate level is even more critical (Kurelić, 2009).

2.4.1.1 STRUCTURE OF RT EDUCATION ACROSS EUROPE

A discrepancy specific to radiography across Europe is the specialisms included in the programmes (RT, MI, NM, ET). In some EU countries, radiography is a single profession, e.g. in Malta (Council for the Professions Complementary to Medicine, 2006), but these specialisms may be independent professions in other countries, e.g. in Portugal (Portuguese Government, 1999).

While multi-specialism programmes seem to be the norm in Europe (63% of respondents to McNulty et al.'s survey (2016)), single-specialism courses are the most common model used worldwide (65% of respondents to McNulty et al.'s survey (2021)). Nevertheless, single-specialism programmes are mostly dedicated to MI, while RT is still most commonly taught together with other specialisms at the European and worldwide levels (McNulty et al., 2021, 2016). Worryingly, 12% of respondents stated that their MI-only programme allows them to practise RT (McNulty et al., 2021).

When RT is taught as part of multi-specialism courses, it is often a short component in these programmes with only a few weeks of clinical placement in this specialism (Coffey et al., 2018; Eriksen et al., 2012; McNulty et al., 2016). This compromises graduates' competence, and additional training is often necessary following graduation (Coffey et al., 2018). Katzman et al. (2013) and Coffey and Rosenblatt (2018) advocate for education programmes dedicated to RT because of their specific BoK, with TRs in multi-specialism programmes often reporting insufficient education.

There is also a massive lack of awareness and investment in TR education by governments and other decision-makers. Historically, physicians and medical physics were responsible for the clinical and equipment aspects of RT, while TRs took more technical roles (Coffey and Rosenblatt, 2018). Despite the professions' evolution, there is still a perception that TRs do not need to be better educated because it is a technical profession, and this lack of education does not allow TRs to take other roles. This vicious cycle also has a financial side: this perception leads to reduced investment in this expertise, keeping the professionals underdeveloped, which creates the impression that the skill level of these professionals does not justify the investment (Coffey and Rosenblatt, 2018). The lack of governmental commitment is also common due to a lack of understanding of the implications of undertrained TRs on treatment accuracy and, eventually, on patient outcomes (Coffey et al., 2018). It seems essential to keep raising awareness of decision-makers and the general public about the importance of adequately trained TRs, with the ultimate aim of developing adequate regulation for TRs' education.

Katzman et al. (2013) identified the financial benefit of joint courses, especially in small countries where the small number of graduates in RT would not be justifiable and large-group courses would quickly fill the market and create unemployment. The same publication showed that RT-only courses can be financially sustainable (even in small countries) through collaboration with national diagnostic radiography and international RT courses while achieving adequate competency levels.

Lack of harmonisation is again the keyword in RT education. Joint courses can have a large proportion of their programmes dedicated to RT, some have over 75 ECTS dedicated to this specialism (University of Malta, 2021), while others can have as low as 3 ECTS (Kivistik, 2018). Even within the same country, differences may arise for different factors, such as the exposure students receive during their placements or the different teaching methods employed (McPake, 2019).

RT education can be followed by a postgraduation degree where a specialisation may be achieved (Mary Coffey and Leech, 2018). TRs can choose from a variety of programmes addressing RT-specific tasks (e.g. image interpretation in radiation therapy, radiation protection, evidence-based practice), as well as programmes that develop transversal skills (e.g. management, research, education) (HENRE, 2008b). This is one of the results from the Bologna process and the two-cycle system (European Higher Education Ministers, 1999; Reinalda and Kulesza, 2005). Common to all these postgraduate programmes is the importance given to the development of research skills that allow students to produce knowledge (HENRE, 2008b).

Although employability should be achieved at the undergraduate level, there are still countries where the postgraduate programme, following nursing, diagnostic radiography or other undergraduate programmes, are the pathway to practice RT (Coffey et al., 2018). Due to the minimal RT content in multiple-specialism courses in some countries, radiographers may need to undergo a Master’s degree in RT before practising (Kivistik, 2018).

In Israel, where radiography education is also a joint 3-year course, 50% of radiographers identified that RT education is insufficient (Katzman et al., 2018). In addition, TRs from different countries where education is combined with diagnostic radiography identified that having an RT dedicated programme would provide them with better competencies to practice the profession (Karadza et al., 2018; Katzman et al., 2018).

Multiple CPD programmes and courses are available at the European level to help improve TRs’ competencies, compensating for the potentially low RT-specific training. One example is the ESTRO/IAEA programmes to train TRs. These programmes are delivered across different countries to develop TRs’ competencies while preparing them to train others (Coffey and Rosenblatt, 2018). Conferences, courses, webinars, and other online tools are also widely available.

The lack of adequate regulation at the national level is still one of the most significant factors for the underdevelopment of RT education. The work done by RT professional associations at the national and international levels helped define the role of these professionals. However, the lack of detailed regulation of the educational requirements to practise the discipline, including learning outcomes, allow educational institutions to provide the bare minimum training to comply with regulations, hindering the profession's growth (Coffey and Rosenblatt, 2018). In addition, the variation in existing national regulations and the standards of practice defined by national societies lead to a perceived difference in the quality of courses offered across Europe (Bibault et al., 2018).

Regarding the quality of education across Europe, 26% of all RT professionals (including physicians, medical physicists, nurses) identified their national educational programmes as inadequate (Bibault et al., 2018). However, a non-validated survey was used to collect this data, and 88% of the TR respondents came from only eight countries, possibly indicating sampling bias. This study also showed that the average course costs 3000 euros/year (range: 250-8000 euros/year) with a median of 10 years (range: 3-11 years).

In summary, the Bachelor's degree (EQF6 level) seems to be the most common academic level that grants permission to practice RT with the possibility to pursue further studies. However, discrepancies in the programme structures are seen across Europe. The main differences found in the literature include programme duration and specialisms. However, programmes with lower academic levels or postgraduate top-up courses may allow individuals to practise RT in some countries. All these differences in structures suggest that there may be differences in the learning outcomes and competencies (Akimoto et al., 2009; Payne and Nixon, 2001; Pratt and Adams, 2003), but no details of these differences were identified. Ascertaining the gap in content is essential to close these and improve radiographers' mobility and patient safety.

Another central theme in literature is the importance of TRs' education to provide the highest quality of care possible to cancer patients. RT is an essential modality to treat cancer and it is vital that TRs are adequately educated to ensure high quality treatments. As such, the vicious cycles that keep TRs at lower competency levels in some countries need to be reverted. By improving education, TRs can perform tasks with more responsibility and autonomy, take leading role in the RT process, increasing the motivation to adequately fund TRs' education, creating a healthier cycle for the professionals and patients. This can be enormously assisted if professional regulation improves by defining learning outcomes to achieve this goal.

2.4.2 Recommendations and benchmarking documents on the education of therapeutic radiographers

Several organisations issued recommendations regarding the education of TRs that are relevant for the European setting. The guidelines discussed here may address the education of radiographers (all specialisms) or focus on TRs' education, and they are issued both by pan-European or worldwide organisations (EFRS, 2014a, 2018; ESTRO, 2014; HENRE, 2008b; IAEA, 2014; ISRRT, 2014). Although there is an extensive overlap between the documents, there are also considerable differences in their recommendations. Therefore, depending on the guidelines followed, the education programmes across the EU may be different.

All these recommendations aim to define the standards of practice of the TR/radiographer and, consequently, define the education requirements to practice the profession. These guidelines, which in some cases are designated as "benchmarking" documents, also aim to ensure that the best practice is performed in all institutions, ensuring that patients receive the best care possible. This proved to be a challenge, given the practice and education differences worldwide (Cowling, 2008).

The methodologies used by the different organisations to draw their guidelines vary considerably. In the EFRS benchmarking documents, a group of experts was identified to draw the recommended KSC of the radiographers (all specialisms) in Europe. In the 2014 edition, only four specialists were identified; none of them was a TR. The group of experts for the 2018 version is not identified. However, it is identified that their expert committees had an input in this revision whose biographies can be found online, consisting of radiographers with vast RT experience (EFRS, 2018, 2014b, 2014a). EFRS aims to "develop all levels of radiography education and research across Europe" (England et al., 2017, p. S8); as such, they seldom distinguish the diagnostic and therapeutic branches.

The Higher Education Network for Radiography in Europe (HENRE Network) published a template for radiography education as part of the Tuning project (HENRE, 2008b). As mentioned in the project website (Tuning Project, n.d.), the aim is not to achieve uniformity but instead promote a European education that is "in tune" despite their differences and achieve a common understanding between HEIs. This template has a European scope and was drafted by a group of experts; however, their CVs are not available to evaluate their expertise in RT. Despite being the oldest document analysed in this literature review, it makes recommendations on competencies for both the first and second cycles of studies. In addition, it refers to the possibility of pursuing a third cycle of studies, but the descriptors of this cycle were not available. The document divides the competencies descriptors into two parts: the first describes "generic competences" while the second part establishes the "subject-specific competences". The transversal competencies are categorised into instrumental, interpersonal, and systemic competencies described as follow:

> *"Instrumental competences: cognitive abilities, methodological abilities, technological abilities and linguistic abilities.*
>
> *Interpersonal competences: individual abilities like social skills (social interaction and co-operation)*

> *<u>Systemic competences</u>: abilities and skills concerning whole systems (combination of understanding, sensibility and knowledge; prior acquisition of instrumental and interpersonal competences required)" (HENRE, 2008b, p. 8)*

In the second part, the "subject-specific competences" describe technical and specific competencies to the radiographer. Furthermore, it breaks down competencies into four parts: specific competencies for DRs, specific competencies for TRs, quality assurance and radiation safety competencies.

The HENRE template is the benchmarking document with the least number of competencies and do not use the KSC framework recommended by the EQF. This reflects the fact that this is the oldest of the documents. An evolution on the list of competencies is evident when organisations update benchmarking documents (EFRS, 2018, 2014a; ESTRO, 2014; Coffey et al., 2011), building the new documents on the existing knowledge.

The *Handbook for the Education of Radiation Therapists (RTTs)* published by the IAEA (2014) makes recommendations on the competencies of TRs but also on the content to be included in the curricula, teaching and assessment methodologies. This document has a worldwide scope (not only European). The core competencies identified are specific for TRs, and the learning outcomes are defined using the KSC framework. The recommendations in this document literally duplicate many of ESTRO's recommendations published in 2011 (Coffey et al., 2011), projecting these European recommendations to a worldwide scenario. Two authors of the ESTRO recommendations are also in the IAEA document. Collaborations between the different professional organisations are essential to harmonise recommendations, facilitating their implementation.

The methodology used in the ESTRO's 2011 recommendations was a survey of European professional societies to collect information regarding education and scope of practice (28 countries replied). The methodology used in the design of the IAEA document seems to be a mix between the results from the ESTRO's survey and the panel of ten experts, although the methodology used is not clearly stated in the document.

The benchmarking document issued by ESTRO (2014) was developed based on the knowledge already gathered from an extensive survey published together with the recommendations. However, details about the survey methodology are unpublished. The omissions include the population, the sampling technique, and the results of the survey. Nevertheless, there are various strengths of this methodological approach. Firstly, the competencies recommended were based on evidence collected from a range of European countries. Secondly, the survey focused on the RT specialism, identifying various TR-specific learning outcomes. Lastly, the latest version shifts from knowledge-based learning outcomes to competency-based learning outcomes, in line with most current educational paradigms (Bibault et al., 2018).

The International Society of Radiographers & Radiological Technologists (ISRRT) issued the Guidelines for Education of Entry-level Professional Practice in Medical Radiation Sciences (ISRRT, 2004), where the learning outcomes are defined in terms of skills (not in terms of KSC) and "spectrum of practice" that mainly discussed roles of the radiographers. Other aspects include required resources, quality assurance and life-long learning. This document is outdated compared to other documents discussed in this section and does not follow EQF recommendations. ISRRT's updated their guidelines in 2014; despite being entitled "Radiography Education Framework", it includes learning outcomes for diagnostic radiography only, and therefore, was not relevant for this work (ISRRT, 2014).

Recommendations focused on a single specialism (ESTRO, 2014; IAEA, 2014) describe extremely specific professional and technical competencies. For example, ESTRO's benchmark document organises the competencies according to the roles of the TR in practice, such as positioning and immobilisation, image acquisition and virtual simulation or treatment planning. In contrast, general guidelines for all the specialisms (EFRS, 2018, 2014a; HENRE, 2008b) tended to focus on generic competencies. For example, EFRS's benchmarking document (2018) organises the competencies in terms of transversal roles, such as communication, numeracy or ethics. Competencies for the TR are detailed; however, this is limited to eight core competencies.

All documents referred to EQF6 as the academic level recommended to achieve the necessary competencies. The only exception is that IAEA's document refers to the contents to be covered in shorter programmes (considering the practicalities of different worldwide regions). Given this, it seems consensual that EQF6 is the recommended level to practice in the European context, being in line with the Bologna recommendations of the first cycle to be the one that prepares students to be employed.

In most cases, the scope of education guidelines reflected the scope of the organisation that issued it. For example, ESTRO issued recommendations focusing on the TR while EFRS and the HENRE network published recommendations for all radiographers. However, two organisations representing both professions issued specialism-specific guidelines: IAEA issued recommendations for TRs only, and ISRRT only updated the guidelines referring to DRs only. Despite the many differences between the recommendations, it is essential to note that these are not contradictory but rather complementary.

2.4.3 European Union guidelines and regulations on Radiation Protection

Between 2010 and 2013, the MEDRAPET project aimed to assess the implementation of 97/43/EURATOM directive regarding radiation protection and training across Europe (now revoked by the Council Directive 2013/59/EURATOM) (Directorate-General for Energy, 2014). Radiation protection authorities, professional societies and educational institutions were invited to answer the survey, and the main conclusions were as follows (Directorate-General for Energy, 2014):

- There were well developed educational and training frameworks at a national level.
- However, the implementation of these frameworks was poor.
- Individual professionals showed distinct levels of knowledge.
- Most of the professionals acquired their knowledge at the undergraduate level or residency.
- An improvement in communication between radiation protection authorities, professional societies and educational institutions was considered necessary.

This shows that the implementation of educational frameworks is not always efficacious. One possible explanation is that it is the responsibility of the member state to legislate and ensure the provision of "appropriate radiation protection education", which vary according to the country (Directorate-General for Energy, 2014).

This survey prompted an updated of the *Guidelines on Education and Training in Radiation Protection for Medical Exposures* (2000; 2014). The necessity of a revised version of these guidelines arose from the need to adapt to technological evolution in the field, to include other professions that deal with ionising radiation, and to define the learning outcomes in terms of KSC according to the current EQF (Directorate-General for Energy, 2014). This is evidence that learning outcomes need to be updated regularly.

This publication showed that radiation protection competencies are strongly related to the overall quality of care. The development of knowledge (e.g. “Explain the risks to the foetus from exposure to ionising radiation”), skills (e.g. “Identify different image quality standards for different techniques”) and competencies (e.g. “Optimise and evaluate plan options”) that are considered part of radiation protection also provide the patient with better quality of care overall (Directorate-General for Energy, 2014).

These guidelines emphasise that appropriate education is achieved by a good balance between theoretical classes and training. They agreed with the position of EFRS, which recommends a minimum of 25% of the course dedicated to clinical practice (EFRS, 2019). However, as suggested by the survey above, the implementation may not be complete.

The 2013/59/EURATOM, which defines the Basic Safety Standards, puts the responsibility for adequate education of radiographers with training is specialised in the “appropriate area” on the regulatory body (European Council, 2013). Therefore, it can be concluded that RT-specific content should be, by regulation, included in all programmes that allow graduates to practice this specialism. However, the survey on the implementation of radiation protection training showed that its implementation is poor (Directorate-General for Energy, 2014), showing that regulation and frameworks must be followed by enforcement.

2.4.4 Potentially underdeveloped competencies

Research into radiography education and practice has often addressed specific subjects rather than the whole education since this requires extensive data collection and analysis. As such, independent publications identified different issues that may be underdeveloped: critical analysis (Gillan et al., 2015; Reynolds et al., 2009), leadership (Gillan et al., 2015), risk management (Vaandering et al., 2018), numeracy (Peters et al., 2021), communication (Kelly et al., 2021), audit skills (England and McNulty, 2020), evidence-based practice and research (England and McNulty, 2020; England and Thompson, 2019; Higgins et al., 2015; Smoke and Ho, 2015) to name a few. The reasons and urgency to develop these competencies are varied.

Despite the importance of research skills to the growth of the professions BoK, they are an excellent example of the complexity in designing educational paths for TRs. Research skills cannot be fully developed in an undergraduate programme due to time limitations and the long learning curve these skills require. The research skills developed are often limited to critical evaluation and implementation of research into practice rather than conducting the research. Even though research competencies can be developed at the postgraduate level (Master’s and Doctorates), authors argued that the inclusion of research in the undergraduate programme is essential (England and McNulty, 2020; Higgins et al., 2015) since “ensuring best practices and outcomes can only be achieved through […] research” (England and Thompson, 2019, p. S1).

In summary, publications are often limited in scope to the competency/skill that the authors were assessing. There was no published general overview of the competencies of the TR working on the linac and their level of development across Europe.

2.4.5 The constant change in radiography education

Radiography education is constantly changing, including programme structures, learning outcomes and teaching methods. These changes result from changes in the profession, educational models, professional regulation, advanced practice, and research (Andersson et al., 2017; England and McNulty, 2020; McNulty et al., 2021), requiring programmes and curricula to be frequently updated. This constant change also puts pressure on academic staff to keep abreast with the fast-changing practice (Knapp et al., 2017) while still performing all other academic, research and administrative tasks.

Besides changing technology, sometimes, TRs need to change practice to improve outcomes as new evidence is being constantly published. Another source of practice change specific for RT is the continuous risk management that must be performed in every department to avoid undesired incidents. This can also have an inter-departmental and international scope when RT departments use systems such as the Radiation Oncology Safety Education and Information System (ROSEIS) or Safety in Radiation Oncology (SAFRON) initiatives to share their experiences and learn from others. These incident-reporting systems can also be incorporated into the RT courses to increase awareness of radiation risks and improve risk management skills (Vaandering et al., 2018).

Some of the most recent changes in RT teaching include the introduction of MRI-linac, the increase in Artificial Intelligence (AI) in healthcare, and the use of simulation in radiography education, just to name a few. MRI was already included in some TR education programmes since this modality is commonly used in RT planning, yet MRI competency varies between graduates (Hales et al., 2020; Rai et al., 2017). The increase of MRI-linac units led to a re-evaluation of the TR educational needs regarding this imaging modality. This modality requires subjects such as MRI safety, image acquisition and decision-making regarding patient setup (Hales et al., 2020). In-house multidisciplinary competency-based training programmes seem appropriate to prepare TRs to perform specific roles related to MRI-based image verification (Hales et al., 2020; Rai et al., 2017). However, there is a lack of consensus on the required competency level expected from pre-registration graduates in this area since this may be considered an advanced role (Eccles and Campbell, 2019). TRs trained to perform MRI-based image verification are an asset in RT departments and can decrease the overall staff workload by reducing the constant presence of physicians on-site (Eccles and Campbell, 2019; Hales et al., 2020).

AI applied to RT is also rising, requiring TRs and other staff to develop the necessary skills to use it efficiently and safely, impacting education programmes. Despite some concerns regarding loss of job satisfaction and skill, TRs are overall optimistic. The papers discussed here identified the role of education in mitigating these fears and preparing professionals for the digital future (Batumalai et al., 2020; Chamunyonga et al., 2020; Wong et al., 2021). One of the potentials of AI is opening doors for research on applying this technology to radiography (England and Thompson, 2019). AI potential in RT is immense; however, care must be taken to ensure that computer-led tasks are adequately validated (Boon et al., 2018), possibly a new role for the TRs. In addition, the multidisciplinary team in RT may now include a new profession with whom TRs must liaise: Computer Scientists (Boon et al., 2018).

An increase in simulation and other digital tools in education was observed recently, with intentions to keep increasing (Bibault et al., 2018; McNulty et al., 2021; Shanahan, 2016). These tools help develop skills that are difficult in clinical practice (Ball et al., 2021; England and McNulty, 2020; Kelly et al., 2021, 2019; Vestbøstad et al., 2020), enable inexperienced students in understanding complex RT concepts (Bridge et al., 2020; Leong et al., 2018) and practise complex tasks without putting patient safety at risk (England et al., 2017; Issenberg and Scalese, 2007). The Virtual Environment for Radiotherapy (VERT) and Treatment Planning Systems (TPS) are the most commonly used digital-based simulation for RT education, while simulation using role-play and actors are used for patient communication as well as mould room workshops (McNulty et al., 2021).

Simulation is often used due to limitations in real clinical placements, not because there is an increase in the effectiveness of education (Chaka and Hardy, 2021; McNulty et al., 2021; Vestbøstad et al., 2020). However, these systems should not replace actual clinical practice, and many authors noted the importance of validating simulation as an adequate educational tool before applying it to TRs' education (Bridge et al., 2020; Chaka and Hardy, 2021; England et al., 2017; Kane, 2018). In 2017, skill labs constituted less than 16 ECTS for the majority of courses. The limited use of simulation can be explained by the limited availability and cost of the systems and academic staff to provide the necessary training. Nevertheless, students tend to be motivated to participate in simulated sessions (Bridge et al., 2020; Zorn et al., 2019).

The studies above took a specific topic and analysed specific aspects of education such as the subjects (knowledge) in the curricula, teaching and assessment methods. As mentioned before, the current study focuses on course structures and competencies of TRs, which reflect the application of knowledge and skills into practice and should be taught and assessed using appropriate methods (which are beyond the scope of this research). Identifying, in detail, these components may be only possible through independent studies addressing each specific topic, as seen in the literature above.

2.4.5.1 THE IMPACT OF COVID19 ON RADIOGRAPHY EDUCATION

This study started before the COVID19 pandemic, and since the last data collection finished when the pandemic started affecting European countries, its impact on education is not reflected in the findings. However, its influence on radiographers' education cannot be ignored, and a scoping review of the literature was performed after the data collection (May 2021) to identify any COVID-19 related factors that may affect the conclusion of this study.

Radiographers are now more aware of occupational biological hazards, the importance of infection control and appropriate personal protective equipment (PPE) (Rainford et al., 2021). This increase in awareness and training will potentially improve infection control training beyond this pandemic.

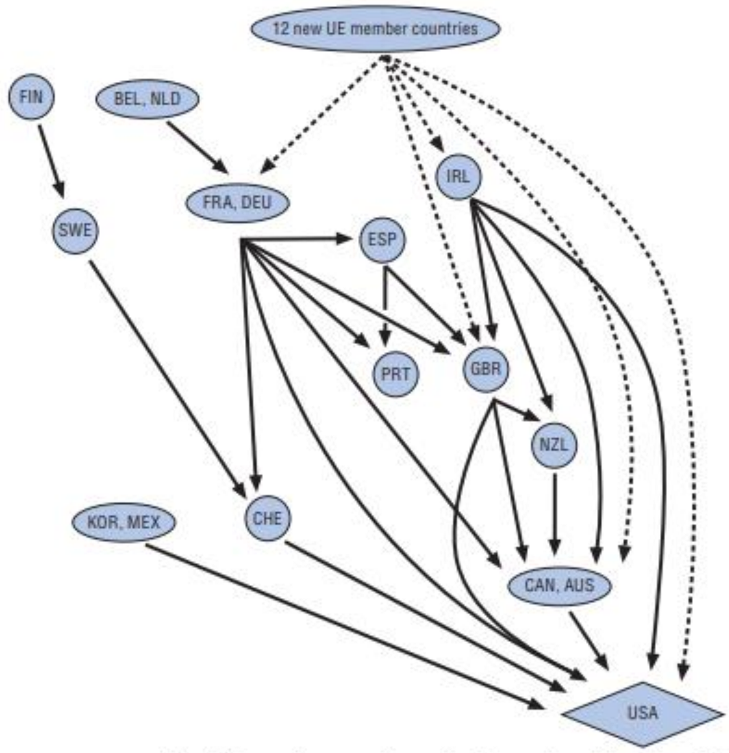
The use of digital teaching methods was the norm during the pandemic, speeding up the implementation of these technologies into radiography education. Online teaching also effectively achieved learning outcomes, becoming permanent in radiographers' education programmes (Higgins et al., 2021; Mc Inerney and Lees, 2018). However, other learning outcomes seem to require live sessions (Wong et al., 2017), and a combination of training techniques may also be beneficial (McLaughlin et al., 2017). In addition, to make these technologies effective, clinical educators must have a positive attitude towards these new technologies, requiring additional training and a change in mentality (McInerney and Druva, 2019).

2.5 PROFESSIONAL MOBILITY OF RADIOGRAPHERS IN EUROPE

Mobility of healthcare professionals occurs throughout Europe. This movement is facilitated by European legislation that grants freedom of movement for EU individuals (European Parliament and European Council, 2004) and by the mutual recognition of qualifications between member states (European Parliament and European Council, 2005).

However, the imbalance caused by this movement of professionals may result in staffing issues worldwide since the movement tends to be unidirectional (OECD, 2007). The pattern of movement for nurses is shown in Figure 2.8 as an example since no studies specific to radiographers were found (OECD, 2007; WHO, 2008). These patterns may lead certain countries to over-educate to compensate for the brain drain (Eyal and Hurst, 2008).

The specific reasons behind the movement may vary from individual to individual. However, job satisfaction resulting from working conditions (Lehmann et al., 2015; Probst and Griffiths, 2009), salary or the general development of the region (WHO, 2008) were identified as reasons for healthcare professionals to make a move. In a 2017 survey distributed to RT professionals, 77% of respondents showed interest in working abroad (Bibault et al., 2018).



Note: Arrows represent a positive difference between the stocks of nurses in origin and receiving countries. Not all possible downward arrows are represented (for instance Finland has a net deficit with Sweden but also with Switzerland and the United States), but there would be no ascending arrows (for instance at the time of the population census Ireland has only a net gain with regards to 12 new EU member countries and the United States was the only country to have a net gain *vis-à-vis* all other OECD countries).

Figure 2.8 – Nurses migration pattern between OECD countries (OECD, 2007)

According to the recently published survey by McNulty et al. (2021), 11-20% of institutions replied that more than 25% of graduates do not find a job in their country. The high unemployment rate in some countries should be addressed since it may hinder professional status and decrease the will for students to join the profession. Moreover, the imbalance in employment rates may also promote the mobility of skilled professionals from countries with high unemployment to areas with a lack of workers, which negatively impacts the country of origin.

Beyond the migration of radiographers, research of professionals across the EU is relevant for the care provided to citizens from all member states. According to Directive 2011/24/EU, citizens may receive health care in any other EU country (European

Parliament and European Council, 2011). Therefore, the education of radiographers in every country affects all EU citizens.

Literature on the movement of radiographers is scarce, and literature on other health care professions tend to focus on staffing issues and job retention, rather than on competencies mismatch across countries (Chen et al., 2004; Eckenwiler, 2014; Eyal and Hurst, 2008; Lehmann et al., 2015; WHO, 2008). This section, therefore, focuses on the recognition of qualifications process in the European Union.

2.5.1 Mutual recognition of qualifications in the European Union

The EC directive 2005/36 describing the recognition of qualifications in the European Union and its application to radiographers is discussed here. Temporary movement of professionals is also laid down in this regulation. However, this work focuses only on the permanent movement of radiographers within the EU.

The European Directive 2005/36/EC states that all EU members states “shall recognise professional qualifications obtained in one or more other Member States (…) allow the holder of the said qualifications to pursue the same profession there, for access to and pursuit of that profession” (European Parliament and European Council, 2005, p. 36). It is stated that “Member States shall not restrict, for any reason relating to professional qualifications, the free provision of services in another Member State” (European Parliament and European Council, 2005, p. 28). However, some additional criteria apply to achieve recognition.

Some professions have automatic recognition if the EU citizen has the minimum training conditions laid down in this directive; this includes medical doctors, nurses, veterinary surgeons, architects, dental practitioners, and pharmacists, but the list does not include radiographers. Radiography falls under the general system of recognition.

To apply for the general system of recognition of evidence of training, the profession needs to be regulated at the national level in both countries, and the applicant's academic level cannot be more than one level below the one in the host Member State - Article 13 (1.b). The levels of qualification stipulated in the directive are defined as below (Article 11):

- Level 1: General primary or secondary school (Article 11.a)
- Level 2: Technical or professional secondary course (Article 11.b)
- Level 3: Post-secondary course of at least 1 year (Article 11.c)
- Level 4: Post-secondary course of at least 3 years (Article 11.d)
- Level 5: Post-secondary course of at least 4 years (Article 11.e)

For example, if the level required to practise radiography in the host country is a level 4 (such as France), the candidate must have at least a level 3 to be granted the right to pursue the profession in that country.

If the recognition of qualifications refers to a profession that may have "public health or safety implications" (European Parliament and European Council, 2013, p. 255), such as radiography, the host member state may evaluate the applicant's professional qualifications. This check must be limited to the essential to pursue the profession, ensuring health and safety (European Parliament and European Council, 2013). If formal education is considered insufficient by the host country, the applicant can choose to undergo an aptitude test or an adaptation period to prove or acquire the necessary qualifications. This is a vital safety mechanism. However, the directive is vague in defining what constitutes similar qualifications or safety implications, allowing countries flexibility to reject or approve applications based on this section alone.

Partial registration helps to deal with the education differences across the EU. For example, graduates from an RT-only programme can obtain partial registration as radiographers in another country where the profession includes RT and MI, but they would only be allowed to practise RT. The partial access to a profession was another amendment introduced by the 2013/55/EU directive (European Parliament and European Council, 2013).

The 2013 amendment clarifies that the regulators in the host country can request the applicant for evidence of good knowledge of the language in the destination country (European Parliament and European Council, 2013).

It is essential to study the requisites to practise radiography across the EU countries because this directive establishes that the applicants' qualifications are compared with the requirements to practice the profession in the host country.

2.5.1.1 Common platforms

The EC directive 2005/36 (European Parliament and European Council, 2005) establishes a tool that allows the Member States to identify differences between qualifications and the corresponding compensation to simplify the recognition process in professions where substantial differences in qualifications are observed. European and national professional associations or organisations can also submit a proposal of common platforms.

This directive defines "common platforms" as "a set of criteria of professional qualifications which are suitable for compensating for substantial differences which have been identified between the training requirements existing in the various Member States for a given profession" (European Parliament and European Council, 2005, p. 33).

These differences may include substantial differences due to variation in the profession's scope, and the compensation can include a combination of formal qualifications or professional experience, as appropriate.

After submitting to the Commission and subsequent approval, applicants that comply with such criteria are exempted from compensation measures (aptitude test or adaptation period). The common platforms could also guide professionals willing to move to another country regarding the requirements to register abroad or any additional qualifications needed.

The current study aims to identify educational differences, which is the first step to establishing common platforms. However, further work may be necessary if there is interest in developing these common platforms.

2.6 CONCLUSION

There is considerable research into specific aspects of the education of TRs; however, there are several aspects where systematic and accurate research is missing. The TR profession is complex and adequate research into the regulation and competencies of these professionals is essential.

The role of the TR on the linac is of utmost importance for patient care and a core role of these professionals across Europe. However, there is a lack of in-depth research into this role, often overlooked, favouring (arguably more appealing) new or advanced roles and techniques.

Radiography is not regulated the same way across Europe. Therefore, it is up to each member state to define the profession and corresponding education. As expected, this resulted in differences between education programmes. Additionally, the regulation is often inadequate to effectively regulate the profession and education of such influential healthcare professionals.

These differences in education curricula have many factors, including the aim of education in general (professionalising vs research-driven vs market-driven), objectives of stakeholders (such as employers and government), course design in terms of outcomes (learning vs teaching objectives), national tradition (in education and the roles of the professionals), among others. Since these factors may apply in different ways across Europe, this again leads to differences in education.

Despite these differences, TRs can still apply for recognition of qualifications in other member states, facilitated by the European Directive 2005/36. It is crucial to assess these differences and the effect of professional mobility and patient safety when this movement occurs.

Most studies that compare the education of radiographers identified that there is variation in course structures such as academic level, duration, number of specialisms included in the programme. However, very few studied the learning outcomes in detail to understand if the different courses reach the same final objective: a competent professional able to practise RT to the highest standards of care.

Despite the vision of a harmonised educational structure across Europe resulting from EU initiatives, local traditions still significantly impact education. The main differences regarding TRs' education across Europe include courses dedicated to RT versus multi-specialism courses, different amounts of RT-specific content, varied programme durations, and different academic levels.

Despite the existence of international educational frameworks, these recommendations have different scopes according to the organisation that publishes them. They complement one another by approaching the education of TRs from different perspectives but may lead to even more differences due to a lack of a single reference point. Since these are non-binding, EIs tend to align with the national requirements.

A gap in knowledge regarding the impact of the educational differences on competencies of TRs, professional mobility and patient care was identified. The same is true regarding knowledge about the regulation of the profession across European countries, thus supporting the aims established for this study. This literature review also informed the methodology, which is further discussed in the next chapter.

CHAPTER 3. METHODOLOGY OVERVIEW

This chapter aims to provide the reader with an overview of the methodology used in this research study, explaining how the phases of the study link to each other.

3.1 RESEARCH PHILOSOPHY - PRAGMATISM

The goal of scientific enquiry is to answer questions with high levels of rigour, providing valid conclusions. By describing the methodology, the researcher also helps the reader understand the research process applied to answer the research questions (Hancock and Algozzine, 2017).

The researcher applied the principles of *pragmatism* in this study. The main principle is that “the meaning of any concept is determined by its practical implications” (Lewis-Beck et al., 2004, p. 847), and this meaning is derived from the continuous interaction between humans and their environments (Thorpe and Holt, 2008). Epistemological philosophies focus on knowledge, and pure ontological philosophies focus on understanding reality. However, pragmatism does not aim to understand reality or knowledge but rather the implications of reality to the collective and subjective interpretation of reality (Given, 2008). This is particularly important in this study, since the aim is to understand the implications of TRs’ education across Europe on their competencies, professional mobility, and patient safety.

Therefore, this practical philosophy does not see truth as an absolute representation of reality “but a moveable and usable construct for understanding the nature of reality” (Given, 2008, p. 672). Pragmatism also asserts that research is a cumulative process and forever incomplete; inferences are not final and should be subject to continuous inquiry

(Mills et al., 2010). Even though the findings contribute to the body of knowledge regarding RT education, this new knowledge is part of a continuous process that should be complemented by future enquiry.

From the beginning of this project, it was known that access to data would be limited. However, pragmatism encourages researchers to make inferences from the evidence available, supporting the concept "that the search for the best evidence must not immobilise the researcher" (Mills et al., 2010, p. 724), making this philosophical approach ideal for this research.

Even though pragmatism approaches reality "without regard to the epistemological rules of validity, reliability, or other issues surrounding the trustworthiness of data" (Given, 2008, p. 675), the evaluation of the rigour and validity of the tools was assessed to increase the readers' confidence in the results. The philosophical principles of pragmatism often lead to mixed-method research designs.

Alternative philosophical paradigms were considered before opting for pragmatism. Examples included a constructivist approach; however, this philosophy focuses on understanding phenomena (knowledge) and not on its implications to reality as is the aim of this study. Nevertheless, traces of this philosophy can be found in the interviews with stakeholders. On the other extreme of the spectrum is the positivist approach, which aims to explain reality (not the interpretation of reality), completely independent of the individuals and societal constructions of this reality. Traces of this philosophy can be found in the questionnaire aiming to describe the educational programmes in Europe. However, none of these philosophies encompassed the overall aim of the study since it intended to obtain both evidence of the reality (course characteristics, patterns of movement) and of the interpretation of this reality (stakeholders' perceptions) to understand the implications of the education programmes to the competency level, patient safety and professional mobility.

3.2 RESEARCH METHOD – EXPLANATORY SEQUENTIAL MULTIPHASE MIXED METHOD

An *explanatory sequential multiphase mixed method* design was used, where each phase is built upon the results from previous phases. Figure 3.1 identifies the three phases of the study and related research questions. The phases have independent objectives, but they all work together to answer the overall research aim. The collective results also allowed conclusions to be drawn that would not be possible from the individual studies (Creswell, 2014).

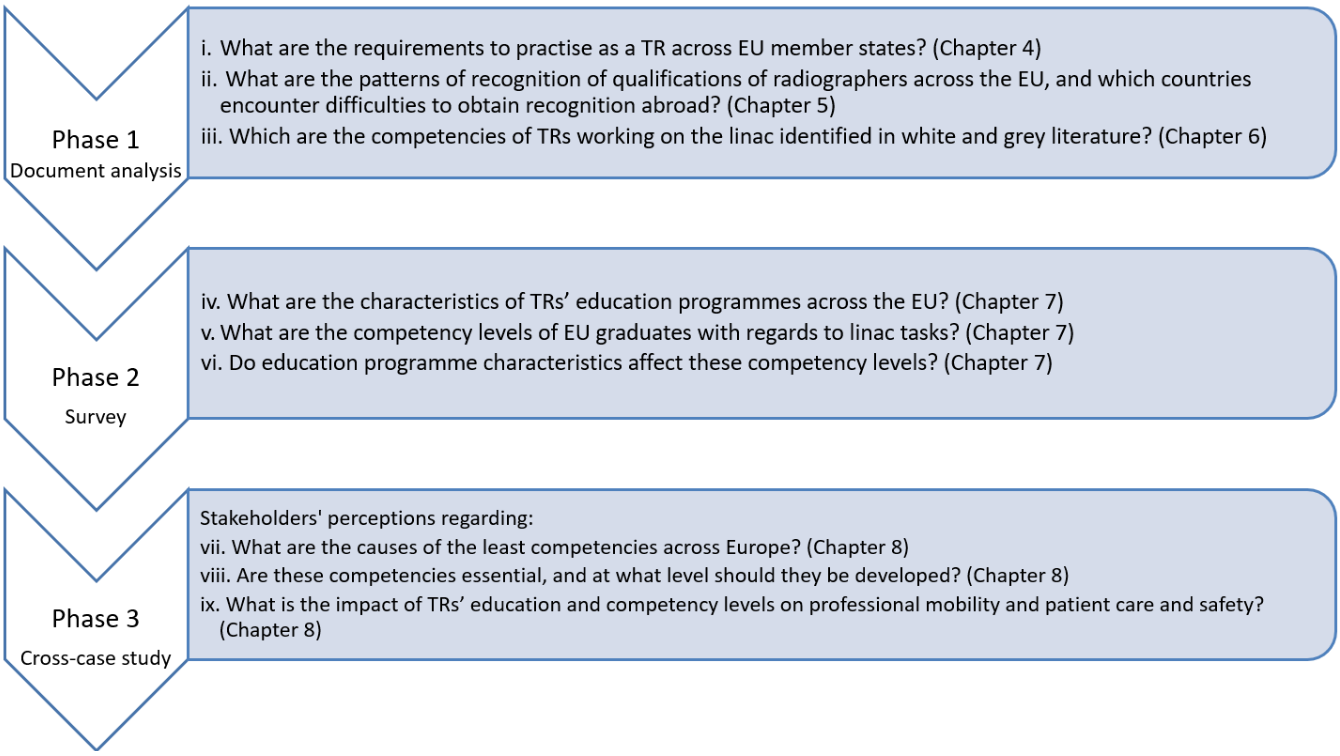


Figure 3.1 – Depiction of the multiphase mixed-method approach, including the research questions and corresponding results chapter.

The quantitative data was collected and analysed in the initial phases, and the qualitative data phase allowed the researcher to expand on the results previously obtained (DeCuir-Gunby and Schutz, 2017). This methodology allowed the publication of results as the phases progressed, obtaining external peer-review at each step of the study, which is one method to verify the trustworthiness of the findings.

Three document analyses were performed in phase 1 to i) understand the basic requirements to practise radiography across Europe, ii) identify the patterns of recognition of qualifications between member states and iii) identify the competencies of the TR working on the linac. The results informed the questions used in the quantitative survey (Phase 2), aiming to identify the competencies developed in educational institutions across Europe. This survey was then used to inform the selection of the case studies and the questions in phase 3 interviews. In this last phase, only qualitative data was collected.

This study used an *inferential* methodology since the tools aimed to collect and analyse the data so that the results can be extrapolated to the entire population: all European countries. A *non-experimental* and *descriptive* approach was used to study the phenomenon without any variables' manipulation, describing the education and competencies of TRs and how/why these affect the movement of professionals and patient care (Hancock and Algozzine, 2017). When research focuses on social institutions and social relationships and examines a group of individuals, such as radiographers, this is considered a *sociological case study* (LeCompte et al., 1993). The methods of the three data collection phases can be found below.

3.2.1 Document analysis (Phase 1)

Three separate secondary data analyses were performed as part of this phase. The results were used to inform phases 2 and 3 methodologies and triangulate the results. These document analyses aimed to answer the following research questions:

i. What are the requirements to practise as a TR across EU member states? (Chapter 4).
ii. What are the patterns of recognition of qualifications of radiographers across the EU, and which countries encounter difficulties to obtain recognition abroad? (Chapter 5).
iii. Which are the competencies of TRs working on the linac identified in white and grey literature? (Chapter 6).

All data used in this phase was publicly available; therefore, no ethical approval was required. The documents used were referenced in the text.

3.2.1.1 REQUIREMENTS TO PRACTISE RADIOGRAPHY ACROSS THE EU

A descriptive cross-sectional, non-experimental, qualitative methodology was used in this study, performed through document analysis. Exhaustive sampling was used where all EU countries were included in the study. All the national “competent authorities” and the “contact points” were included, while the non-EU countries or member-states where the profession is not regulated were excluded. The national competent authorities and contact points were identified through the European Commission’s Regulated Profession Database (European Commission, n.d. b) and contacted (email and letter) and invited to identify the educational requisites to practise these professions in their country. These were deemed appropriate since their role includes providing information to the public regarding requisites to practise regulated professions, as defined by the EU directive (European Parliament and European Council, 2005).

When information was available in English or Portuguese, the data was directly collected from official documents since the researcher fluently understood these languages. When there was no response, professional associations or professionals in the country were asked to identify the requisites for practice and official documentation. Since the information in the RPD is submitted and maintained by the member states, the RPD itself was considered as a source of data.

The thematic analysis of the following sources, submitted by the respondents, was then performed using NVivo software (v. 11.4.0.1062):

- Legislation;
- Official documents from the regulatory bodies;
- Regulated Profession Database; and/or
- Email reply with the indication of the requisites to register.

The codes were agreed beforehand based on the literature review and were used to identify the course characteristics that allow graduates to practise the profession. The information collected from these documents was organised into a matrix, summarising the information into a table. This method is known as the Framework Approach (Richie and Spencer, 2002). Each row represented a country, and each column corresponded to a characteristic of the courses that give access to the profession (such as course duration, ECTS, academic level). This method also facilitates the quantification of qualitative data (Hancock and Algozzine, 2017). Additional themes were identified and added to the results.

Limitations were identified prior to the data collection: the complexity of the subject; outdated information; and subjectivity of the replies. Triangulation of sources was used to tackle all the issues identified; therefore, the results presented were confirmed from at least two sources.

The translation of official documents to English was completed using an online translation tool (Google Translate). Studies showed that this tool has high accuracy (62%-74%) in translating European languages (Aiken and Balan, 2011; Patil and Davies, 2014). To compensate for any risk of incorrect translation, the results focused on requisites to practise (e.g. academic level, programme duration), which are highly objective parameters, resulting in low risk of misinterpretation of results. This risk was even further minimised by using triangulation of sources mentioned above. This also allowed assessment of the quality of the translations that were shown to be highly reliable, where the data translated always led to the same result when compared with other sources.

The findings regarding national professional regulations were used as justification to study the patterns of recognition of qualifications. The course characteristics identified in national regulations were used in the survey and semi-structured interview protocol design. The findings of this phase were also used to triangulate the data found in the cross-case study. The results of this phase are included in Chapter 4.

3.2.1.2 PATTERNS OF RECOGNITION OF QUALIFICATIONS BETWEEN MEMBER STATES

A quantitative retrospective analysis of the data available at the European Commission's Regulated Professions Database (RPD) was performed (European Commission, n.d. h). This database provided the results of the applications for recognition of qualifications between EU countries, which can be used to predict the patterns of professional mobility.

Since the data was available in a single platform, it enabled efficient data processing. The competent national authorities are responsible for submitting the data into the RPD; therefore, this data was deemed reliable and suitable for the aim of the study. During the data analysis period (June – September 2019), the UK was still part of the EU and was included in the study.

Very few countries submitted data to the RPD more recently than 2017. Therefore, the chosen target period for data analysis was 2015-2017. Due to the inconsistency of data submitted, the data was collected as follows:

- All data within the 2015-2017 period was collected
- If the country has less than two years of data available within the target period, the two most recent years were collected, if available.

The years collected for each country were presented in the results (Chapter 5). The lack of data for some countries and years was a limitation of the study; nevertheless, the data available gives an overview of the recent movement of radiographers. This approach aligns with the pragmatism philosophical principles under which this study was performed (Mills et al., 2010).

When countries do not submit data to the RPD, the number of radiographers moving to these countries cannot be evaluated. However, radiographers moving from these countries are still available since the host country submits the data into RPD, not the origin country.

The RPD provides data regarding “Radiographer / Radiotherapist” recognition of qualifications; it does not have separate data for TRs. Therefore, this phase included all specialisms of radiography encompassed by the definition of “radiographer” used in this study. The RPD data regarding “Nuclear Medicine Technician” was also assessed to encompass all radiography specialisms.

The number of radiographers achieving recognition of qualifications and their origin was collected for each country. The number of rejected applications and their origin were also recorded. Descriptive statistics (measures of position: quartiles) were performed to rank the most common routes of movement and the routes with the highest average of negative replies. These movement routes were graphically represented in a map of the EU (Chapter 5).

The number of radiographers obtaining recognition of qualifications across member states following compensation measures was also measured. This data indicates the patterns of movement where the educational differences were significant to justify such measures.

This phase allowed an understanding of the impact of professional mobility, emphasising the importance of this research. The findings influenced the design of the questions related to professional mobility during the interviews and were used to triangulate information provided by the stakeholders.

3.2.1.3 COMPETENCIES OF TRS WORKING ON THE LINAC

A search query was constructed to search different databases and journals systematically. This query was based on three main keywords: "*competencies*", "*therapeutic radiographer*", and "*linear accelerator*". A map of the synonym keywords was constructed based on a previous literature review and using the expertise of the researcher and his supervisory team. All titles for the profession, as found on the Regulated Profession Database and published by the European Federation of Radiography Societies (EFRS), were included in the query.

The inclusion of keywords related to "linear accelerator" may not be specific to this role since these terms are also mentioned in other roles of the TR. The selection of publications related to the actual practice of the profession on the linac was achieved through the appraisal of the publications.

The search query was as follows:

> *(Competenc* OR task* OR role* OR skill*) AND (radiographer* OR ((radiolog* OR radiograph* OR roentgen OR diagnostic OR electroradiology OR radiation) AND (technologist* OR technician* OR therapist* OR engineer)) OR Radiotherapist* OR RTT*) AND ("linear accelerator" OR "linear accelerators" OR linac*)*

This query was run on the following databases and journals: Academic search complete, CINAHL Plus with Full Text, MEDLINE and PubMed, ScienceDirect, ProQuest Education Journals, ERIC (ProQuest), Radiography journal, tipsRO journal.

Since the role of the TR is constantly changing due to the evolution of medicine and technology, the studies included were limited to those published in the 10 years prior to the literature search. In all databases, an alarm was set up to inform the researcher about new publications matching the query. The impact factors of the journals or citations of the paper indicate the prestigious nature of the publication but were not considered as inclusion or exclusion criteria.

The relevant publications were selected based on the following inclusion/exclusion criteria:

Inclusion criteria:	• Competencies of TRs practising on the linear accelerator which apply to the European setting The statements in the literature were considered to be a "competency" when: • The literature considered them as such or • The literature identified that a certain task is performed under TRs' autonomy and responsibility – as per EQF definition (European Parliament and European Council, 2008).
Exclusion criteria:	• Competencies specific to other roles of the TR (planning, CT, mould room, manual calculations). • Competencies in veterinary radiotherapy • Competencies developed in further education (above those required to practise) • Non-English publications • Publications discussing competencies that apply to specific countries outside Europe

To increase the breadth of the search, relevant grey literature was also analysed. Recommendations from European and worldwide organisations regarding the competencies or curriculum of the radiography courses were also used to identify competencies (Challen, 2008; Coffey et al., 2011; Directorate-General for Energy, 2014;

EFRS, 2018; ESTRO, 2014; IAEA, 2014; ISRRT, 2014). None of the regulatory bodies of the three European countries where English is an official language (Ireland, Malta and the UK) established a list of competencies. Note that, in the UK, the Standards of Proficiency (Health and Care Professions Council (HCPC) (UK), 2013) lists the skills practised by an “autonomous professional” but does not establish if these tasks are the responsibility of the radiographer. In this study, the European Qualifications Framework (European Parliament and European Council, 2008) definition for competency was used where both autonomy and responsibility must be considered, therefore, the list of skills from the Standards of Proficiency were not considered (Health and Care Professions Council (HCPC) (UK), 2013).

Scientific papers were considered relevant when they discussed competencies in the European setting. Scientific papers from non-European countries that discuss the role of the TR and use methodologies that allow to extrapolate the results to Europe were included on the data analysis. In addition, snowballing (Sayers, 2007) was also performed.

The existing literature was assessed, and the competencies performed by the linac-TR, were identified. Then, these competencies were coded using an inductive open thematic analysis (Maguire and Delahunt, 2017) using NVivo software (v. 11.0) for coding and analysis. The thematic analysis allowed organisation of the competencies identified across different documents into themes. It also allowed the compilation of a comprehensive list of the dimensions of these professionals’ competencies.

The coding was performed by a single researcher with expertise in the education of TRs. The resulting competencies and themes were assessed by the supervisory team and five external experts, resulting in further amendments to the list and themes.

This data collection was performed to design the survey (Phase 2). The results also allowed triangulation of the interviews data regarding the competencies of TRs working on the linac (Phase 3). The results of this study are presented in Chapter 6.

3.2.2 Survey (Phase 2)

Even though the minimum course requirements were established in the previous phase, countries often do not regulate the competencies required to practice. In addition, courses may develop competencies beyond the minimum required in the regulations. Therefore, this phase aimed to evaluate the competency levels related to the linac of students across the EU and establish relationships between the levels and course characteristics.

A quantitative cross-sectional study using an anonymous online questionnaire (Appendix 2) distributed to academic staff teaching RT across the EU was deemed appropriate to answer the research questions for this phase (Hulley et al., 2013; Leininger, 1985; Polit and Beck, 2010; Van Selm and Jankowski, 2006):

iv. What are the characteristics of TRs' education programmes across the EU?
v. What are the competency levels of EU graduates with regards to linac tasks?
vi. Do education programme characteristics affect these competency levels?

Surveys allow the collection of large amounts of data with minimal contact with the participants, while online surveys facilitate the survey's distribution across a large geographical area, such as the whole EU (Hancock and Algozzine, 2017).

Due to the lack of a database of RT education programmes, extensive sampling and probabilistic sampling was not possible. Convenience sampling was undertaken using multiple strategies to maximise the dissemination of the study. The SAFE EUROPE project partners (SAFE EUROPE project, 2019) distributed the questionnaire through email to their members, through social media and on the consortium's webpage between April and September 2019.

3.2.2.1 QUESTIONNAIRE DESIGN

The first part of the survey (Appendix 2) inquired about the characteristics of the education programmes (Table 3.1) based on the literature review (Chapter 2) and the results from Phase 1 (Chapters 4 to 6). Closed-ended questions were designed for ease of data analysis; however, an option to submit "other" answers was available in all relevant questions and respondents could provide additional comments in every section of the questionnaire.

Table 3.1 – Variables studied in this research project

Course Characteristics	Competency dimensions
- Academic level	1 Radiation safety
- Specialisms	2 File verification
- Duration of the programme	3 Positioning and immobilisation
- Duration of placement (all specialisms)	4 Radiotherapy treatment delivery
- Duration of RT-specific placement	5 Image verification of patient setup
- Proportion of course dedicated to RT	6 Equipment quality assurance
- Proportion of placement dedicated to RT	7 Professional and ethical practice
- Proportion of RT placement in skill labs	8 Patient care
- Guidelines used in the design of the course	9 Pharmacology
- Regulation of learning outcomes	10 Research and education
- Requirement of registration to practice	11 Quality and risk management
	12 Management and leadership
	13 Decision making
	14 Teamwork and multidisciplinarity

In the second part of the questionnaire, the respondents were asked to score how competent graduates are at the end of the programme. They were invited to rate 63 competencies related to the linac, organised under 14 competency dimensions (Table 3.1). The selection of the competencies was based on the results of the literature analysis (Chapter 6) and feedback from expert partners within the SAFE EUROPE project.

The respondents were asked to classify each competency between 1 (competency not developed in the programme) and 7 (competent) based on their experience and perception. Respondents were also provided with the definition of competency described above.

Three experts in RT education were invited by the EFRS (a SAFE EUROPE partner) to assess the content validity of the questionnaire. They were all TRs with experience in education from different European countries (Greece, Slovenia, and the Netherlands). They were asked to classify each item (scale from 1 to 4) with regards to their relevance to the study aims. An Item Content Validity Index (I-CVI) of 1 was obtained for all items on the questionnaire showing that the experts agreed that the items were relevant to the study aims (Almanasreh et al., 2018; Boynton and Greenhalgh, 2004; Lawshe, 1975; LoBiondo-Wood and Haber, 2014; Wilson et al., 2012).

For the classification of the competency level, a 7-point Likert scale was chosen as it provides a more refined scale to measure the intensity of a rating evaluation, compared with a 5-point scale (Colman et al., 1997; Miller, 1956; Symonds, 1924). Four academic staff from two higher-education institutions were asked to answer the questionnaire, and the Inter-Class Correlation (ICC) was calculated using a two-way random, single rater and absolute agreement model. This test assessed if one member of academic staff would reliably represent the perception across one institution and if the answers of these raters could be generalised to the entire population (European academics) (Koo and Li, 2016). ICCs of 0.788 ($p<0.001$) and 0.536 ($p<0.001$), and a Cronbach's alpha coefficients of 0.880 and 0.706 were achieved for each institution (Koo and Li, 2016). These tests showed a slight variation between respondents from the same institution when rating the competency levels. However, these values reflect a moderate to good inter-rater reliability (Cortina, 1993; Koo and Li, 2016). Also, having multiple respondents from the same country further minimises the impact of subjective perception by the respondents (Atkinson and Murray, 1987; Weir, 2005).

3.2.2.2 STATISTICAL ANALYSIS OF THE DATA

In large-N analysis, such as a survey of European EIs, quantitative methods facilitate data management (Gerring, 2007). The following hypotheses were tested using different statistical tests. Friedman's test was used to compare competency levels between dimensions (the Wilcoxon signed-rank test with Bonferroni correction was conducted as a *post hoc* test). The Kruskal-Wallis test compared competency levels between groups with different course characteristics (the Dunn's test with Bonferroni correction was used as a *post hoc* test). The Spearman's rank correlation test was used to measure the strength of the relationship between course characteristics and competency scores. For all statistical tests, a 0.05 level of significance level was adopted.

3.2.2.3 ETHICAL CONSIDERATIONS

Ethical permission for the study was granted by the Institute of Nursing and Health Research Ethics Filter Committee at Ulster University, Belfast (Appendix 3). A participant information sheet was provided. Neither the participant's name nor the institution was asked in the questionnaire, ensuring anonymity, and data was stored in password-protected or locked places. To avoid coercion, recruitment was performed by the SAFE EUROPE partners and social media. No harm was caused to the participants nor researcher.

The findings of this study, presented in Chapter 7, were essential to draw some of the most important conclusions about the influence of course characteristics on TRs competency levels. However, the quantitative data could not explain the reason behind the correlations found. Therefore, these correlations were explored further in the cross-case study (Phase 3), where interviews with stakeholders were performed.

3.2.3 Cross-Case study (Phase 3)

The current phase used a qualitative *cross-case study* method (Yin, 2018) to further analyse the findings of the Phase 2 survey (presented in Chapter 7), which quantitively evaluated the impact of course characteristics on TRs' competency level in tasks related to the linac. Specifically, this phase aimed to answer the following research questions:

vii. Why are some competencies less developed across Europe?
viii. Are these competencies essential, and at what level should they be developed?
ix. What is the impact of TRs' education and competency levels on professional mobility and patient care and safety?

This research strategy required that an *explanatory case study* was used since it aims to explain (why/how) a phenomenon that was already identified in the previous phases, rather than simply exploring it (Yin, 2018). Hancock and Algozzine (2017) would further classify the method as an *instrumental case study* since it aims to see the bigger picture of the education and movement of radiographers in Europe by exploring the individual countries. This is possible through *analytical generalisation*, where the cases are not a population sample but allow exploring theoretical principles and concepts that apply to other cases (Yin, 2018). Findings from previous phases were also instrumental for triangulation, increasing the trustworthiness of the results.

Multiple cases distributed geographically (Gerring, 2007) were studied to analyse European stakeholders' perception of the impact of TRs' education on competency level, mobility and patient care. Interviews were performed to collect stakeholders' perceptions. Compared with experimental research, case studies are often illustrative rather than comparative, allowing further exploration of the subject (Hancock and Algozzine, 2017). This study is bounded in space and time: EU between November 2019 and August 2020 (Hancock and Algozzine, 2017). Each country studied constituted a case; this structure is often used by political scientists (Gerring, 2007), which is appropriate for this study since policy and regulation strongly influence education.

3.2.3.1 SAMPLING AND RECRUITMENT

Maximum variation sampling was used to select the countries (cases) (Hancock and Algozzine, 2017). Countries with different course characteristics (specialisms, duration, academic level and percentage of the programme dedicated to RT) were selected based on findings from previous phases (Table 3.2). This sample allowed collecting different perspectives whilst allowing an analysis of the differences across the EU.

Table 3.2 – Characteristics of the countries included in the interviews.

Country	Course characteristics of the countries included in the study
Finland	RT+MI, <20%* of the programme dedicated to RT, 3-year programme
Portugal	RT+MI (recently transitioned from RT-only), 4-year programme
Poland	RT+MI+EP, programmes from EQF5 (2 years) to EQF7 (5 years)
UK	RT-only, >80%* of the programme is dedicated to RT, various pathways available (Bachelor's degrees, apprenticeships, pre-registration master's programmes)

EP = Electrophysiology; MI = Medical Imaging; RT = Radiotherapy; EQF = European Qualifications Framework
*In the survey, respondents identified the proportion of the programmes dedicated to RT (excluding other specialisms and general/common subjects).

Although all selected countries regulate the profession, they regulate education and the educational requirements to practice differently (Phase 1 results: Chapter 4). Finland and Portugal regulate the role of TRs and have national registration. However, they do not regulate the competencies to be developed in training programmes (Ministry of Education (Finland) [in Finnish], 2006; Ministry of Health, Education and Science and Solidarity (Portugal), 2014; Ministry of Health (Portugal) [in Portuguese], 1999). In Poland, regulations define that a degree in electroradiology is necessary to practise (which can vary between EQF5 and EQF7), but the learning outcomes are not regulated. In addition, there is no national register for these professionals. In contrast, the UK established the standards of proficiency that graduates must develop in all education programmes to allow graduates to register with the professional body (Health and Care Professions Council (HCPC) (UK), 2013). Even though the UK was leaving the EU, it was the only country with an EQF6 RT-only programme that answered the SAFE EUROPE survey. Since this study used a *maximum variation sampling* to obtain varied perspectives from different education models, it was very relevant to include the UK model in this research. The data was collected at the beginning of the transition period; therefore, UK stakeholders' answers still reflect their status as a member-state.

Cross-case studies aim to achieve more compelling results than single case studies by replicating the study with multiple cases. A *theoretical replication* was used in the present study since the extreme cases were expected to show the differences, not to provide similar results (Yin, 2018).

This study required the identification of gatekeepers (Creswell, 1998). Professional organisations, part of the SAFE EUROPE consortium, agreed to invite stakeholders for the interviews. Invitations were also posted on social media to reach other stakeholders who may not be linked with the SAFE EUROPE partners, reducing the risk of sampling bias. All participants received the information letter at least two weeks before the interview (reflection period).

Participants were selected based on their ability to provide rich information (*critical case sampling*) and a mix of experiences that would allow different points of view to be gathered. A 25 Euros or British pounds voucher from an international bookstore was offered as an inducement. A combination of stakeholders with different roles and backgrounds were invited to participate, including:

- local TRs (who trained and worked in the same country);
- migrant TRs;
- clinical managers;
- RT lecturers;
- Students;
- representatives of the national professional associations.

Service users (patients) were not included since the SAFE EUROPE project has a separate study focusing on their perspectives.

The first semi-structured interview (Portugal, November 2019) was performed face-to-face. However, the remaining interviews (Poland, Finland and UK) were done online between April and August 2020 due to COVID-19 restrictions. In addition, online group interviews made it challenging to collect the individuals' perceptions; therefore, the online group interviews were changed to individual online interviews. This change in method does not affect the findings since the aim of this case study was to explore the stakeholders' perceptions, and both individual and group interviews are suitable methods. Group interviews facilitated discussion of different points of view since participants may prompt each other creating discussions that would not happen in individual interviews; while individual interviews allowed an exploration of each participants' opinion without external influence what is often not possible in group interviews. As such, these methods can be considered complementary and appropriate to the case study methodology used.

3.2.3.2 INTERVIEW GUIDE

The interview guide (Appendix 40) aimed to answer the research questions for this phase, which focus on exploring the least developed competencies of TRs and discussed the impact of education structure on competency level, patient safety and recognition of qualification abroad. The questions were designed based on the results of previous phases and bibliographic review. Feedback was also sought from a panel of the SAFE EUROPE project members with expertise in RT to ensure that the questions answered the aims of this phase. The themes of the questions are identified in Table 3.3. However, the semi-structured interview guide allowed for additional probing based on responses given by the stakeholders.

Table 3.3 – Themes of the questions in the semi-structured interviews.

Themes
1. Stakeholders' education background and professional experience
2. Stakeholders' perception of education in the country being studied
3. Stakeholders' perception of how the competencies least developed across the EU are developed in the country being studied
4. Stakeholders' perception of the impact of education on professional mobility
5. Stakeholders' perception of the impact of education on patient safety and care
6. Other comments

The interview guide (Appendix 40) includes instructions to run the individual and group interviews, the ethical aspects that must be identified before requesting consent, and examples of prompting that the researcher may want to use to explore each of the individual topics. Therefore, the interview guide supported the researcher during the interview process.

3.2.3.3 THEMATIC ANALYSIS

Thematic analysis was performed using NVivo (v12). This software was used to identify themes from the interview transcripts (Guest et al., 2012). This process started with familiarisation with the transcribed data, followed by coding the data, and finished with identifying the thematic framework and reporting the findings.

Coding is the process of labelling qualitative data to facilitate its management and display. In this process, labels (codes) are assigned to bundles of data to organise and make sense of the data given the research questions being explored. Ultimately, this process led to ideentifying the themes arising from the data (O'Reilly, 2022).

Initial *line-by-line coding* was performed to prevent the researcher's assumptions from potentially influencing the findings (Gibbs, 2020). This means that each line was coded independently rather than assigning a code to a more extensive section of text, as seen in Table 3.4. This method ensures that each code is objective and reflects the content of the line, rather than the researcher's summary of a large section, which could be influenced by his interpretation. In addition, this type of coding ensures an extensive exploration of the data until nothing new emerges (Emerson et al., 2011).

Table 3.4 – illustrative example of the coding process

Transcript from participant UK4	Line-by-line coding	Elaborative coding
"Then they all go and do something like a systematic review or something that doesn't require ethics.	Students prefer research that "doesn't require ethics approval"	
Whereas if they had more time, say, for example, if you did your master's degree and you did two modules a year or three modules a year, and you'd done all of the modules within a space of three years, you may have two years to complete the thesis.	Some educational models allow more time to perform research	Least developed competencies sub-theme: research
Then you find that people are a lot more willing to be more experimental with the thesis and really push to get approval, information governors, learn how to use statistical packages, all of these types of things"	More time for research allows students to do experimental research	

To perform this first line-by-line coding cycle, *structural* and *in vivo coding* were performed. This means that each code is an actual word or expression from the text (*in vivo*) or a summary of the topic that the phrase is dealing with (*structural coding*). This type of coding is considered descriptive (O'Reilly, 2022), and it aims to be objective and avoid bias since it does not involve any interpretation of the data.

The initial coding was followed by *elaborative coding,* which is the process of re-coding the data by organising it into a tentative thematic framework based on previously known themes (Saldaña, 2013). This coding method was used to organise the qualitative data to answer the research aims of this study (section 1.1, "Research aim and questions"). As such, the initial thematic framework included themes such as "underdeveloped competencies", "impact of education on competency", "impact of education on mobility" and "impact of education on patient care". However, this initial tentative framework evolved during the analysis, especially the sub-themes, which were created during the coding process.

This coding process requires a repeated analysis of the data and the labelling, moving the codes and aligning them until they are as perfectly aligned with the thematic framework as possible, allowing the researcher to easily display the findings and answer the research questions (Dey, 2003; Grbich, 2013).

This type of coding requires a reflexive and interpretive interaction between the researcher and the data (O'Reilly, 2022). Therefore, the researcher constantly self-checked his interpretation against his own biases described in "section 3.3 Researcher background, values, beliefs, and biases". A potential weakness of this method is that it may decontextualise the data (Grbich, 2013). To minimise this risk, the analysis was performed with constant reference to the original data. This is shown by adding quotes from the original data in the reporting of the findings.

The coding of all interviews was revised after the end of the second round, ensuring that the codes were still valid. As the themes got established, the thematic framework determined how the findings were reported and reported (Chapter 8).

Several methods were used to ensure the validity (rigour) of the findings: triangulation, negative case analysis, member checking, peer debriefing, and researcher reflexivity (FitzPatrick, 2019; Johnson, 1997; Robson, 2002). The peer debriefing included interviewing three RT committee members from a European-wide professional organisation and presenting the results to the SAFE EUROPE consortium.

Triangulation can have multiple objectives (Brink, 1993); in this study, triangulation was performed to ensure validity. Therefore, the research questions were answered using different sources of data collection methods (triangulation of methods) and different sources (triangulation of respondents) (Hammersley, 2008). Triangulation was performed at the end of each coding round, and the conclusions drawn from the interviews were discussed against findings from previous data collections (triangulation of methods). The responses from different participants related to each theme were also compared (triangulation of respondents). Flick (2020) also considers that using different approaches within the same method is a form of triangulation. In the current study, this triangulation type was achieved using individual and group interviews. While the individual interviews remove the inhibitions that the peers may cause, the group interviews allow participants to build on each other's information – these different sources of information can be triangulated to guarantee the validity of the final findings (Flick, 2020). This triangulation was part of the triangulation of respondents.

Understanding that all phenomena are context-bound is vital (Hammersley, 2008). Therefore, different data may arise from different contexts, drawing competing conclusions. This was especially true in this study since the method included multiple countries and stakeholders with different roles, resulting in different opinions. As such, the triangulation was complemented with negative case analysis, where conflicting information was analysed and presented to the reader in the results — allowing the reader to understand the variety of perspectives arising from the data and adding transparency.

Triangulation of methods was performed between the interviews with previously collected information: the literature review (Chapter 2), document analysis (Chapter 4 to 6) and survey (Chapter 7) (Flick, 2020). This can be observed across the chapters, but it is more prominent in Chapter 9, "General discussion and conclusions", where the findings of the different methods are discussed against each other to draw trustworthy conclusions.

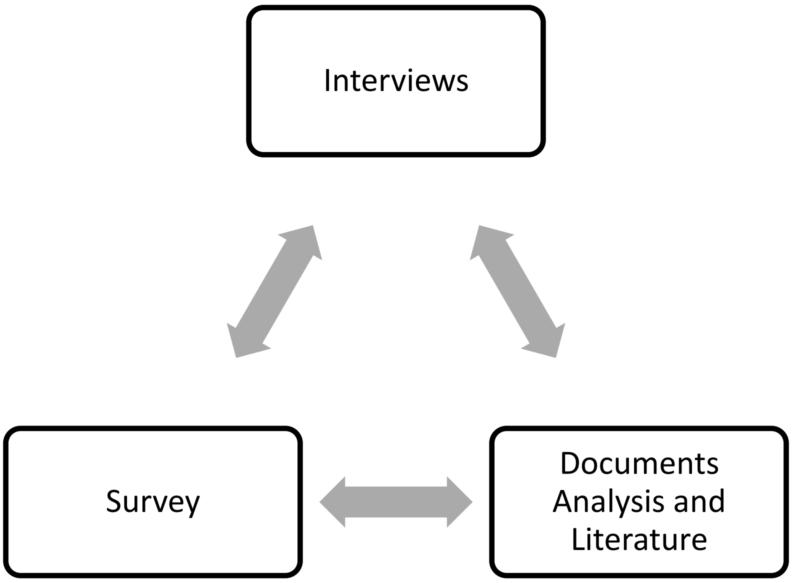


Figure 3.2 – Triangulation of methods

3.2.3.4 ETHICAL CONSIDERATIONS

The Institute of Nursing and Health Research Ethics Filter Committee at Ulster University, UK, granted permission for this study (Ref 10/19/3.3a) (Appendix 5). The participants were informed that the interviews were audio-recorded. Confidentiality was guaranteed through pseudonymisation of the transcriptions, and the Chatham House Rule was used for the group interviews, which states that *'participants are free to use the information received, but neither the identity nor the affiliation of the speaker(s), nor that of any other participant, may be revealed'* (Chatham House, n.d.). Participation was voluntary, and consent was taken at the start of the interview (written for the face-to-face and audio-recorded for the online interviews). Recruitment was performed by the SAFE EUROPE partners and via social media to avoid coercion.

3.2.4 Data protection

All data is protected under the Data Protection Act 2018 that was updated following the introduction of the General Data Protection Regulation (GDPR). The researcher abides by the GDPR policy at Ulster University (available at: https://www.ulster.ac.uk/__data/assets/pdf_file/0006/286008/GDPR-Policy-updated-20-08-19.pdf). The information was treated with strict confidence, and none of the participants was or will be identified.

All data was kept protected in lockers or password-protected computers, as applicable. Electronic data was saved and adequately backed up in UK servers.

Only the named investigators had access to the data. The data was used exclusively for this research project and will be kept for ten years following the end of the project as per Ulster University regulations.

3.2.5 SAFE EUROPE project

The SAFE EUROPE project aims to evaluate the education of TRs given the current pan-European job market. The main objective is to identify educational gaps across EU countries in various dimensions, such as treatment delivery, digital skills, and advanced roles, and offer tools, such as lecture plans and webinars, to close these gaps.

This project, funded by the Erasmus+ grant agreement 2018-2993/001-001, is led by Ulster University and comprises of two universities (Ulster University – UU – and the University of Malta – UM), one oncology hospital (Instituto Portugues de Oncologia Porto – IPOP), three national associations (Associacao Portuguesa de Radioterapeutas –

ART; Polskie Towarzystwo Elektroradiologii – PTE; Society of Medical Radiographers Malta – SRM) and one European professional organisation (European Federation of Radiographer Societies – EFRS).

This project stemmed from the initial results of this PhD research. Phases 2 and 3 of this PhD were incorporated into this European study, allowing an expansion of the initial study's scope. It also helped engage the gatekeepers, who have access to participants across Europe, who would otherwise be challenging to access. More information about this project can be found on the consortium website www.safeeurope.eu.

3.3 RESEARCHER BACKGROUND, VALUES, BELIEFS, AND BIASES

In studies that include qualitative data analysis, it is good practice to disclose the researcher's background, beliefs, and values. This disclosure allows the researcher to be aware of his own biases, increasing rigour of the results while providing the reader with this information for their evaluation (Creswell, 2014; Locke et al., 2007). The values and beliefs were identified through self-analysis and journaling before and during data collection and analysis.

The researcher obtained his BSc in Radiotherapy in Porto, Portugal. He registered and practised RT in a local hospital following this four-year programme, working on the linac for six years and two years as a dosimetrist. During this period, the researcher also lectured part-time in the BSc in Radiotherapy at the HEI where he graduated. The researcher then moved to Malta to practise as an Assistant Lecturer in the Radiography department at a local university, teaching mostly BSc Radiography students able to practise both MI and RT at graduation.

There are three independently regulated professions in Portugal: radiology, radiotherapy, and nuclear medicine technicians, and the researcher was registered and able to practice RT only. In Malta, there is a single profession ("Radiography"); however, the researcher's is only allowed to practise RT.

The researcher's official professional title in Portugal was "técnico de radioterapia" (radiotherapy technician). However, due to the perception that this was not a technical occupation but a profession, the title of "radioterapeuta" (radiotherapist) was often used among these professionals. This title was also defended by one of the professional associations. Upon moving to Malta, he was asked not to use that title and use "radiographer" instead. This had an impact on the researcher's professional identity because the researcher believed that the etymology of the word "radiographer": radio- (radiation) + graph (image) misrepresented his abilities, while the word "radiotherapist" is more explicit about the boundaries of his competence. An interest in radiography professionalism was sparked, despite briefly discussed in this dissertation, this subject benefits from independent research.

By the conclusion of this thesis, seven years after the migration, the researcher worked with excellent professionals with MI and RT specialisms, locally and internationally. These collaborations helped develop a sense of professional belonging and a greater acceptance of the "radiographer" title. The researcher still prefers the title of "therapeutic radiographer" since it is much more specific. Nevertheless, he often introduces himself as a "radiotherapy lecturer" since it reflects his current role without having to choose between the two national titles.

The differences between education and professional regulation in Portugal and Malta led the researcher to pursue this PhD topic. In virtue of this background and experiences, it can be considered that the researcher has insider's knowledge which contributes to the research. However, he is also aware that past experiences may create biases, which must be constantly checked. For example, the researcher believes that improved education leads to improved patient care, which he aimed to assess through this study.

The differences between the researcher's education (4-year course in RT) and the education in his current occupation (assistant lecturer in a 4-year course covering both diagnostic and therapeutic radiography) led the researcher to believe that some aspects must be left out when multiple specialisms are covered in the same period. Therefore, the researcher started this study believing that courses to one specialism allow the graduate to develop more competencies. This bias was balanced by the supervisory team of this PhD, which includes academic staff from both education models.

Based on his migration experience, the researcher developed a belief that migration and recognition of qualifications occur in Europe, but qualifications checks are limited to analysis of transcripts and degree certificates against relatively vague regulations of the requirements to practise. Therefore, the belief was that there is a potential risk for patient safety when migration occurs. Nevertheless, the researcher acknowledged that his experience was an individual case, and the interviews with stakeholders across Europe could help assess this risk.

Overall, the researcher guarantees that he conducted this research ethically, that the data collection was fair, while the findings were compared against these values and beliefs to ensure that they did not influence the results. Multiple data sources across the three study phases were triangulated to strengthen the findings, reducing the risk of researcher bias. When data did not confirm these beliefs, the researcher was able to reframe his beliefs and report the evidence.

CHAPTER 4. RESULTS OF THE EVALUATION OF THE NATIONAL EDUCATIONAL REQUIREMENTS TO PRACTISE RADIOGRAPHY ACROSS THE EUROPEAN UNION

This chapter discusses the results of the analysis of national regulations from all EU member states with the aim of answering the first research question: "What are the requirements to practise as a TR across EU member states?".

The methods used are described in detail in section 3.2.1.1, "Requirements to practise radiography across the EU". In summary, the regulations were collected from the regulatory bodies and national contact points and were analysed and quantified using a framework approach thematic analysis. The findings from this document analysis were used in the design of survey (Phase 2) and cross case study (Phase 3).

4.1 RESULTS

Data regarding the title for the professions under the generic name of "Radiographer / Radiotherapist" was collected from the RPD (Table 4.1). Most countries submitted the national title in the original language, of which a total of 24 titles are available in English with a total of 14 different English titles. This number is due to a wide variety of original language titles that, when translated, correspond to a variety of English titles. Not all countries submitted an equivalent English title, so the actual number of different titles in Europe might be greater.

Table 4.1 – Name of regulated professions associated with the generic name of "Radiographer / Radiotherapist" and "Nuclear Medicine Technician" (European Commission, n.d. b, n.d. a)

Country	Name of Regulated Profession	Translation into English
Austria	Radiologietechnologin / Radiologietechnologe	Radiological technologist (EN)
	Röntgenassistent/in	Radiology assistant (EN)

Belgium	Technologue en imagerie médicale / Technoloog medische beeldvorming	undefined
Bulgaria	Рентгенов лаборант	Medical X-ray technician (EN)
Croatia	Radiološki tehničar/Prvostupnik Radiološke tehnologije	Radiology Technician/Radiology Technician (Bachelor's degree)
Cyprus	n/a	n/a
Czech Republic	Radiologický asistent	Radiographer/Radiotherapist (EN)
Denmark	Radiograf	Radiographer (EN)
Estonia	n/a	n/a
Finland	Röntgenhoitaja / Röntgenskötare	Radiographer (EN)
France	Manipulateur d'électroradiologie médicale	Radiologist Assistant (EN)
Germany	Med.- tech. Radiologieassistent(in)	undefined
Greece	Technologos Radiologias - aktinologias (TEI)	undefined
Hungary	Képalkotó diagnosztikai analitikus	Imaging diagnostic analyst (EN)
	Képi diagnosztikai, nukleáris medicina és sugárterápiás asszisztens	Visual diagnostic, nuclear medicine and Radiotherapy assistant (EN)
	Radiográfus	Radiographer (EN)
	Gyakorló képi diagnosztikai, nukleáris medicina és sugárterápiás asszisztens	Practising diagnostic medical imaging, nuclear medicine and radiation therapy technician (EN)
Ireland	Diagnostic Radiographer	Diagnostic Radiographer
	Radiation Therapist	Radiation Therapist
Italy	Tecnico sanitario di Radiologia medica	undefined
Latvia	Radiografers	Radiographer (EN)
	Radiologa asistents	Radiologist's assistant (EN)
Lithuania	Radiologijos bakalauras	Radiology Technologist
Luxembourg	Assitant technique medical de Radiologie	undefined
Malta	Radiographer	Radiographer
Netherlands	Radiotherapeutisch laborant/ Radiodiagnostisch laborant	Radiographer / Radiotherapist (EN)
Poland	Technik elektroradiolog	Electroradiology technician (EN)
Portugal	Técnico de Radiologia	Radiographer (EN)
	Técnico de Radioterapia	Radiation therapist (EN)
	Técnico de Medicina Nuclear*	Nuclear medicine technologist (EN)
Romania**	n/a	n/a
Slovakia	Rádiologický technik	Radiological technician (EN)
Slovenia	Radiološki inženir	Radiographer (EN)
Spain	Tecnico superior en imagen para el diagnóstico	undefined
	Tecnico superior en Radioterapia	undefined
	Técnico especialista de medecina nuclear*	undefined
Sweden	Röntgensjuksköterska	Radiographer (EN)

UK	Radiographer	Radiographer

* Under the generic name of “Nuclear medicine technologist”
** Not a regulated profession
n/a = not available

The titles include a combination of keywords related to radiation professions (e.g. radiology, radiation) with role-defining keywords (e.g. therapist, technician, technologist). Thirteen of these entrances include the term “Radiographer” either alone, with variants (e.g. “diagnostic radiographer”) or together with other titles (e.g. “Radiographer/Radiotherapist”).

Since RPD does not identify a generic name for Radiography Assistants, three countries included these in the same category. Radiography Assistant’s role may vary from country to country, however, in the UK, their role is to perform “clinical imaging examinations or treatment procedures in concert with, and under the supervision of, registered Radiographers” (p. 2) (Society of Radiographers, 2012, p. 2).

Only Romania does not have the profession regulated and is therefore not being considered in the data analysis. This means that 96% of the 28 EU member states have radiography regulated. Two countries (Cyprus and Estonia) did not submit information in the RPD, however, it was confirmed by their competent authorities that the professions were regulated at national level.

Thematic analysis was performed, and the following themes were identified:

- Presence/absence of mandatory registration;
- Specialisms included in the regulated professions;
- Required programme duration;
- Number of ECTS;
- Academic level:
    - According to European Qualification Framework (EQF);
    - According to 2005/36/EC directive;
- Subjects required to be covered in the educational programme:
    - Presence/Absence of a list of subjects;
    - Structure according to the Recommendation of the European Parliament and of the Council on the establishment of the European Qualifications Framework for lifelong learning;
- Other country-specific academic requirements identified through thematic analysis.

It is important to note that not all countries submitted enough information to triangulate sources for each theme. Only themes that could be identified in at least two sources of data were included in the results. The triangulation ensures rigour of the data collection and allows the researchers to have high confidence in the results, since results are not dependent on a single interpretation of the text but confirmed in another source. The type of data collected is also very objective, limiting researcher bias.

4.1.1 Mandatory registration

Twenty-six countries submitted sufficient information to identify if professionals are required to register with a regulatory body to practise. Although most respondents (81%) require registration to practise, 15% do not have mandatory registration (Austria, Estonia, Poland and Slovenia) and 4% (The Netherlands) has optional registration (Figure 4.1). Depending on national legislation, the registration might be done with a regulatory body (responsible for the regulation or approval of a particular area), a statutory body (oversees a particular area) or with a professional body (oversee the activities of a particular profession).

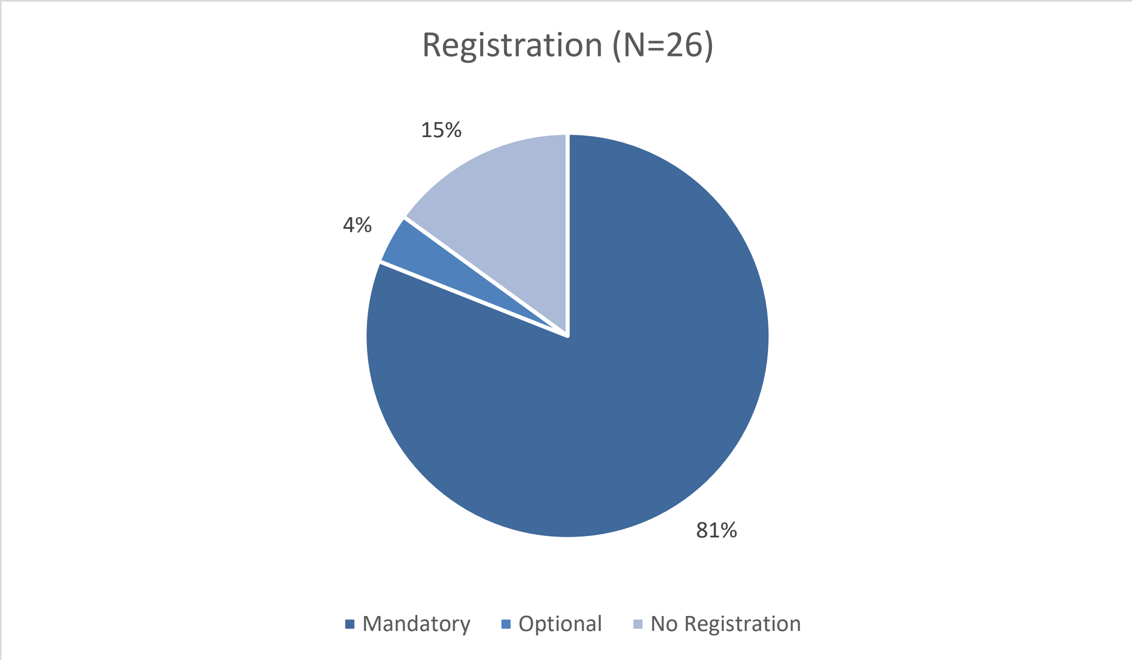


Figure 4.1 - Requirement to register with a regulatory body prior to practising radiography

4.1.2 Specialisms under regulated professions

In Figure 4.2, it can be seen that most countries (19 EU countries - 83% of respondents) regulate a single profession that includes all the specialisms. Three countries (8%) regulate two professions (Cyprus and Ireland), separating diagnostic and therapy and two other countries (8%) regulate a third profession corresponding to nuclear medicine (Spain and Portugal). Three countries did not provide enough information to assess the specialisms.

Thematic analysis indicated that the specialisms in education can be different from the professions regulated, for example, in Portugal where although three separate professions are regulated, diagnostic, radiotherapy and nuclear medicine have been covered in one single educational programme since 2014. The UK, on the other hand, has two distinct course programmes for diagnostic and therapeutic radiography but these professionals fall under the same professional title.

Figure 4.2 - Number of regulated professions according to specialism

4.1.3 Programme duration

The required programme duration was assessed in 23 EU member states, and it varies from 2 to 4 year programmes. The most common requirement (57% of respondents) was a three-year programme, while Spain was the only country requiring a two-year programme (4%) (Figure 4.3). It is important to note that although Germany has a 3-year programme, it occurs at EQF4 level (Secondary Education). Although the respondents did not identify the course length in Poland, it is possible to say that it is lower than 3 years duration as it is an EQF level 5 programme (higher education short course).

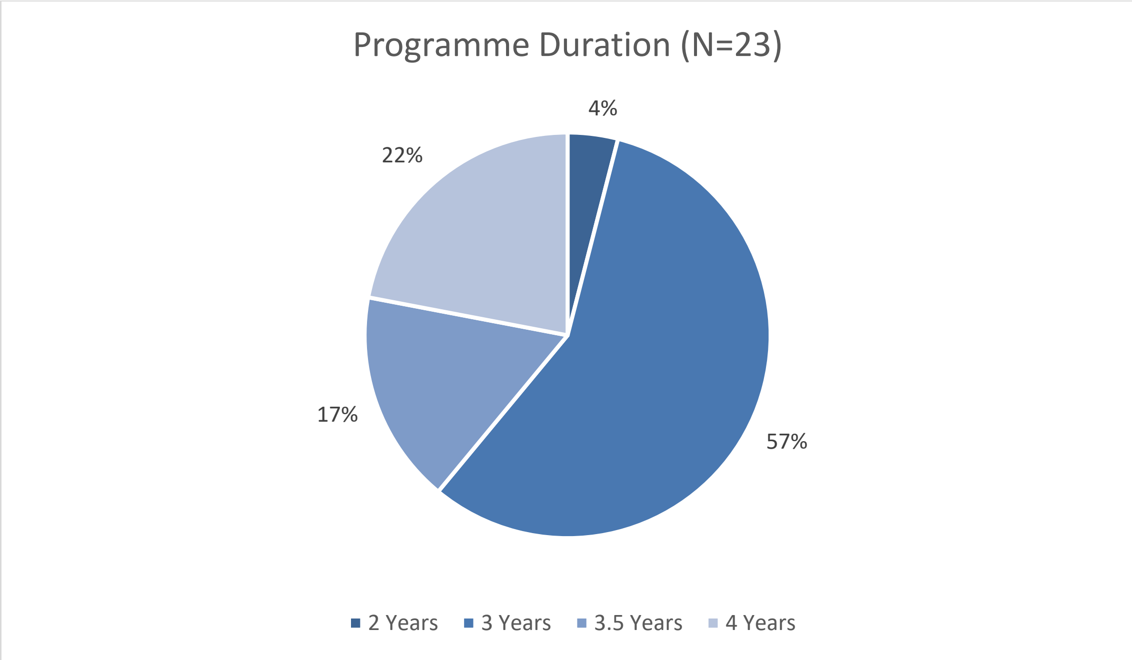


Figure 4.3 – Education programme duration requirements across EU

4.1.4 European Credit Transfer and Accumulation System (ECTS)

The number of ECTS was identified as a requirement in only 14 member states (50%). Most respondents (36%) require 240 ECTS (Figure 4.4). Lithuania requires a minimum of 120 ECTS, although they also require a three-year programme, which according to EQF recommendations, corresponds to 180 ECTS.

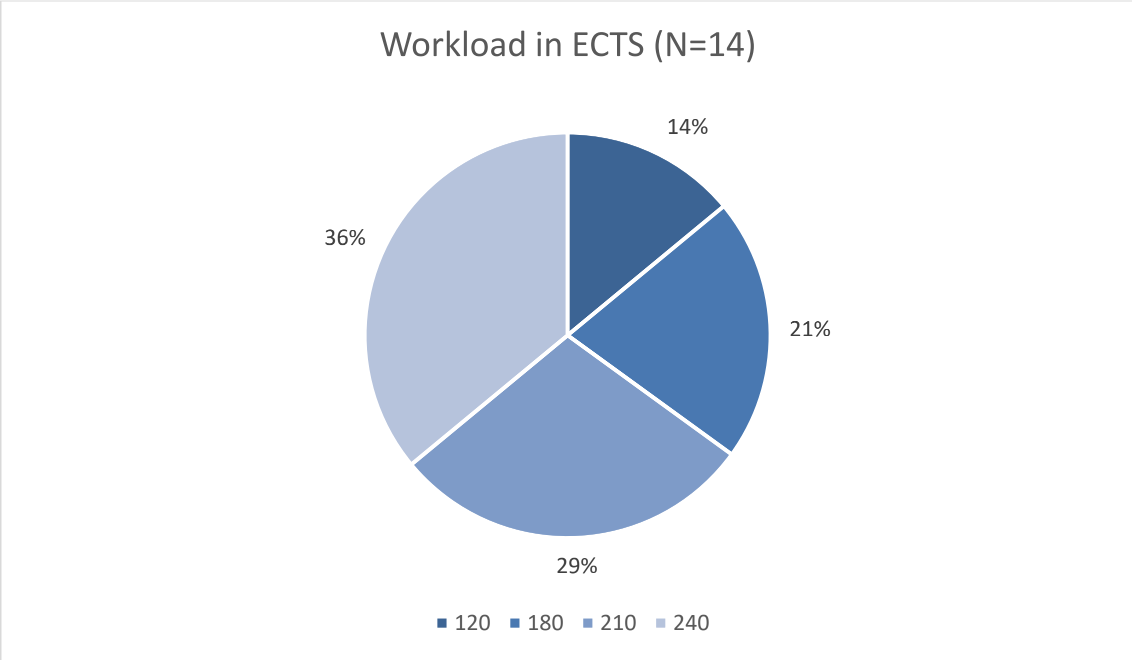


Figure 4.4 – Required number of ECTS to practise radiography.

4.1.5 Academic Level

The academic level was studied using two classifications: the EQF and the 2005/36/EC classifications. EQF data was mainly found in documents submitted by the respondents, while the 2005/36/EC level was collected from the RPD.

It was possible to collect enough information to assess the academic level in 26 countries. Out of these, the majority (69%) require HE programmes with at least three years duration but less than four years (level 4) followed by HE with a duration of 4 years or longer (Level 5) (19%) (Figure 4.5).

Only 12% of the programmes require lower qualifications than a Bachelor's degrees: 8% are Level 3 requiring HE short courses of more than 1 and less than 3 years' duration (Poland and Spain) and 4% are Level 2 requiring a technical/professional secondary course to practise (Germany).

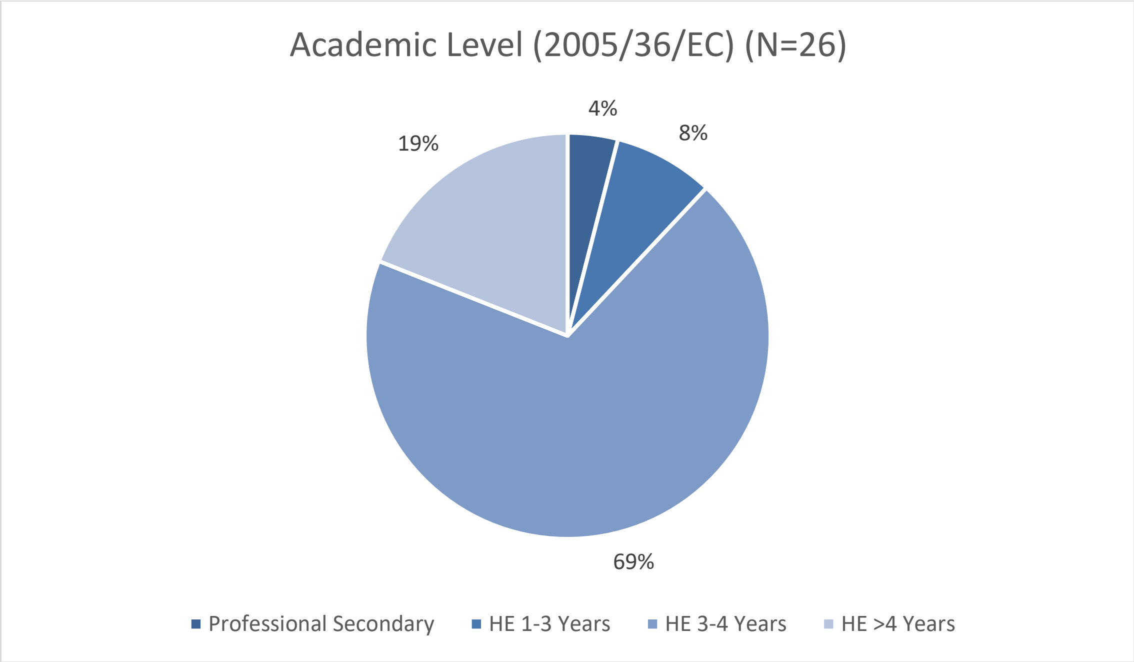


Figure 4.5 – Academic level according to 2005/36/EC classification level.

With regard to the EQF level, the vast majority (88%) achieve a EQF6, 8% have an EQF5 (Poland and Spain) while only Germany requires an EQF4 (Figure 4.6). Academic Levels 4 and 5 of the directive correspond to an EQF level 6 (Bachelor degree), demonstrating that the results for both classifications are in agreement.

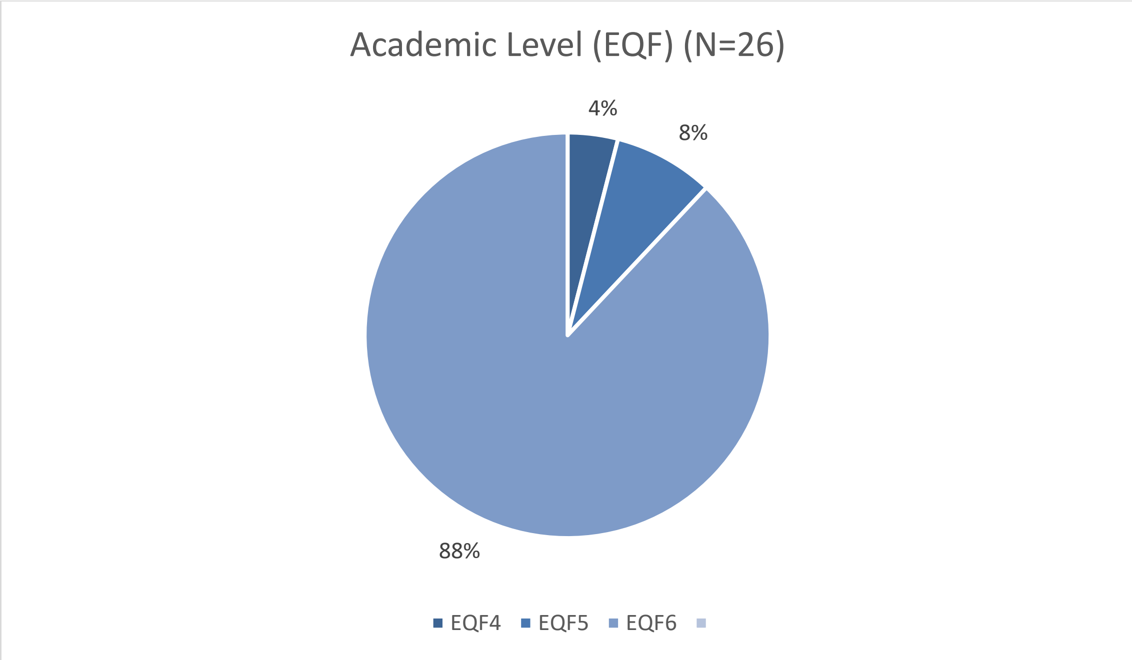


Figure 4.6 - Academic level according to EQF levels

Estonia requires a minimum of EQF6 to practise most roles of radiography, however, some specialisms (e.g. Radiotherapy and Ultrasound) require a Master's degree to practise (EQF7). Across Europe, it is common for the employer to require the radiographer to undergo further education to practise certain specialisms, however this was only stipulated in the regulations for Estonia.

4.1.6 Curricula

Curricular information was obtained directly from regulations identified by competent authorities and contact points and since this information could not be assessed elsewhere, it was not possible to triangulate. Thirty-five percent of respondents did not identify the subjects covered in the documentation (Figure 4.7), nonetheless, the researcher cannot exclude the possibility that this information is available in documents not provided.

Seven countries (26%) identified a list of subjects, for example these requirements are written in terms of study units, generic subjects (e.g. radiation physics, radiobiology, etc.) or knowledge to be covered, while three countries (13%) define educational content in terms of skills: cognitive or practical ability to complete tasks and solve problems (European Parliament and European Council, 2008).

A total of 26% of respondents identified the competencies required to practise – which reflect responsibility and autonomy (European Parliament and European Council, 2008) – either by requiring a list of competencies (9%) or by regulating in terms of Knowledge, Skills and Competences (17%) according to EQF recommendations (European Parliament and European Council, 2008).

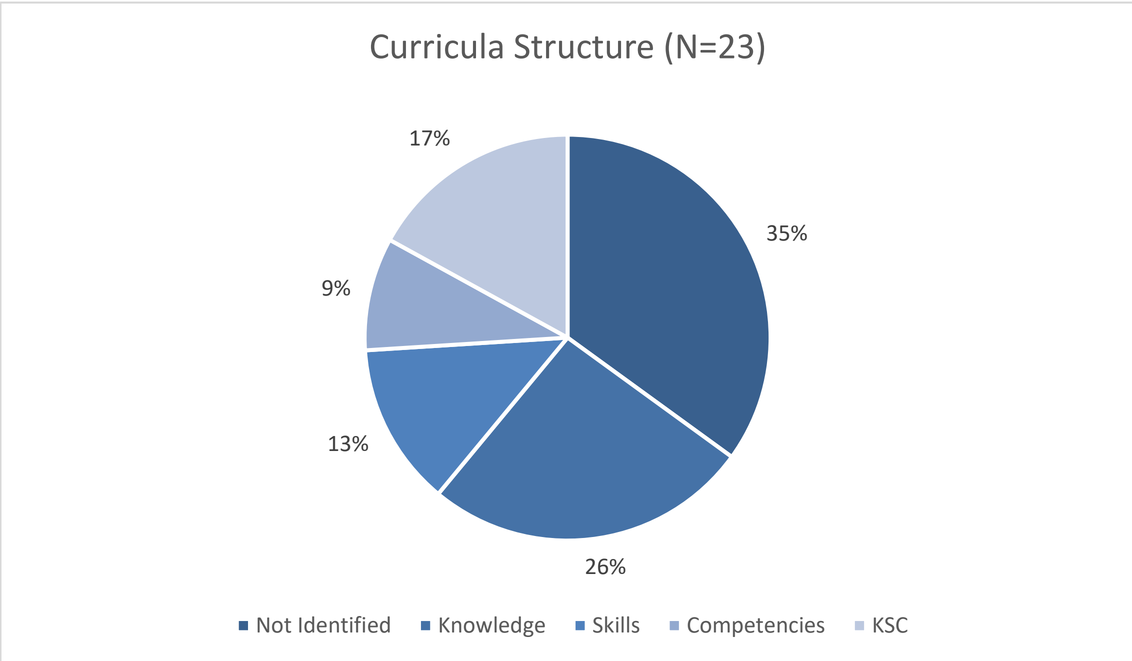


Figure 4.7 – Structure of the subjects to be covered in the educational programmes

It was found that in order to apply for recognition, in most EU countries, the radiographer must submit detailed information of their educational programme (e.g.

transcripts) allowing competent authorities to verify that the profession complies with national regulations.

4.1.7 Clinical training

Clinical training was noted as a requirement in documents submitted by 11 countries. However, variances were observed in terms of structure and content of the clinical training requirements. In addition, the requirements regarding clinical practice are not defined in terms of competencies across the EU.

Some countries identify areas of specialism where clinical placement occurs, e.g. in Belgium, an internship is required in five areas: radiology, ultrasound, MRI, intervention procedures in medical imaging and in vivo nuclear medicine. RT is not contemplated, although the reply from the competent authority indicated that staff are able to practise this role. Furthermore, specialisms included in “radiology” are not detailed. No specification of time or workload is defined in the legislation. On the other hand, France and Italy clearly define the specialism and procedures, which the student must practise, respectively.

The format in which the workload of the clinical training is defined also varies between EU countries. Examples of different ways of describing the clinical training workload requirements are presented in Table 4.2.

Table 4.2 – Examples of requirements regarding clinical training workload

Country	Minimum workload requirements
Denmark	90 ECTS for clinical placements (all areas)
Bulgaria	600 hours in each of the specialisms
France	6 weeks in radiotherapy
Italy	15 external beam radiotherapy treatments
UK	not specified – as long as clinical training is in line with standards of proficiency (Health and Care Professions Council (HCPC) (UK), 2013)
Portugal	Legislation does not specify the minimum workload

In summary, the format used to define the curricula and the workload of clinical training varies from country to country in the EU.

4.1.8 OTHER REQUIREMENTS

Demographic information of the radiographer, proof of fitness to practise (e.g. medical certificate) and proof of trustworthiness (e.g. police conduct certificate) are common requirements to register when the registration is mandatory.

In addition, mastering of the language of the host country is a common requirement to register and practise as a radiographer. Although this was not included in the original 2005/36/EC directive, this requisite was added in an amendment in 2013 (European Parliament and European Council, 2013).

Although most countries do not specify the presence of a final exam in the legislation, a final exam as part of the education programme can be done in some countries (e.g. France), while in other countries this exam is performed by an external entity, independent from the educational organisation (e.g. Germany or Poland).

4.2 DISCUSSION

As identified in the literature (EANM, 1998; ESTRO, 2012; European Commission, n.d. b; ISRRT, 2014, 2012), there are a variety of titles at national level, reflecting the national variations of the professions. Although European professional organisations define titles for the radiographer with the intention of harmonisation, these have different titles according to the specialisms that they represent. It is important to note that these do not have a binding power as opposed to the protected titles of each country. The lack of an international homogenous title might reflect a lack of homogeneity in terms of body of knowledge, levels of autonomy and authority across the EU, indicating that there might be, in fact, several professions. The only official indication of the relationship between these national titles is the RPD that aggregates most of the professions under the same generic name of “Radiographer / Radiotherapist” (European Commission, n.d. b), although it also includes different branches of the professions as well as radiography assistants, reflecting some lack of reliability.

Lack of registration is an issue that may compromise the process of recognition of qualifications since the host country commonly requests proof of registration in the home country, however this can be compensated by other means: e.g. proof of experience (European Parliament and European Council, 2005).

The lack of uniformity in the specialisms covered may compromise movement in both directions. Since the subjects covered by the applicant must comply with the requisites to practise, if the training was performed in a single specialism, the applicants might be refused registration since the other specialisms were not covered. This issue might be solved with partial recognition but this must be set in place by the individual countries (European Parliament and European Council, 2013). On the other hand, it is likely that courses covering all specialisms might not cover all subjects for each branch of radiography when compared to courses that focus on one specialism or might need to compromise on the depth due to similar course durations to cover all specialisms.

Although programme duration is not a requirement affecting recognition of qualifications, it influences two criteria: 1) academic level, where a higher education course can be classified in different levels depending on the duration and 2) professional qualifications, since the amount or depth of the subjects covered depends on the time allocated.

Regarding academic level, the 2005/36/EC directive establishes that the applicant should have a maximum of one level below the destination country education. Considering the results obtained, only three countries establish an education level that compromises the free movement, regarding this criteria. The EQF academic level is not mentioned in the 2005/36/EC directive, however there is a relationship between EQF and 2005/36/EC directive (Table 4.3).

Table 4.3 – Relationship between EQF and 2005/36/EC directive academic level classification

EQF	2005/36/EC Directive Classification
EQF4	Level 2 (Secondary education)
EQF5	Level 3 (HE >= 1 year)
EQF6	Level 4 (HE >= 3years) and 5 (>= 4 years)

HE = Higher Education

In addition, the academic level has an impact on the curriculum, since at different levels, the depth at which the subjects are covered are not the same, for example, at EQF5 “Comprehensive, specialised, factual and theoretical knowledge within a field of work or study and an awareness of the boundaries of that knowledge” (European Parliament and European Council, 2008, p. 4) is expected while at EQF6 an “Advanced knowledge of a field of work or study, involving a critical understanding of theories and principles” (European Parliament and European Council, 2008, p. 4) must be achieved. As mentioned before, the academic qualifications must be equivalent, since radiography has an implication in the population’s health and safety (European Parliament and European Council, 2005).

The subjects covered within the educational programmes are the most heterogeneous aspect observed. These requirements are presented using different frameworks (only a few follow EQF recommendations) in addition to differences in content. Likewise, the requirements regarding clinical placements vary considerably.

Education programmes aim to achieve the requirements at national level, therefore how the subjects/outcomes are regulated influences the curriculum. If the requirements are set up in terms of competencies, the education outcomes must be competency-based; while if the requirements are a list of subjects covered, the programme might aim for the acquisition of knowledge without the development of a competency.

Differences in terms of structure compromises the comparison of the applicant’s education programmes against requirements. To overcome this issue, the countries commonly require the transcripts with details of the curriculum to ensure that there is a match between the education and the requirements. It is however important to remember, that although the EQF guidelines aim to facilitate mobility, this is a non-binding document.

The lack of information available was a limitation of this study, however, this reflects another hindrance to the movement of professionals across the EU, since without information, radiographers cannot assess if their qualifications are eligible to apply for recognition in another country.

4.3 CONCLUSIONS

The requirements to practise radiography across the EU are considerably heterogeneous. The disparity is visible in the themes that emerged from the thematic analysis: registration in a professional body, specialisms included in the regulated profession, programme duration and ECTS, academic level and subjects covered.

Differences in education can compromise the successful recognition of qualifications in the host country due to lack of compliance with the criteria. When recognition is granted, the safety of the patients may be compromised due to discrepancies in the competencies developed in the training and those practised in the destination country.

The differences observed might compromise the movement of professionals since each country aims to educate students to comply with national regulations. If these regulations are different, then a radiographer educated in one country might not be able to practise in another country. The lack of national regulation of radiography in one EU country (Romania) only compromises the movement to-and-from this country, while variance in academic level impedes movement of professionals who have graduated from three member states (Germany, Poland and Spain) to countries with higher levels of educational requirements. However, this criteria still allows movement to those countries with lower level requirements. Lack of registration at national level can make the process more difficult, however there are means to overcome the issue.

The educational programme curricula are the criteria where national regulation is most heterogeneous across the EU and therefore hinders the movement of professionals, since 2005/36/EC directive establishes that professions affecting health and safety subjects covered in the education must match the destination country requirements.

Since not all countries have a competency-based regulation, radiographers may be able to move to these countries, since they comply with the requirements, although there is no certainty that competencies developed are the same, compromising health and safety of the patient.

The programme duration and the workload (in terms of ECTS) are not requirements in the directive, however, they influence the academic level and professional qualifications that are required to achieve recognition of qualifications. This heterogeneity between countries also compromises the comparison of qualifications across countries and make it difficult to design education programmes/curricula that would comply with the needs of all the member-states.

Although the researcher understands the complexity of the subject, the recommendations from this research are that the profession should be regulated at EU level with definition of the outcomes to be achieved in terms of Knowledge, Skills and Competencies. An agreed entry level, which might be separated for the different specialisms/professions in order to cater for national differences in terms of the specialisms is recommended.

A theoretical or practical exam (e.g. provided by an international association) can be used as a tool to allow radiographers to prove the acquisition of knowledge, skills and competencies as described in the 2005/36/EC Directive (European Parliament and European Council, 2005). The results of this exam can be used in the application for recognition of qualifications and facilitate the movement across European countries.

4.4 BRIDGING SECTION

This chapter discussed the most relevant variations between European regulations; however, Appendix 6 describes the professional regulations in each EU country, exposing the differences between countries. It also allows the reader to identify how triangulation was performed for each country, ensuring transparency of the findings.

This study showed that specific criteria are repeatedly used in national regulation to establish the minimum requirements to practise (academic level, programme duration, ECTS and specialisms) and that there is variation between countries regarding these aspects. However, the regulation of the learning outcomes (which represent the professional qualifications) varies considerably across Europe, with very few countries regulating the competencies required to practice.

It can be questioned if these course characteristics commonly identified in national regulation are a good proxy for the actual competency of graduates. Even though regulations may establish the minimum requirements, EIs may develop their students' competencies beyond the minimum required. As such, even though the legislation may indicate that radiographers from certain countries would not achieve recognition of qualifications in another country, their actual education may prepare them at higher levels, allowing this movement. As such, it is crucial to understand the actual course characteristics across Europe. This was explored in the survey discussed in Chapter 7.

Despite the differences encountered between EU countries, it is important to understand if this affects the recognition of radiographers' qualifications abroad. The patterns of movement were explored in the next chapter, and the stakeholders' perception of education impact on professional mobility is discussed in Chapter 8.

CHAPTER 5. RESULTS OF THE ANALYSIS OF THE REGULATED PROFESSION DATABASE REGARDING THE PATTERNS OF MOVEMENT OF RADIOGRAPHERS IN THE EU

This chapter discusses the data analysis collected from the Regulated Profession Database of the European Commission. It aims to answer the second research question "What are the patterns of recognition of qualifications of radiographers across the EU, and which countries encounter difficulties to obtain recognition abroad?".

This entailed an analysis of the data regarding the number of radiographers who obtain recognition of their qualifications abroad as well as those who obtain a rejected application. Details on the methodology were presented in section 3.2.1.2, "Patterns of recognition of qualifications between member states". The findings of this section were used in the design of phases 2 and 3.

5.1 RESULTS

From the 22 countries included in the study, most host countries submitted data for the target period of 2015-2017. Croatia, Cyprus, Estonia, Latvia, Lithuania and Romania had not submitted any information on the RPD.

Table 5.1 identifies the years corresponding to the data collected for each host country. The target period for the data collection was 2015-2017. However, not all countries have submitted data for this period. Nevertheless, it is possible to observe that most countries submitted at least two years within the target period. Data collected from periods before 2015 were underlined in Table 5.1 for easy identification.

Table 5.1 – Period of data collected for each host country.

Host country	Period of data collected
Austria	2015-2016
Belgium	2015-2017
Bulgaria	2016
Czech Republic	2015-2017
Denmark	2015-2016
Finland	<u>2014</u>-2016
France	<u>2013-2014</u>
Germany	2015 & 2017
Greece	<u>2010-2011</u>
Hungary	<u>2009</u> & 2015
Ireland	2016-2017
Italy	2015-2017
Luxembourg	<u>2008-2009</u>
Malta	2015 & 2017
The Netherlands	2015-2017
Poland	<u>2009</u>
Portugal	<u>2009-2010</u>
Slovakia	2015-2017
Slovenia	2015-2017
Spain	<u>1997</u>
Sweden	2015-2017
UK	2015-2017

Data prior to 2015 is <u>underlined</u>

5.1.1 GEOGRAPHICAL PATTERNS OF MOVEMENT

Radiographers movement across the EU is a complex migration network. Some routes have a higher number of radiographers achieving the recognition of their qualifications than others. However, all countries were involved in this network.

Based on the data, an average of 510 radiographers achieved recognition of qualifications in another EU country every year, and possibly more since some countries did not submit data. The average number of radiographers achieving recognition across the EU (per year) are shown in Table 5.2, while Figure 5.1 depicts the most common recognition of qualifications on the EU map.

Table 5.2 - Average number of radiographers granted recognition of qualifications between EU member states (per year), including automatic recognition, aptitude test and probation period.

From -> to	AT	BE	BG	CZ	DK	FI	FR	DE	EL	HU	IE	IT	LU	MT	NL	PL	PT	SK	SI	ES	SE	UK	TOTAL
Austria (AT)								10.5				0.3	0.5						0.3				11.7
Belgium (BE)							7.0				0.5		2.0		0.3								9.8
Bulgaria (BG)		0.3						1.5	0.5													0.7	3.0
Croatia (HR)	2.0							13.5			3.5										7.3	3.0	29.3
Republic of Cyprus (CY)																						0.7	0.7
Czech Republic (CZ)								3.0							0.3			1.7				0.7	5.7
Denmark (DK)																					0.7	0.3	1.0
Estonia (EE)						2.0																0.3	2.3
Finland (FI)												0.3									3.0	0.3	3.7
France (FR)		10.3						1.5					11.0							3.0		1.0	26.8
Germany (DE)	3.5	0.3			0.5										0.3					2.0	0.7	0.7	8.0
Greece (EL)		0.3						3.0				0.3									0.3	6.0	10.0
Hungary (HU	3.0							4.5			0.5			0.5				0.3			1.0	3.0	12.8
Ireland (IE)	0.5																					4.0	4.5
Italy (IT)		2.7			0.5	0.5	2.0	7.5			3.0			0.5		1.0			0.3			90.0	108.0
Latvia (LV)											0.5											0.3	0.8
Luxembourg (LU)								1.5															1.5
Malta (MT)																						0.7	0.7
Netherlands, The (NL)		18.0						7.5													4.3	0.3	30.2
Poland (PL)	0.5	0.3			0.5		0.5	10.5				1.0									0.7	5.3	19.3
Portugal (PT)		7.7					4.5				2.0	0.7		0.5	0.7						4.3	69.7	90.0
Romania (RO)	1.0	0.7			0.5		1.0			0.5		0.7										2.7	7.0
Slovakia (SK)	0.5			5.0						0.5												0.7	6.7
Slovenia (SI)	4.0													0.5							0.3	0.7	5.5
Spain (ES)					1.5		1.5	3.0				0.7	0.5				0.5				0.7	11.0	19.3
Sweden (SE)	0.5																					1.3	1.8
United Kingdom (UK)					0.5						85.5	0.0	0.0	1.0	1.3						1.0		89.3
TOTAL	15.5	40.7	0.0	5.0	4.0	2.5	16.5	67.5	0.5	1.0	95.5	4.0	14.0	3.0	3.0	1.0	0.5	2.0	0.7	5.0	24.3	203.3	509.5

>72.8 >11.0 >7.5 >5.1 >4.1

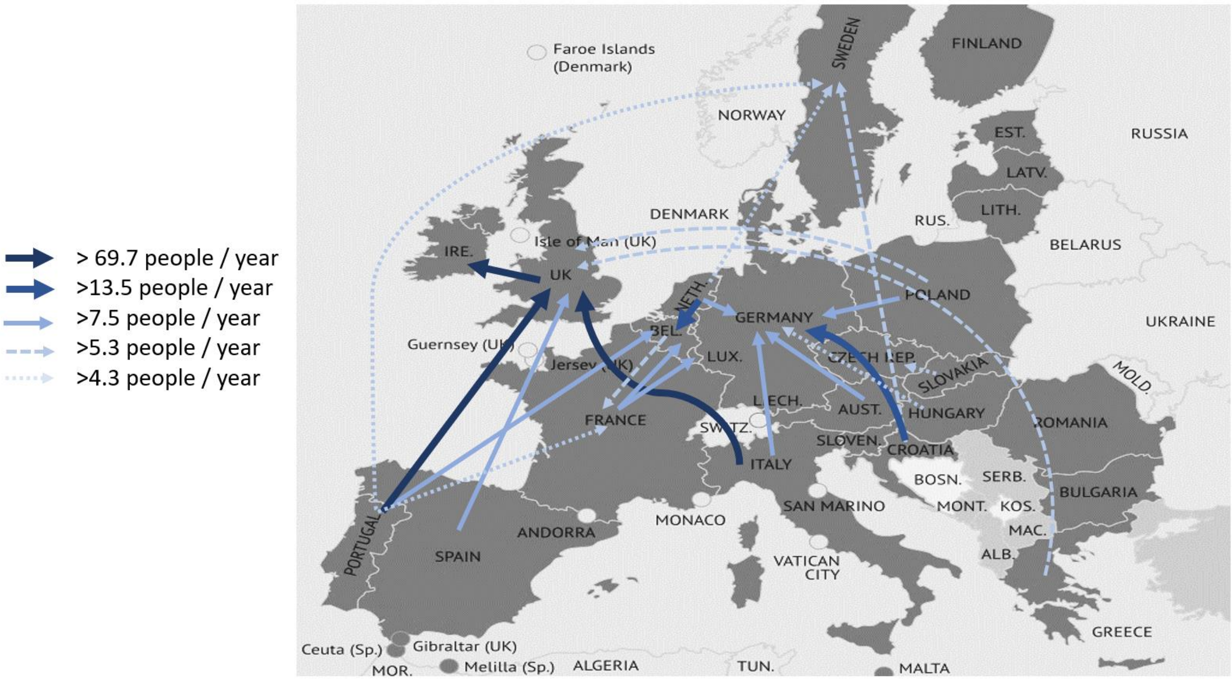


Figure 5.1 – Most frequent patterns of recognition of qualifications between EU member states, including recognitions following aptitude test or adaptation period. Values represent yearly average. Map adapted from Centanni (2016)

The top-ranking host country recognising qualifications was the UK (203 recognitions per year). The most common countries of origin were Italy, Portugal and Spain.

However, another significant route is radiographers qualifying in the UK who obtain recognition in neighbouring Ireland, making Ireland the second-highest to recognise qualifications from other countries (96 recognitions per year). One possible explanation for this phenomenon are citizens from the Republic of Ireland who undertake their studies in the UK and return to their country to practise, in addition to actual UK citizens working in Ireland.

Germany is the third-largest receiver of radiographers from the EU (68 recognitions per year). These radiographers come primarily from Croatia, Austria, Poland, Italy, and the Netherlands.

Italy (108 radiographers per year) has the larger number of graduates obtaining recognition of their qualifications abroad. However, Portugal (90) and the UK (89) closely follow. Italian radiographers move mainly to the UK and Germany, the Portuguese mainly to the UK and Belgium, while the British graduates request recognition mainly in Ireland.

Radiography is not a profession that can apply for automatic recognition of professional experience (as per 2005/36/EC Title III Chapter II). Although no recognition was expected through this pathway, Austria recognised the experience of three radiographers from Hungary through this pathway.

5.1.2 RECOGNITION FOLLOWING COMPENSATION MEASURES

For the whole European Union, 11% of qualification recognitions was through compensation measures. This corresponds to 57 out of the 510 radiographers recognised every year.

However, certain countries applied compensation measures to a more substantial proportion of the total number of radiographers achieving recognition. In fact, 94% of the foreign radiographers achieving recognition of qualifications in France had to undergo either probation period or aptitude test. Other countries with high proportions of recognitions only after compensation measures were Italy (83%), Finland (80%), Germany (38%), Malta (33%) and Sweden (32%). The remaining host countries have proportions below 6%.

The countries of origin from where the applicants have the highest proportion of compensation measures requested were Estonia (86% of the recognition of qualifications were after compensation measure), Belgium (61%), Bulgaria (50%) and Hungary (34%). The remaining countries have proportions below 28%.

All applicants that underwent compensation measures were granted recognition of qualifications. Therefore, there were no rejections following compensation measures.

The RPD does not provide details regarding which compensation measures were chosen (aptitude test or adaptation period) nor the characteristics of these compensation measures. Therefore, this data was not collected.

5.1.3 Geographical patterns of rejected recognitions

Although an average of 510 recognitions per year are achieved across the EU, only 18 negative replies per year were observed for the same period. This means that, for all EU countries, the overall rejection rate is 3%.

The same 22 countries and data collection periods were studied. However, only six of these countries recorded negative replies. Table 5.3 describes the average number of negative replies per year. The countries that had no negative replies were removed from the table for simplicity. Figure 5.2 represents the routes where the average number of rejections are higher.

Table 5.3 – Average number of negative replies for applications

From -> to	BE	DK	EL	IE	IT	NL	SE	TOTAL
Belgium (BE)							0.3	0.3
Bulgaria (BG)	0.3							0.3
Czech Republic (CZ)					0.7			0.7
France (FR)					0.3			0.3
Germany (DE)			0.5			0.3	0.3	1.2
Greece (EL)						0.3		0.3
Hungary (HU	0.3							0.3
Italy (IT)	0.3						0.3	0.7
Netherlands, The (NL)	0.7						0.3	1.0
Poland (PL)	0.7						0.3	1.0
Portugal (PT)	9.0						0.3	9.3
Romania (RO)	0.3			0.5	0.3			1.2
Spain (ES)	0.3	0.5			0.3	0.3		1.5
TOTAL	12.0	0.5	0.5	0.5	1.7	1.0	2.0	18.2

>0.7	>0.6	>0.5

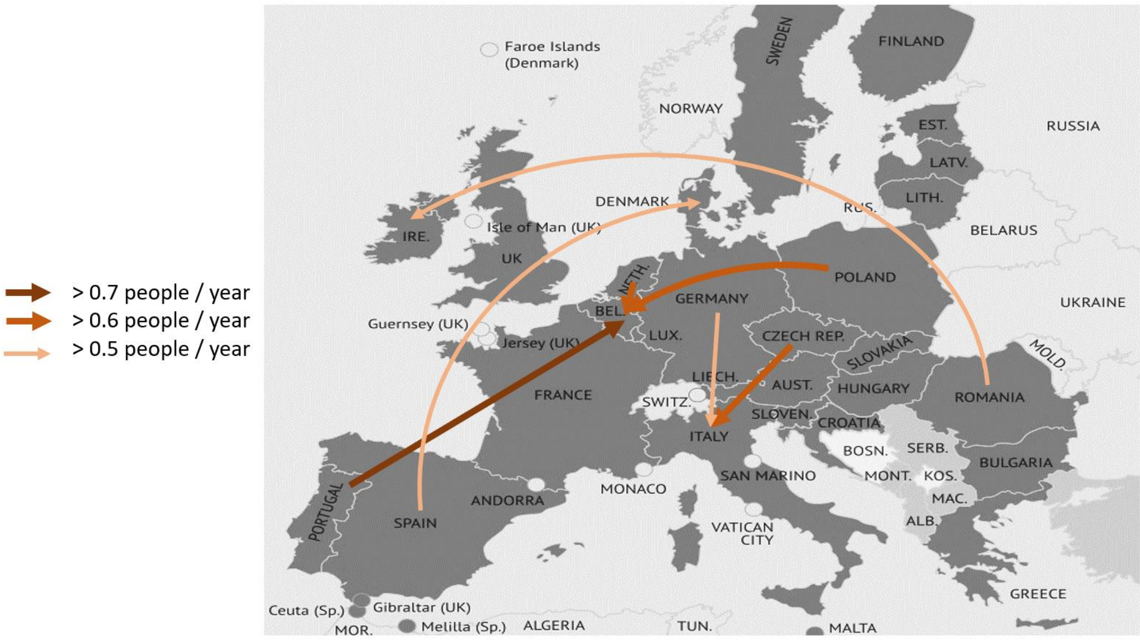


Figure 5.2 – Routes with the highest average number of negative replies to applications for recognition of qualifications. Values represent yearly average. Map adapted from Centanni (2016)

In absolute numbers, the host countries that replied negatively most often were Belgium (average of 12 negative replies per year), Sweden (2) and Italy (1.7). The host countries which recognise foreign qualifications the most (Table 5.2) reject very few applicants: UK (average of 0 rejections per year), Ireland (0.5) and Germany (0).

In percentages, the host country which rejects applications most often was Greece. Fifty per cent (50%) of the applications received by Greece obtained a negative reply. Other host countries with high rates of negative replies were Italy (29%), the Netherlands (25%) and Belgium (23%). The remaining host countries have rejection rates below 11%.

The countries whose applicants received a higher average number of negative replies were Portugal (9.3 rejected applications per year) and Spain (1.5 rejected applications per year). However, in percentages, the countries with the highest rate of applicants receiving a negative reply were Romania (14%), Germany (13%), Czech Republic (11%) and Bulgaria (10%). The remaining countries have rates below 9%.

5.2 DISCUSSION

Radiographers move between all EU member states, showing that the professional mobility of these professionals affects all countries. When combining this with the differences regarding minimum requirements to practise radiography (Chapter 4) and differences in education across Europe (ISRRT, 2012; McNulty et al., 2016), the need to study this phenomenon further becomes clear.

Although movement occurs across the EU, two patterns of movement are more prominent (Figure 5.1). The first pattern is from the south-outer to north-central Europe. This may be explained by radiographers moving to countries with higher Gross Domestic Product (GDP) per capita and higher wages (Eurostat, 2019a, 2019b), which is a known factor for the choice of country of destination (Chiswick and Miller, 2015).

This movement pattern from low-income to wealthier countries confirms that radiographers follow the same patterns as other healthcare professionals. Therefore, workforce planning for radiographers should have a pan-European vision and acknowledge the inequality of the free movement of professionals between member states raised by other authors (Glinos, 2015; Kovács et al., 2017).

The other pattern observed is the migration between neighbouring countries. The smaller the “linguistic distance”, the higher the likelihood of choosing that country as a destination (Chiswick and Miller, 2015), explaining why one of the most common exchanges is between the UK and Ireland. The same authors (Chiswick and Miller, 2015) also suggest that higher-earning may motivate professionals to move to a country with a “distant language”, supporting the south-outer to central-northern Europe pattern.

Compensation measures (exam or adaptation period) may be applied to applicants if concerns regarding their professional qualifications may put the population health or safety at risk (European Parliament and European Council, 2005). Although the average rating of application of compensation measures is 11% of the total recognitions, some host countries apply compensation measures to a high proportion of applicants. The most relevant was France, with 94% of the applicants being applied compensation measures. One of the reasons for this phenomenon may be that French radiographers also perform electrophysiology exams (such as electrocardiograms, electroencephalograms), which is not part of the training of most radiographers across the EU, as seen in Chapter 4 and the literature (McNulty et al., 2016).

The country from where the most substantial proportion of applicants had to undergo compensation measures were Estonia (86% of the recognitions) and Belgium (61%).

Compensation measures are applied when there are differences between the applicants' professional qualifications and the requirements in the destination country. As examples of this discrepancy, in both Estonia and Belgium, the undergraduate programmes are mostly dedicated to medical imaging with little dedicated to radiotherapy: as low as 7 out 210 ECTS in Estonian's single undergraduate programme (Tartu Health Care College, 2019), and 6 out 180 ECTS for some Belgian programmes (Haute Ecole Leonard de Vinci, 2021). Therefore, applicants from courses with a high workload in radiotherapy and less medical imaging may need to undergo compensation measures. In some countries, radiotherapy can have the same amount of ECTS as diagnostic radiography (University of Malta, 2013) or the whole undergraduate course is dedicated to radiotherapy (Health and Care Professions Council (HCPC) (UK), 2013; Radiographers Registration Board (Ireland), 2015).

Greece was the host country conferring the highest rate of rejections (50% of all applications). However, it is crucial to notice that all negative replies were given to applicants from Germany, whose radiographers have the lowest academic level in the EU: EQF4. As the academic level is one of the requisites to apply for the General System of recognition (European Parliament and European Council, 2005), this may explain the high proportion of automatic negative replies by Greece.

On the other hand, the country whose applicants received the highest rate of negative replies was Romania (14%). Romania is the only EU country that does not regulate the profession. Since the regulation of the profession in both the home and host countries is a criterion to apply for the General System of recognition of qualifications (European Parliament and European Council, 2005), this explains the results obtained.

An additional reason for the automatic rejection of recognition is destination language proficiency. This was introduced in 2013 and may explain why some radiographers from the same country are accepted while others are not.

5.2.1 LIMITATIONS OF THE STUDY

The lack of data from six of the 28 EU countries and lack of data for the 2015-2017 period for some of the remaining countries may introduce inaccuracies in the conclusions. However, 57% of the EU countries had provided data between 2015-2017, while data from 79% of the EU countries was analysed even though it may refer to data before 2015 (Table 5.1). This provides confidence that the results represent a reasonably accurate picture of the EU movement of radiographers.

The "routes" show the pattern from where they graduated to where they achieved recognition of qualifications, not necessarily professional mobility. For example, a Belgian national may study in France and seek recognition back in Belgium; therefore, qualification recognition was actually obtained to return to the country of origin. Additionally, it is possible that radiographers achieve recognition of qualifications abroad but never, actually, move. However, the recognition of qualifications is essential for the movement between countries. As such, it is expected that most recognitions of qualifications reflect the actual movement of the professional.

5.3 CONCLUSION

There is considerable mobility of radiographers across the EU (average of 510 radiographers per year). However, this movement is not homogeneous. Some routes have a considerably higher average number of moving radiographers: from south-outer to north-central European countries and between neighbouring member states. These patterns may be due to economic reasons and language proximity, respectively.

Some countries do not achieve the recognition of qualifications automatically and require compensation measures. One possible explanation is that applicants comply with the criteria to achieve automatic recognition of qualifications (2005/36/EC Title III Chapter I) but have significant differences in their professional qualifications.

On the other hand, the routes where the outcome of the application is mostly negative happen when radiographers apply from countries with low academic levels or from a country where the profession is not regulated. Therefore, not complying with the criteria to apply for the General System of recognition of qualifications (2005/36/EC Title III Chapter I).

Harmonisation of the education of the radiographers across Europe, in terms of academic level and curriculum (essential/core competencies), would promote the automatic recognition of qualifications. As a result, this would facilitate the movement of professionals between member states. However, national tradition may hinder this standardisation since professions are well established, and a reform of education may require changes to the profession.

The directive 2005/36/EC established mechanisms to prevent unsafe movement. However, some results may raise questions with regards to the effectiveness of these mechanisms. For example, 100% of the applicants who underwent compensation measures got their qualifications recognised; or that applicants from countries where the profession is not regulated achieve recognition through the General System.

Given the differences in education across Europe, understanding how these professionals are trained and the competencies required at the destination countries are essential to understand if patient safety is guaranteed when movement occurs. Further studies on the differences in competencies between member states and the effect of differences in education on the movement of these professionals and patient safety are recommended.

5.4 BRIDGING SECTION

This study showed that there are, in fact, certain countries that have a higher rejection rate when applying for recognition of qualifications. Some possible explanations were drawn when accessing these countries' education characteristics: lack of regulation of the profession, lower academic levels and differences in the specialisms included in the profession. However, it was of utmost importance to further explore the impact of these educational differences in professional mobility across the EU as part of the interviews with stakeholders (Chapter 8).

In addition, a substantial movement of professionals was observed between EU countries. Even though these migrant radiographers must undergo a verification of their qualifications before the movement, some countries do not regulate the minimum competencies to achieve registration (Chapter 4). Therefore, there is potential for radiographers to register even though they do not have the same competencies as the destination country's radiographers. The competency differences were evaluated through the survey of EU educational institutions and interviews with stakeholders

(Chapter 7 and Chapter 8). The impact of the competency differences on patient safety was explored in the interviews with stakeholders (Chapter 8).

The current and the previous chapters addressed radiography in general since in many countries the different specialisms fall under a single profession, making it impossible to identify the regulation and recognition of qualifications of TRs separately from other specialisms. However, from this point onwards, the study focuses on TRs specifically since it was possible to collect data on competencies and education of these professionals independently from the other specialisms.

CHAPTER 6. RESULTS OF THE SYSTEMATIC SEARCH AND ANALYSIS OF THE LITERATURE TO IDENTIFY THE COMPETENCIES OF THERAPEUTIC RADIOGRAPHERS WORKING IN THE LINEAR ACCELERATOR

This chapter includes the results from the analysis of published literature discussing competencies of TRs working in the linear accelerator. A systematic approach was taken to search white and grey literature, followed by thematic analysis to group the competencies into themes. A detailed description of the methodology can be found in section 3.2.1.3, "Competencies of TRs working on the linac". The list of competencies was used as the backbone for the survey design (Phase 2).

This chapter aims to answer the third research question: "Which are the competencies of TRs working on the linac identified in white and grey literature?"

6.1 RESULTS

6.1.1 RESULTS OF THE LITERATURE SEARCH

The query was run on the databases and journals described in section 3.2.1.3, "Competencies of TRs working on the linac" and a total of 114 sources were identified. After removal of duplicates, a total of 110 sources remained. Following assessment of these papers, a total of 22 sources were considered relevant to answer the research question. Snowballing was performed which added other scientific publications, benchmarking documents, guidelines and recommendations, reaching a total of 28 sources (Figure 6.1).

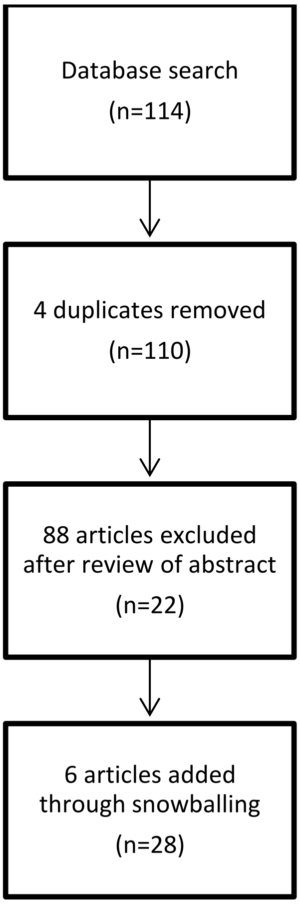


Figure 6.1 – Literature selection process

6.1.2 Thematic analysis

From these sources, a total of 363 competencies were identified in the literature. These were analysed by the researcher and coded using NVivo (v 11.0). A total of 72 sub-themes were identified and then in order to easily understand them, these were grouped under 16 themes. Using the mentioned themes as a guideline, the competencies were listed and the repeats were removed resulting in a total of 170 competencies (Table 6.1). The competencies for each theme are discussed in more detail below.

Table 6.1– List of competencies of the TR practising in the linear accelerator in the European setting, according to published literature.

Dimensions (themes)	Competency	Sources
QUALITY AND RISK MANAGEMENT		
Risk Management	– Perform risk and hazard analysis in the workplace – Reduce risks and hazards for patients and staff – Ensure appropriate workload for safe practice – Report incidents and near-misses	(Adams et al., 2010; Directorate-General for Energy, 2014; EFRS, 2018; ESTRO, 2014; Gillan, 2011; Gillan et al., 2015; Mazur et al., 2012; Simons PA et al., 2010; Smoke and Ho, 2015; Williamson et al., 2008)
Quality Improvement	– Contribute to the continuous improvement of practice – Analyse errors and near-misses and ensure prevention of future events – Develop technology and its application into practice	(Adams et al., 2010; EFRS, 2018; Gillan et al., 2015; HENRE, 2008b; IAEA, 2014; Patel and Mitera, 2011; Probst and Griffiths, 2009; Routsis et al., 2010; Smoke and Ho, 2015)
Radiation Protection	– Recognise the radiation hazards in the workplace – Ensure protection of staff and public against radiation – Ensure protection of patients against radiation – Adhere to the use of personal dosimeters – Know and adhere to legislation regarding radiation protection	(Directorate-General for Energy, 2014; EFRS, 2018; ESTRO, 2014; HENRE, 2008b; IAEA, 2014)
Justification	– Be able to select a suitable treatment, based on own analysis – Critically question radiological referrals – Refuse to carry out an exposure which, in one's professional opinion, is inadvisable	(Directorate-General for Energy, 2014; EFRS, 2018; ESTRO, 2014; HENRE, 2008b)
Optimisation	– Maintain ALARA principle – Minimise dose to normal tissues	(Directorate-General for Energy, 2014; EFRS, 2018; HENRE, 2008b)
Carry out audits	– Develop and implement audit programmes	(Clark et al., 2015; EFRS, 2018)
Evidence-Based Practice	– Apply relevant scientific evidence into practice – Take decisions based on scientific evidence – Apply results of research into practice	(Directorate-General for Energy, 2014; EFRS, 2018; ESTRO, 2014; Gillan et al., 2015; HENRE, 2008b; IAEA, 2014; Smoke and Ho, 2015)
Individual Professional Development	– Continuously assess their own competencies, knowledge and skills – Ensure their own professional development	(EFRS, 2018; Gillan, 2011; Gillan et al., 2015; HENRE, 2008b; Patel and Mitera, 2011; Probst and Griffiths, 2009; Smoke and Ho, 2015)
Development of the profession	– Contribute to the profiling of the profession – Contribute to the content-related development of the profession	(EFRS, 2018)

Protocols, Standards, Guidelines and Regulations	– Implement professional standards into professional practice – Adhere to legal regulations – Follow national and international guidelines – Implement institutional protocols into practice	(Directorate-General for Energy, 2014; EFRS, 2018; ESTRO, 2014; HENRE, 2008b; Simons PA et al., 2010; Smoke and Ho, 2015)
Application of Knowledge	– Be able to apply necessary knowledge into critical analysis and decision making	(EFRS, 2018; Gillan et al., 2015; HENRE, 2008b; IAEA, 2014)
DECISION MAKING AND CRITICAL ANALYSIS		
Critical Analysis	– Critically analyse results from any procedure – Critically analyse results from research and literature – Continuously question practice	(Adams et al., 2010; Directorate-General for Energy, 2014; ESTRO, 2014; Gillan et al., 2015; IAEA, 2014; Reynolds et al., 2009; Routsis et al., 2010)
Decision Making	– Make decisions within the remits of own competencies – Be aware of the process of decision making – Take decisions to improve patient outcome – Be able to apply corrective actions	(EFRS, 2018; ESTRO, 2014; HENRE, 2008b; IAEA, 2014; Li et al., 2010; Nisbet and Matthews, 2011; Probst and Griffiths, 2009; Reynolds et al., 2009)
MANAGEMENT AND LEADERSHIP		
Management	– Plan the workload of the treatment unit for safe practice – Set priorities – Manage the use of resources – Assess educational needs – Identify factors of burnout – Promote transparency – Participate in project management	(EFRS, 2018; ESTRO, 2014; HENRE, 2008b; Li et al., 2010; Mazur et al., 2012; Patel and Mitera, 2011; Probst and Griffiths, 2009)
Leadership	– Contribute to team development – Contribute to conflict resolution – Promote expertise of colleagues – Promote openness to discussion – Give feedback to colleagues – Lead new initiatives and projects	(EFRS, 2018; Gillan et al., 2015; Probst and Griffiths, 2009; Smoke and Ho, 2015)
Efficiency	– Practise efficiently – Ensure organisation of the treatment unit is optimum – Ensure an interruption-free environment	(Directorate-General for Energy, 2014; EFRS, 2018; ESTRO, 2014; HENRE, 2008b; Mazur et al., 2012; Probst and Griffiths, 2009)
PATIENT CARE		
Patient Dignity	– Adopt a holistic approach to the patient – Maintain a respectful approach – Take patient's perspective into account during practice and decision making – Show intercultural awareness – Respect patient's privacy – Demonstrate care towards the patient – Act as an advocate for the patient – Empower the patient to be involved in their treatment	(Bibault et al., 2016; Collier, 2013; Directorate-General for Energy, 2014; EFRS, 2018; ESTRO, 2014; HENRE, 2008b; IAEA, 2014; Miller, 2009; Patel and Mitera, 2011)
Patient Identification	– Perform appropriate patient identification	(Directorate-General for Energy, 2014)

Patient assessment	– Identify patient requirements and concerns – Assess patient physically – Assess patient psychologically – Assess treatment side effects – Assess social aspects of patient interaction – Develop patient assessment protocols	(Directorate-General for Energy, 2014; EFRS, 2018; ESTRO, 2014; HENRE, 2008b; IAEA, 2014; Miller, 2009; Patel and Mitera, 2011; Probst and Griffiths, 2009; Routsis et al., 2010)
Management of Side-Effects	– Give advice with regard to management of side effects – Refer to other professionals when advisable	(Directorate-General for Energy, 2014; EFRS, 2018; ESTRO, 2014; Miller, 2009; Probst and Griffiths, 2009)
Patient Information	– Give information prior to treatment – Give information during treatment – Adapt the information for individual patient needs – Explain the radiotherapy process to the patient – Develop patient information material	(Bibault et al., 2016; EFRS, 2018; ESTRO, 2014; HENRE, 2008b; IAEA, 2014; Miller, 2009; Smoke and Ho, 2015)
Consent	– Seek consent prior to any procedure	(Directorate-General for Energy, 2014; HENRE, 2008b)
Follow up	– Give information after the last treatment – Perform patient review after the last treatment	(Collier, 2013; EFRS, 2018; ESTRO, 2014; Miller, 2009; Patel and Mitera, 2011)
First Aid	– Provide first aid to patients, if necessary	(HENRE, 2008b)
Infection Control	– Perform appropriate infection control prior, during and after each procedure	(HENRE, 2008b)
TEAM WORK AND MULTI-DISCIPLINARITY		
Team Work	– Promote collaboration – Promote expertise of other colleagues	(Directorate-General for Energy, 2014; EFRS, 2018; HENRE, 2008b; Mazur et al., 2012; Patel and Mitera, 2011; Probst and Griffiths, 2009)
Multi-disciplinarity	– Be involved in a multi-disciplinary approach to the patient – Work with other professionals to improve practice – Recognise limits of the therapeutic radiographers' roles – Seek other professionals' expertise when required	(EFRS, 2018; ESTRO, 2014; HENRE, 2008b; IAEA, 2014; White and Kane, 2007)
Peer review	– Implement and participate in the peer-review processes – Analyse the results of peer-reviewing	(Adams et al., 2010; EFRS, 2018)
COMMUNICATION		
Communication with other TRs	– Provide the necessary information to colleagues – Establish appropriate verbal and non-verbal communication with other TRs – Advise other members of the team	(ESTRO, 2014; HENRE, 2008b; IAEA, 2014)
Communication with multi-disciplinary team	– Provide other professionals with necessary information – Establish appropriate verbal and non-verbal communication with other professionals – Advise other professionals	(EFRS, 2018; ESTRO, 2014; HENRE, 2008b; IAEA, 2014)
EDUCATION		

Education of other members of staff	– Teach and supervise staff to develop their expertise – Transmit new knowledge to other staff members – Participate in the education of other professionals	(Directorate-General for Energy, 2014; EFRS, 2018; ESTRO, 2014; HENRE, 2008b; IAEA, 2014; Smoke and Ho, 2015)
Education of students	– Teach and supervise students – Transmit knowledge to students – Be responsible for the student's acquisition of clinical skills	(EFRS, 2018; ESTRO, 2014; HENRE, 2008b; IAEA, 2014)
PHARMACOLOGY		
Administration of pharmaceuticals	– Administer pharmaceuticals to patient – Critically assess the pharmaceuticals prescribed – Take responsibility for pharmaceuticals-related tasks	(EFRS, 2018; HENRE, 2008b)
Response to complications	– Respond to complications of the administration of pharmaceuticals – Seek advice from other professionals when necessary	(EFRS, 2018)
PROFESSIONAL AND ETHICAL PRACTICE		
Autonomy	– Practise autonomously – Perform decision making autonomously	(Directorate-General for Energy, 2014; EFRS, 2018; HENRE, 2008b; Patel and Mitera, 2011)
Responsibility	– Take responsibility for the tasks performed	(EFRS, 2018; HENRE, 2008b)
Limitations	– Develop self-awareness – Recognise limitations of their scope of practice – Seek advice when necessary	(Directorate-General for Energy, 2014; EFRS, 2018; Gillan, 2011; IAEA, 2014; White and Kane, 2007)
Accuracy	– Practise with high levels of accuracy – Accurately prepare and administer radiotherapy treatments – Accurately complete documentation and reports	(Directorate-General for Energy, 2014; EFRS, 2018; ESTRO, 2014; IAEA, 2014)
Best Practice	– Practise following the highest scientific, ethical and moral standards – Ensure all aspects of their practice are optimum	(ESTRO, 2014; IAEA, 2014)
Confidentiality	– Maintain confidentiality at all times	(EFRS, 2018; HENRE, 2008b)
Ethics	– Demonstrate ethical approach to the patient – Take decisions ethically – Deal with ethical issues in the workplace	(EFRS, 2018; HENRE, 2008b)
Good Character	– Exemplify good character within a professional context – Internalise professional standards in private life	(EFRS, 2018; IAEA, 2014)
Professional appearance and manner	– Project a professional image at all times – Ensure a professional manner and appearance	(IAEA, 2014)
Self-reflection	– Practise self-reflection on a regular basis	(Nisbet and Matthews, 2011)
RESEARCH		
Carry out research	– Initiate and develop research ideas – Carry out research independently and as part of a multi-disciplinary team	(ESTRO, 2014; HENRE, 2008b; Smoke and Ho, 2015)

Clinical Trials	– Participate in national and international clinical trials	(ESTRO, 2014; HENRE, 2008b; Smoke and Ho, 2015)
Dissemination of research results	– Present and publish results of research	(EFRS, 2018)
Implement results of research	– Implement the results of research into practice	(ESTRO, 2014)
RECORDING AND HANDLING OF DATA		
Record data	– Maintain and update records of any relevant information – Record patient's side effects – Document any information in a coherent way	(Directorate-General for Energy, 2014; ESTRO, 2014; HENRE, 2008b; IAEA, 2014)
Handle and archive data	– Administer and archive data	(EFRS, 2018)
FILE VERIFICATION		
Assess patient's file	– Revise the file prior to irradiation – Report errors	(Gillan, 2011)
Plan analysis	– Assess dose distribution in the radiotherapy plan – Evaluate the dose volume histogram – Evaluate other plan options – Assess plans for clinical acceptability	(Directorate-General for Energy, 2014; EFRS, 2018; Routsis et al., 2010)
Verify prescription	– Interpret treatment prescriptions – Verify treatment prescription and report discrepancies – Compare the plan with the prescription	(Directorate-General for Energy, 2014; ESTRO, 2014; IAEA, 2014)
Data transfer	– Carry out necessary data transfer checks	(ESTRO, 2014)
POSITIONNING AND IMMOBILISATION		
Critically assess immobilisation	– Confirm appropriate immobilisation considering aim of treatment and patient condition	(ESTRO, 2014)
Reproduce immobilisation	– Position the patient according to planning and simulation	(ESTRO, 2014)
Accuracy	– Ensure accuracy in positioning	(ESTRO, 2014; Li et al., 2010)
Patient comfort	– Promote patient comfort, as much as possible	(ESTRO, 2014)
DELIVERY OF TREATMENT		
Choice of devices	– Choose the appropriate therapeutic, imaging and ancillary devices	(EFRS, 2018; HENRE, 2008b)
Parameters check	– Check if appropriate treatment parameters were selected	(Directorate-General for Energy, 2014)
Treatment administration	– Administer treatment accurately and safely – Apply best practice at all times – Interrupt treatment, if required, in an emergency	(EFRS, 2018; ESTRO, 2014; IAEA, 2014)
Patient observation	– Constantly observe the patient during treatment	(Gillan, 2011)
Avoid treatment gaps	– Avoid radiotherapy treatment gaps	(Routsis et al., 2010)
VERIFICATION OF PATIENT SETUP		
Image acquisition	– Select the appropriate image modality – Acquire planar (2D) images – Acquire volumetric (3D) images	(EFRS, 2018; ESTRO, 2014; HENRE, 2008b)

Image interpretation	– Analyse verification images: o Analyse planar (2D) verification images* o Analyse volumetric (3D) verification images* – Make decisions regarding the action to take following image analysis, within the protocols – Follow patient setup verification protocols – Develop patient setup verification protocols – Analyse images to evaluate the result of radiotherapy treatments	(EFRS, 2018; ESTRO, 2014; Gillan et al., 2015; HENRE, 2008b; IAEA, 2014; Li et al., 2010; Reynolds et al., 2009; Routsis et al., 2010; White and Kane, 2007)
* The sub-theme "Image interpretation" was further divided to include two sub-themes: Analysis of 2D and 3D images.		
EQUIPMENT QUALITY ASSURANCE		
Perform QA	– Perform daily QA of the linear accelerator – Perform QA of imaging systems – Carry out in vivo dosimetry	(Directorate-General for Energy, 2014; ESTRO, 2014; HENRE, 2008b; Smoke and Ho, 2015; Williamson et al., 2008)
Evaluate and report results of QA	– Evaluate results of QA procedures – Take corrective actions in view of QA results – Report inconsistencies in QA procedures	(Directorate-General for Energy, 2014; ESTRO, 2014; Williamson et al., 2008)

6.2 DISCUSSION

The themes described above vary with regard to how technical and how specific the competencies are to the linac-TR (Table 6.2). Technical competencies are those required to perform a specific job (or group of jobs) and are in alignment with the autonomous and responsible application of knowledge and skills in specialised fields such as radiography (HRSG, 2017). These are complemented by non-technical competencies (”soft skills”) which can be applied to several professions (HRSG, 2017).

Table 6.2 – Classification of the competencies with regard to technicality and specificity

Non-technical competencies	Technical competencies (not specific of the linac-TR)	Technical competencies (specific of the linac-TR)
- Quality and risk management - Decision making and critical analysis - Management and leadership - Team work and multi-disciplinarity - Communication	- Professionalism - Patient Care - Pharmacology - Research - Education - Equipment quality assurance	- File verification - Positioning and immobilisation - Delivery of treatment - Verification of patient setup

This demonstrates the complexity of the tasks performed by the linac-TR which include technical competencies that are specific for the profession but also non-radiography specific competencies such as research or team-work. Therefore, despite the fact that this study focused on the linac-TR competencies, it is clear that the training of these professionals must include all roles of these professionals (such as imaging and planning).

With regard to the literature sources, we can clearly distinguish between three types of literature: the grey literature with recommendations regarding the competencies that should be developed by TRs, white literature that aims to study competencies and white literature that aims to study other matters but part of their discussion or conclusions includes the identification of competencies. All were relevant for this study.

The well-established competencies were mostly found in the benchmarking documents (Challen, 2008; Coffey et al., 2011; Directorate-General for Energy, 2014; EFRS, 2018; ESTRO, 2014; IAEA, 2014; ISRRT, 2014). These documents list the competencies without discussion. The data collection methods used in the benchmarking documents include surveys and experts.

White literature (Adams et al., 2010; Clark et al., 2015; Li et al., 2010; Patel and Mitera, 2011; Routsis et al., 2010; Simons PA et al., 2010; White and Kane, 2007; Williamson et al., 2008) mostly discussed the less well-established competencies (e.g. participating in audits). Although new technology may have influenced these new competencies, these less well-established competencies are not directly related to new modalities or techniques.

Additionally, white literature (Bibault et al., 2016; Collier, 2013; Gillan, 2011; Gillan et al., 2015; Mazur et al., 2012; Miller, 2009; Nisbet and Matthews, 2011; Probst and Griffiths, 2009; Reynolds et al., 2009; Smoke and Ho, 2015; White and Kane, 2007) often discussed competencies in greater detail instead of just listing them, frequently decomposing generic competencies (e.g. “reduce risks and hazards for patients and staff”) into its sub-competencies (e.g. “perform risk and hazard analysis in the workplace”, “analyse errors and near-misses and ensure prevention of future events”, among others). This phenomenon of decomposing competencies into its sub-dimensions was discussed by Adams et al. (2010) and Gillan et al. (2015).

The literature does not provide information regarding which competencies are developed in the individual European countries. Therefore, these competencies should be taken as a European standard. The implementation of these competences at national level would promote a homogeneous practice across Europe. Nevertheless, these competencies may apply differently at the national level.

Furthermore, the literature does not discuss which modalities or techniques the linac-TRs should be competent on. Although some literature (Li et al., 2010; Routsis et al., 2010; White and Kane, 2007; Williamson et al., 2008) directly relates the need for further development of competencies with the rising of new technologies, these focus on the development of competencies that ensure that the treatments are administered adequately, rather than specifying which modalities should the professionals be trained on.

The different dimensions of the competencies developed by the linac-TRs are discussed in more detail below.

6.2.1 Quality and Risk assessment

Quality and risk assessment was the most coded theme. The frequency of this theme may be correlated to the importance of these competencies for these professionals in view of the risks of using ionising radiation. As part of this theme, there was also emphasis on continuous improvement in quality as a result of personal development and the application of research, guidelines and protocols into practice to protect all groups of people. This can be observed in literature, for example:

> *"Develop individual responsibility for the use of appropriate methods to reduce all risks and hazards which may affect self, patients, staff and the general public." (EFRS, 2018, p. 7).*

Competencies concerning specific aspects of the TR practice were also found. For example, to "avoid unnecessary exposure and minimise necessary exposure as part of optimisation" (Directorate-General for Energy, 2014, p. 66).

6.2.2 Decision making and critical analysis

The competencies that fall under this theme ensure that the linac-TR must be autonomous and responsible for assessing each situation, using critical analysis and as a result apply decisions that allow improvement in the patient's outcome and overall safety. TRs should perform their roles "questioning practice, evaluating ideas [and] critically analysing the evidence" (Gillan et al., 2015, pp. 430–431); "Use professional decision making, independently or as a team member when carrying out radiation therapy" (HENRE, 2008b, p. 9).

6.2.3 MANAGEMENT AND LEADERSHIP

Linac-TRs must "take on administration and leadership roles through supervisory responsibilities, process development, leading new initiatives, driving improvement [and] project management (...)" (Smoke and Ho, 2015, p. 390) as well as proper use of resources in an efficient matter (Probst and Griffiths, 2009). This includes the management of the workload to ensure safe practice (Mazur et al., 2012).

6.2.4 PATIENT CARE

The competencies around patient care were found to have multiple dimensions. Starting by ensuring adequate patient identification and finishing with following-up after the completion of the radiotherapy treatment. The patient care has a holistic scope and should include the patient's family. The linac-TR must "facilitate the smooth entry into treatment for patients and family members experiencing radiotherapy for the first time" (Miller, 2009, p. 21), while "taking the patient's physical and psychological aspects into consideration" (ESTRO, 2014, p. 35).

Competencies related to communication with patients were extensively discussed in the literature. These were sub-divided into several dimensions: patient information, empowerment, identification, assessment, consent and follow-up. Therefore, the linac-

TR must “inform, encourage, advise and support each patient before, during and post examination/treatment” (EFRS, 2018, p. 8).

6.2.5 Teamwork and multi-disciplinarity

This theme emerged as a result of the multiple literature sources identifying the responsibility of “cooperation among team members” (Mazur et al., 2012, p. 575). This includes promoting each professional group and individual’s area of expertise (Probst and Griffiths, 2009), “recognise the limitations to one’s own scope of competency and seek advice and guidance accordingly” (Directorate-General for Energy, 2014, p. 66) in order to offer the patient the best possible care. The assessment of each other’s practice is also important to assure a better service to the patient:

> *“The specific inclusion of peer review as a component of the scope of practice for radiation therapists (...) is an emerging trend in radiation therapy clinical practice”(Adams et al., 2010, pp. 321–322).*

6.2.6 Communication

Communication with patients was coded under “Patient Care”, therefore, this theme focused on communication with colleagues (TRs and other professions): It was found in the literature that TR must “interpret, apply and disseminate the appropriate information for each stage of the process to the relevant personnel” (IAEA, 2014, p. 15) to “ensure an appropriate chain of care” (EFRS, 2018, p. 9)

6.2.7 Education

Despite the responsibility of educate other staff and patient being identified in most guidelines/benchmarking documents (Directorate-General for Energy, 2014; EFRS, 2018; ESTRO, 2014; HENRE, 2008b; IAEA, 2014), Smoke and Ho (2015) argued that it is an, “often overlooked role [of the TR]. This includes undergraduate, graduate, and postgraduate students within the radiation oncology programme. Education and orientation of other staff within the hospital may also be done by [TRs]” (Smoke and Ho, 2015, p. 390).

6.2.8 Pharmacology

This was one of the least frequent codes across the thematic analysis, with only two sources referring to it. However, this may be considered a well-established competence of TRs at the time of graduation since it is listed in two different benchmarking documents (EFRS, 2018; HENRE, 2008b). The TR should be competent to “assess and administer essential medication used in the professional context” (HENRE, 2008b, p. 9) and “respond appropriately to contra-indications, complications and emergencies” (EFRS, 2018, p. 9). TRs must be knowledgeable of “side effects of radiotherapy treatments and their management” (EFRS, 2018, p. 16) to advise pharmacological treatments for these side effects.

6.2.9 Professionalism

This theme was related to competencies that can be considered generic to all professions and therefore was divided into multiple sub-themes such as ethical practice, autonomy, responsibility, accuracy, confidentiality, limitations and best practice (please see Table 6.1 for the complete list of sub-themes). Some example competencies cited in the literature can be found below:

“Take individual responsibility for carrying out work in a safe manner” (EFRS, 2018, p. 6)

“Accept responsibility for one’s own actions within the scope of professional practice” (HENRE, 2008b, p. 30)

“Accurately prepare and deliver a course of treatment” (IAEA, 2014, p. 7)

“Carry out treatment preparation and delivery based on best practice at all times” (ESTRO, 2014, p. 19)

“Address identified gaps in the knowledge, skills, and judgment within [TRs] scope of practice” (Gillan et al., 2015, p. 104)

6.2.10 Research

According to the literature found, “research and development [is] an essential component for a new staffing model [for TRs]” (Smoke and Ho, 2015, p. 390) and the TRs should be autonomous and undertake responsibility for audits and research (including trials) (Clark et al., 2015; EFRS, 2018; ESTRO, 2014; HENRE, 2008b; Smoke and Ho, 2015). In addition, it is part of their competencies to “disseminate results of clinical audit and research” (EFRS, 2018, p. 12) and “participate in the implementation of the research findings” (ESTRO, 2014, p. 43).

6.2.11 Recording and handling data

Recording and handling data competencies were identified in five different EQF6 benchmarking documents (Directorate-General Environment, 2000; EFRS, 2018; ESTRO, 2014; HENRE, 2008b; IAEA, 2014) showing that these are well established competencies of TRs. Specifically, the linac-TR must be autonomous and responsible for “accurately and comprehensively completing all documentation” (ESTRO, 2014, p. 38) and for the appropriate “archiving of [...] treatment data” (EFRS, 2018, p. 7) and “of data related to the patient” (EFRS, 2018, p. 8).

Despite being considered part of the TR’s usual practice, these competencies are essential to ensure good communication between staff members and good patient care. As mentioned in the ESTRO benchmarking document, TRs must be competent to “complete accurate and detailed documentation consistent with accurate and safe treatment delivery” (ESTRO, 2014, p. 20), showing the relationship between recording of data and patient safety.

Although extensively mentioned in benchmarking documents, none of the white papers discussed these competencies. This is expected since white literature tends to focus on new competencies and those which are not well-established, which require further research.

6.2.12 File verification

The linac-TR must be competent to “interpret the radiation prescription and treatment plan” (EFRS, 2018, p. 16). Some literature goes into more detail and identifies which aspects must be checked by the TR, such as Dose-Volume Histograms (DVH) or Monitor Units (MU) (HENRE, 2008b). The TR must perform critical analysis with the aim of carrying out a “plan evaluation for clinical acceptability” (Routsis et al., 2010, p. 677) and identifying and reporting errors (Directorate-General for Energy, 2014).

6.2.13 Positioning and immobilisation

This theme encompasses very specific competencies of the TRs practising on the linac. These professionals are responsible for "correctly position the patient consistent with implementation of the treatment prescription, (...) consistent with optimum treatment delivery" (ESTRO, 2014, pp. 23–24). This demonstrates the responsibility for reproducing the patient setup that was defined during planning but also the critical assessment, ensuring that this setup is optimum for the patient. The linac-TR must also be responsible for "taking the patient's physical and psychological aspects into consideration" (ESTRO, 2014, p. 35) and "ensuring comfort as far as possible" (ESTRO, 2014, p. 32).

6.2.14 Delivery of treatment

Another of the specific technical competencies of the linac-TR is to "accurately (...) deliver a course of treatment to an individual patient" (IAEA, 2014, p. 7) using critical analysis to ensure they "use appropriate diagnostic, therapeutic and ancillary devices (...)" (HENRE, 2008b, p. 30) and that "treatment delivery [occurs] in an accurate and safe environment" (ESTRO, 2014, p. 35).

In particular, the literature states that the linac-TR has the responsibility to be vigilant during the exposure, in virtue of the multiple parameters to be selected during a radiotherapy treatment (Gillan, 2011) and their responsibility in "avoiding gaps in radiotherapy" (Routsis et al., 2010, p. 678).

6.2.15 Verification of patient setup

The most relevant competency of the linac-TR in this theme is the acquisition of the verification images following the justification of the appropriate image modality (HENRE, 2008b).

The verification image interpretation was the only sub-theme that was further divided as a result of one article where it described the competency to “interpret and critically evaluate the verification images” (ESTRO, 2014, p. 32) for volumetric images (CBCTs) in addition to planar images (Reynolds et al., 2009) and “make adjustments as necessary and in accordance with protocol” (ESTRO, 2014, p. 32).

Despite the fact that the development of protocols in radiotherapy was discussed before (under the theme “Quality and Risk Management”), the specific competency of “develop [the] position verification process” (Reynolds et al., 2009, pp. 127–128) was mentioned in the literature.

6.2.16 Equipment quality assurance (QA)

With regard to equipment QA competencies, the TR must “apply quality assurance techniques” (HENRE, 2008b, p. 30) but also “analyse and record the results and report any deviations” (Directorate-General for Energy, 2014, p. 72). Not only concerning the treatment machine but also the accessory equipment (ESTRO, 2014) and “carry out in-vivo dosimetry” (Directorate-General for Energy, 2014, p. 72).

6.2.17 LIMITATIONS OF THE STUDY

Competencies in languages other than English were not assessed, therefore, there is the potential for having excluded competencies practised in non-English speaking countries. Despite the large range of documents found by the search query, there is a small chance that relevant literature was missed during the systematic search.

With regard to the coding process, this was performed by a single researcher due to the extensive amount of work required for this process and the lack of human resources available to perform such a task. To reduce researcher bias, the thematic analysis was followed by the verification of the competencies list by the PhD supervisors (three experienced researchers) and five external experts.

Another limitation of this methodology was that the competencies identified may not be practised by TRs across Europe: they may not be developed in all countries. In addition, some of the competencies are part of recommendations and may not be in practice yet. These competencies may, in some countries/institutions, be practised by other professions (such as radiation oncologists); however, these results showed that in some cases, they can also be performed by TRs. Regardless of the profession practising the task, patient safety can only be assured if the individual is competent to do so. In view of this, the list should be used as a recommendation for the design of educational programmes or for further development for professionals already in practice and not as a list of practised competencies across Europe.

6.3 CONCLUSION

This is the first study to comprehensively collate all of the competencies recommended to be developed by TRs practising in the linear accelerator, across Europe, from all the available literature. The most evident conclusion of this study is that there is a great number of competencies that are identified in the literature as being the responsibility of linac-TRs. This is the result of very intricate tasks that require the TR to apply their knowledge and skills in order to autonomously take responsibility for those tasks.

When the researcher started this study, the question “what are the competencies of the therapeutic radiographer working on the linac?” did not have an immediate and concrete answer. The benchmarking documents were the most relevant source of information, but they do not perfectly align with each other regarding the competencies of these professionals. They actually complement each other with their uniques points-of-view. In addition, other published scientific literature discussed competencies that were not considered in the benchmarking documents. This work offered a critical revision of the competencies scattered through grey and white literature.

Differences in the regulation of the professions led to differences in the competencies developed and practised by TRs in each country, therefore, the competencies identified in this literature review are not country-specific but aim to develop education in the pan-European setting. Since the profession is not regulated at the European level, none of the documents used in this study has a regulatory scope across Europe. As a result, this comprehensive list of competencies also does not have a regulatory scope but can provide evidence-based information to support stakeholders during decision-making (such as universities, employers, TRs, patients, regulatory bodies, and students).

A recommendation is that the competencies of the linac-TRs identified in this study (Table 6.1) should be endorsed by education institutions across Europe. This promotes the highest quality of practice for the most common role of the TR, taking into consideration the complementary perspectives of the benchmarking documents available across Europe. Nevertheless, this is not the only role of these professionals and education institutions should refer to benchmarking documents (Challen, 2008; Coffey et al., 2011; Directorate-General for Energy, 2014; EFRS, 2018; ESTRO, 2014; IAEA, 2014; ISRRT, 2014) and complementary literature when designing their education programmes.

A more homogeneous education promotes the free movement of professionals between countries since one of the requisites to achieve recognition of qualifications in the EEA is to have similar curricula (European Parliament and European Council, 2013, 2005). However, all the other criteria must also be achieved, such as a similar academic level and course duration.

Different levels of competency can be achieved as a result of education at different academic levels (McNulty et al., 2016). When academic level was discussed in the analysed literature, the recommended level is the university first cycle (EQF level 6) (Directorate-General for Energy, 2014; EFRS, 2018; ESTRO, 2014; HENRE, 2008b; IAEA, 2014) which corresponds to the following competency descriptor, according to EQF:

> *"Manage complex technical or professional activities or projects, taking responsibility for decision-making in unpredictable work or study contexts (and) take responsibility for managing professional development of individuals and groups" (European Parliament and European Council, 2008, p. 13)*

In addition, and perhaps more importantly, patients undergoing radiotherapy can only be offered the best treatment and consequently the best chances of a cure, independent of their country, if professionals undertake roles for which they are competent. Therefore, ensuring that appropriate competencies are developed by TRs before entering the job market is of utmost importance for the success of the radiotherapy treatment.

Further research is required to determine which of these competencies are developed in educational institutions across Europe and which are practised by TRs in the clinical setting. In addition, it is recommended that a compilation of the competencies from benchmarking documents and literature should be performed for all roles of the therapeutic radiographer.

6.4 BRIDGING SECTION

This literature analysis allowed to list the competencies of TRs working on the linac; decision-makers can use this list when proposing regulations and designing education programmes. However, these competencies may (or may not) be currently developed in TRs' educational programmes.

The list was used in the survey design distributed to academic staff across the EU (Chapter 7) to assess the level of graduates in the competencies identified above. This literature analysis was also helpful in structuring the questionnaire, dividing it into sections: linac-specific; non-specific; and transversal competencies.

CHAPTER 7. RESULTS OF THE SURVEY EVALUATING THE RADIOTHERAPY EDUCATION ACROSS THE EU AND THE IMPACT ON GRADUATES' COMPETENCIES WORKING ON THE LINEAR ACCELERATOR

This chapter presents the results of the survey distributed to radiotherapy lecturers and heads of departments across EU HEIs. A detailed methodology was presented in section 3.2.2, "Survey (Phase 2)". This survey aimed to answer the following research questions:

- What are the characteristics of TRs' education programmes across the EU?
- What are the competency levels of EU graduates with regards to linac tasks?
- Do education programme characteristics affect these competency levels?

The results of this survey informed the design of the case study methodology (Phase 3).

7.1 RESULTS

A total of 73 responses were obtained. Twenty-three responses were excluded because they were from non-EU countries, did not include RT in their course, or the respondents were not RT lecturers or head-of-department in the education programmes. Therefore, a total of 50 valid responses were analysed, representing 19 EU member-states. Some respondents identified different course structures inside the same country (Table 7.1). These programmes with different structures allow graduates to practise RT but have different academic levels, specialisms or programme duration. Since the UK was an EU member-state at the time of the data collection, it was included in the data analysis.

Table 7.1 – Total respondents by country

Country	Number of respondents
Austria	1
Belgium	1
Denmark	1
Estonia	1
Finland	1
France	1
Germany	3
Greece	1
Italy*	3
Latvia*	2
Lithuania*	2
Malta	2
The Netherlands*	5
Poland**	10
Portugal	6
Slovakia	1
Slovenia	2
Sweden	1
United Kingdom	7
TOTAL	50 respondents 19 countries 25 course structures

* two different course structures
** three different course structures

7.1.1 Characteristics of radiotherapy education programmes across EU countries

Based on the responding countries, a picture of the education characteristics across the EU is presented here. For countries with more than one programme structure, these were analysed independently since the respondents referred to these programmes separately, resulting in a total of 25 entries (Table 7.1).

7.1.1.1 MAIN CHARACTERISTICS: ACADEMIC LEVEL, SPECIALISMS AND PROGRAMME DURATION

The majority of programmes are Bachelor’s degrees (EQF6) (Figure 7.1), most of which are dual-qualification programmes (imaging and radiotherapy). A minority of countries identified the existence of RT-only programmes (UK and Italy). Portugal recognised that the programme changed from RT-only to dual-qualification in 2014. Italian respondents identified the presence of both dual-qualification and RT-only programmes. While in two countries, the Bachelor’s degree includes radiotherapy, imaging and electrophysiology (France and Poland).

Only two programmes were identified as having an EQF level lower than 6: Germany has a dual-qualification programme at EQF4, and Poland offers a programme in radiotherapy, imaging and electrophysiology at EQF5.

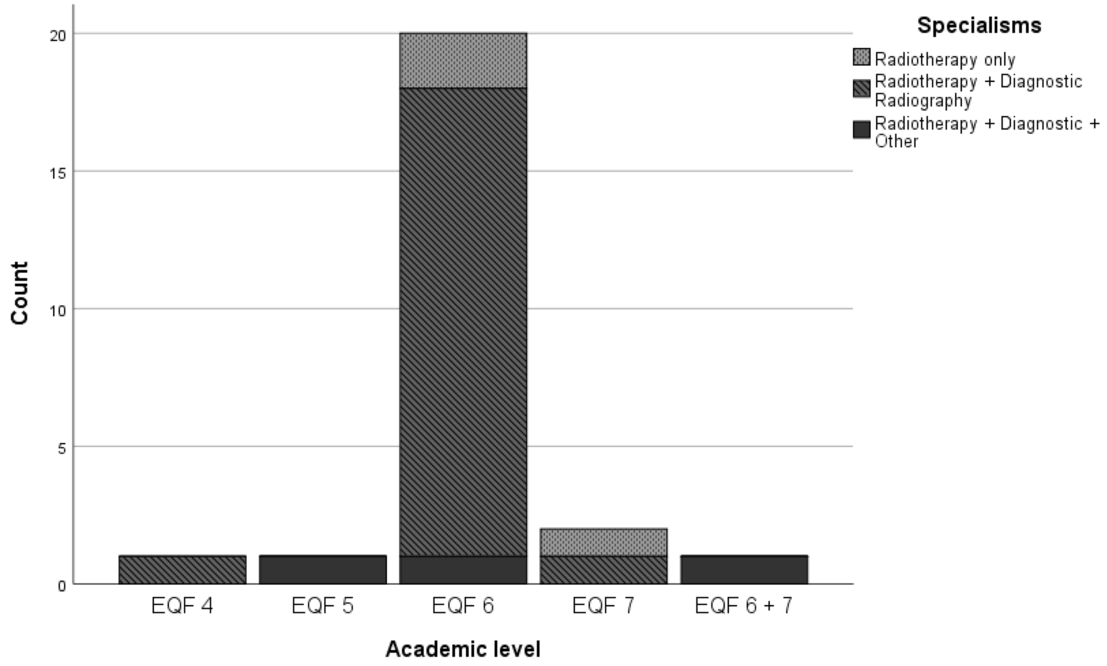


Figure 7.1 – Academic level and specialisms included in the education programmes in RT across European countries.

Regarding postgraduation programmes, one RT-only programme with the duration of a single semester was identified in Sweden. This course was identified as suitable for nurses or diagnostic radiographers. Poland has a 2-year dual-qualification MSc, which allows graduates to practise RT. However, some Polish respondents identified that a total of 5 years are required to practise, which includes a BSc followed by an MSc (represented as "EQF 6 + 7" in the graphs).

Most EQF6 courses have a 3-year duration. However, programmes with a 3.5-year or 4-year duration exist (Figure 7.2). Although the course duration seems different between academic levels, a statistical difference was not observed ($H(2) = 3.393$, $p = 0.183$). The most prolonged programme duration corresponds to the Polish model of BSc followed by MSc; the shortest term refers to the Swedish postgraduation course.

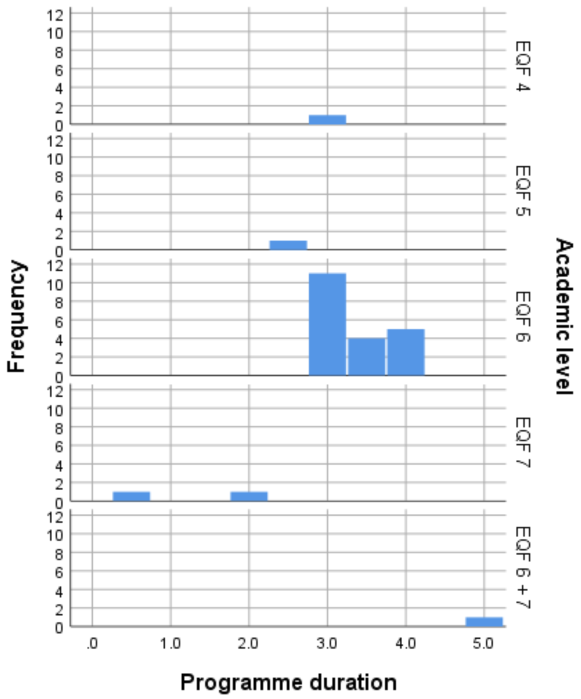


Figure 7.2 – Duration of course programmes (according to academic level)

7.1.1.2 DURATION OF CLINICAL PLACEMENT (INCLUDING ALL SPECIALISMS)

Across the responding countries, the average placement duration (including all specialisms) was 1179h (SD = 721.8). Regarding EQF6 programmes, the average is 1200h of clinical placement (SD = 757.9). RT-only programmes have a lower average clinical placement duration (845h), followed by dual-qualification programmes (1186h). Programmes that have more specialisms include longer placement duration (2100h) (Figure 7.3). Despite the difference in mean placement duration between RT-only programmes and those with other specialisms, this was not statistically significant ($H(2) = 0.442$, $p = 0.506$).

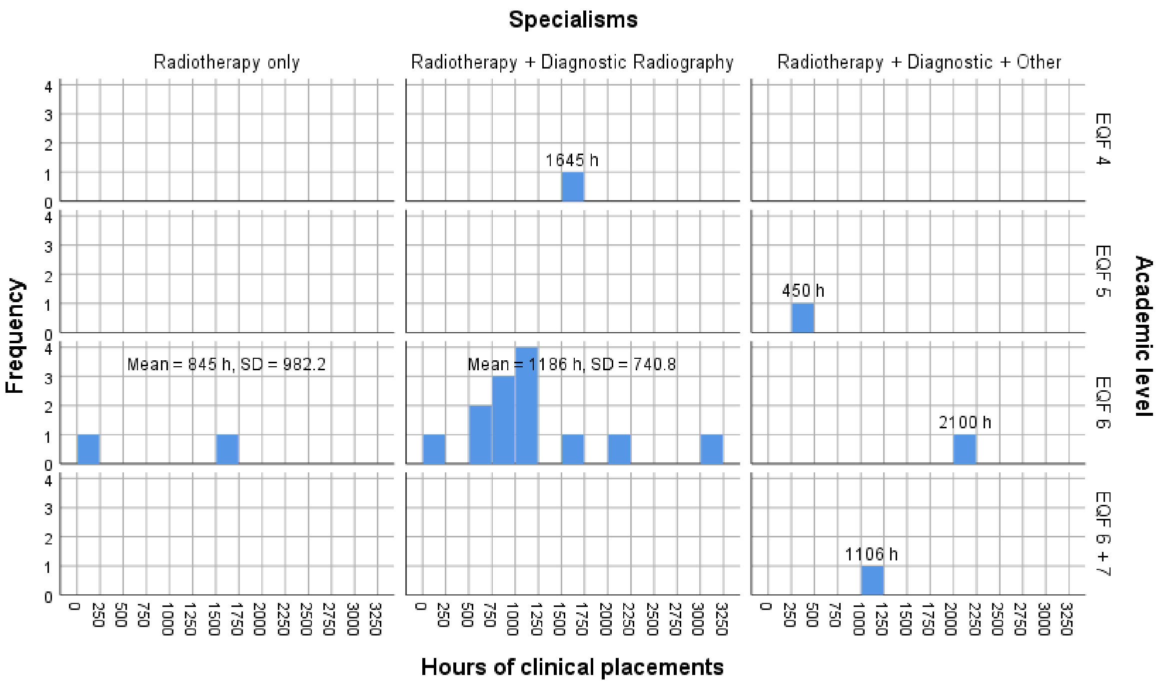


Figure 7.3 – Duration of clinical placement in all specialisms (in hours) (according to academic level and specialisms)

The EQF4 programme has a longer duration of clinical placement (1645h) than the average of the Bachelor's degrees (1200h), while the clinical placement in the EQF5 programme was the shortest of all academic levels (450h). Although the "EQF 6 + 7" programme corresponds to a total of 5 years, it has 1106h of clinical placement, which is shorter than the Bachelor's degrees. The duration of clinical placement was not statistically different between academic levels ($H(2) = 0.058$, $p = 0.972$).

7.1.1.3 PROPORTION OF THE COURSE DEDICATED TO RADIOTHERAPY

The average percentage of the programme devoted to radiotherapy subjects across the responding countries is 31%. As expected, RT-only programmes have a very high proportion of the programme dedicated to RT, with an average of 88% of the programme dedicated to this specialism (Figure 7.4). However, in courses that include other specialisms, the amount of the programme devoted to RT drops considerably (average of 25%). The average workload dedicated to RT is statistically higher in RT-only programmes when compared with programmes that include other specialisms (H(1) = 7.935, p=0.005).

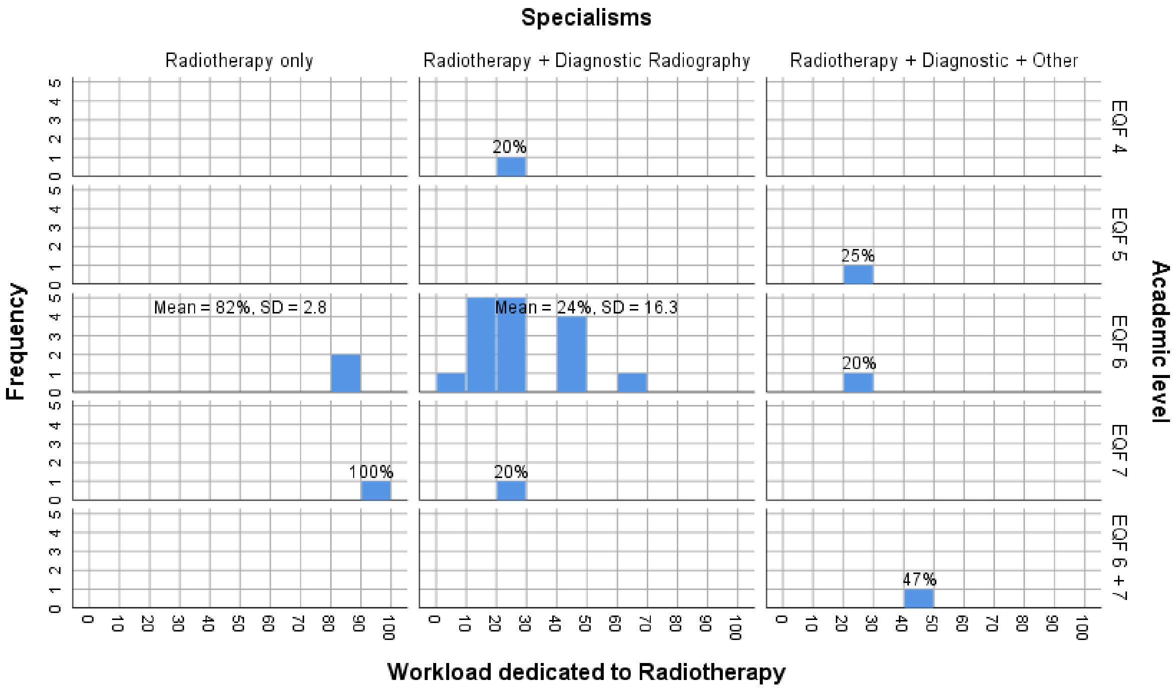


Figure 7.4 – Proportion of the programme dedicated to RT (according to academic level and specialisms)

Regarding dual-qualification courses at the EQF6 level, the average percentage of RT in the programme is only 24%. In one country, the proportion of workload was less than 10%, even though the course allows the graduate to practise RT. On the other hand, some dual-qualification courses can have up to 60% of the programme dedicated to RT. No statistical difference was found between countries with different academic levels (H(2) = 2.202, p = 0.333).

7.1.1.4 PROPORTION OF CLINICAL PLACEMENT IN RADIOTHERAPY

RT-only programmes have a high proportion of clinical placement dedicated to this specialism, with an average of 94% of the placement in this specialism (Figure 7.5).

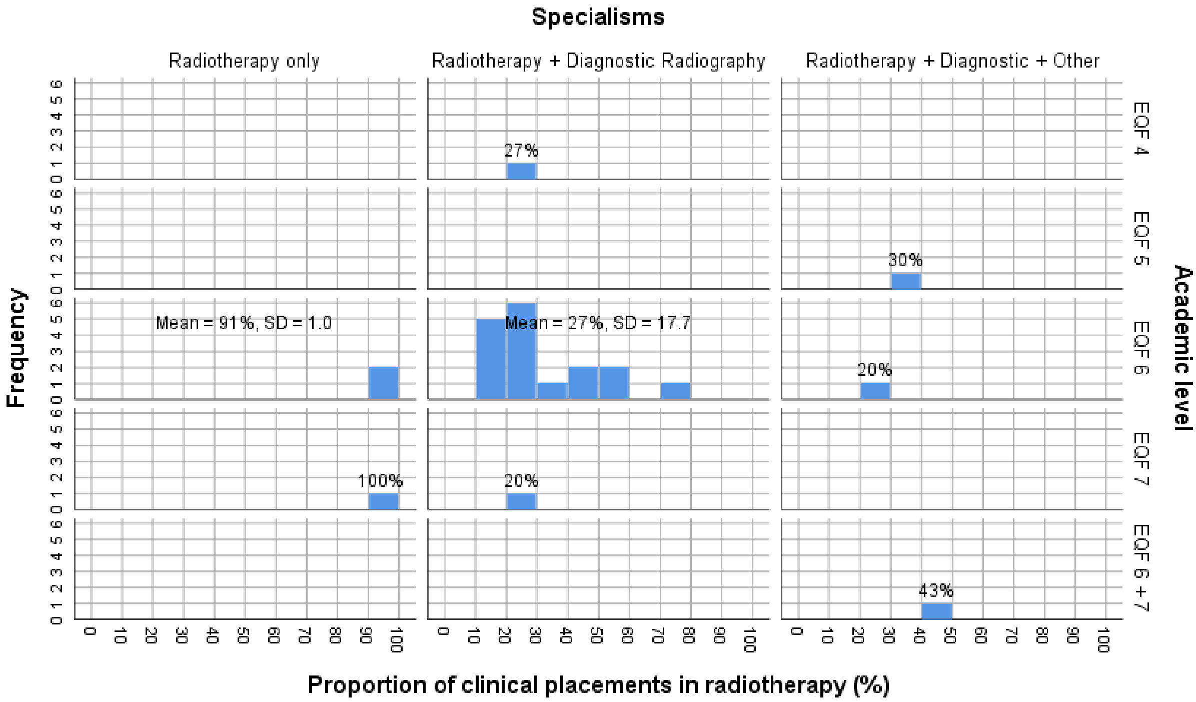


Figure 7.5 – Proportion of clinical placement in RT (according to academic level and specialisms)

Dual-qualification programmes (radiotherapy and imaging) tend to dedicate a higher proportion of the clinical placement to imaging. On average, courses with other specialisms besides RT only devote 27% of the clinical placement to RT. The mean proportion of the placement in RT is statistically higher in RT-only courses than in courses that include other specialisms ($H(1) = 8.052$, $p = 0.005$).

Although the majority of the dual-qualification EQF6 programmes (11 out of 17) have a proportion of RT placement lower than 30%, there are a few courses with higher percentages of placement dedicated to RT. One of these dual-qualification courses has more than 70% of clinical placement dedicated to RT.

7.1.1.5 DURATION OF THE CLINICAL PLACEMENT IN RADIOTHERAPY

The respondents provided data regarding the total number of clinical hours and the proportion of this time that is dedicated to RT. From this data, the researcher computed the number of hours in RT (Figure 7.6). The average number of hours was 459h (SD = 532.9)

RT-only courses have the highest average RT clinical practice hours (771h). Dual-qualification courses have a shorter RT placement duration (439h), with most of the dual-qualification programmes (7 out of 13) having less than 250 hours of placement in RT. Nevertheless, dual-qualification programmes can have as high as 2114 hours of clinical placement in RT. No statistical significance was found between RT-only courses and courses with other specialisms ($H(1) = 0.217$, $p = 0.642$).

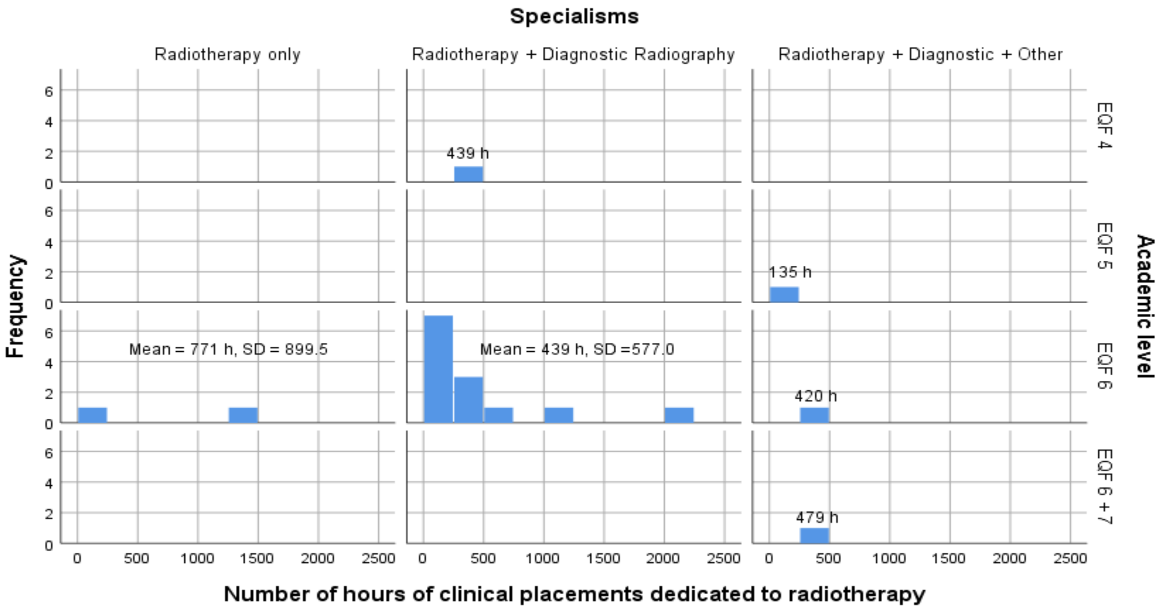


Figure 7.6 – Duration of clinical placement in RT (in hours) (according to academic level and specialisms)

7.1.1.6 PROPORTION OF RADIOTHERAPY PLACEMENT DELIVERED IN SKILL LABS

In average, 233h (SD = 254h) or 18% (SD = 16.2%) of the clinical placement is delivered using skill labs. Although the tendency is to have a low proportion of training in skills labs, this proportion can be as high as 890h or 60% of the clinical placement hours. The percentage of clinical training in skill labs is similar across the course programmes (Figure 7.7). No statistical differences were found between RT-only courses and courses with other specialisms (H(1) = 0.158, p=0.691).

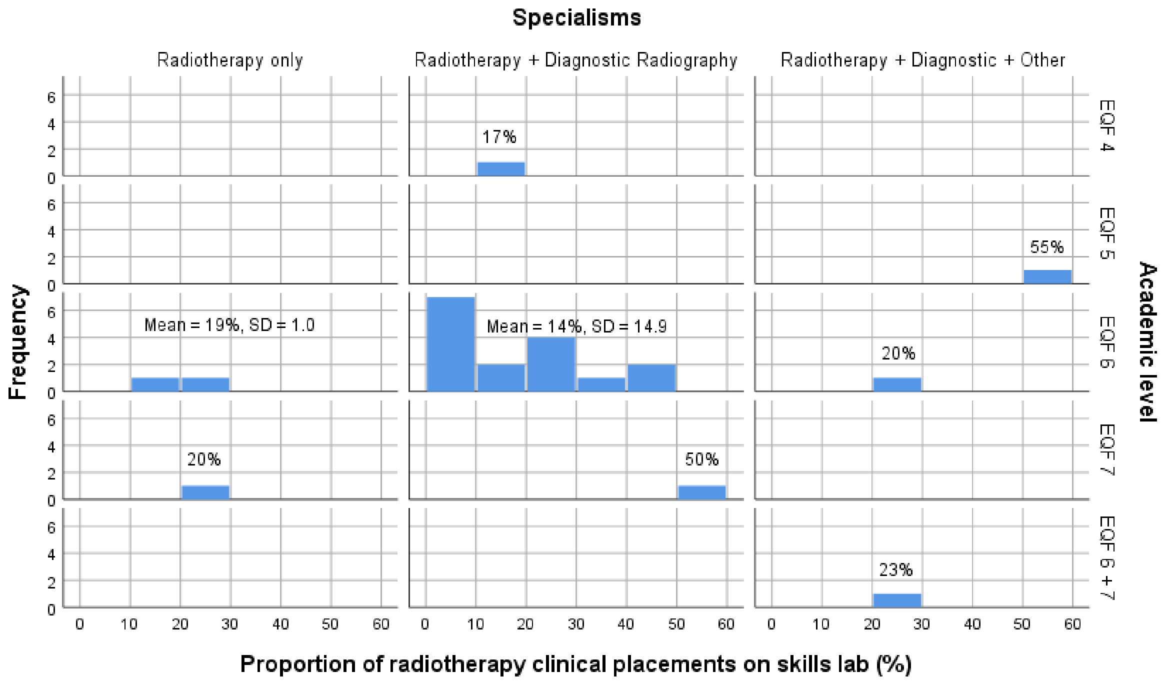


Figure 7.7 – Proportion of RT placement delivered on skill labs (according to academic level and specialisms)

7.1.1.7 REGULATION OF LEARNING OUTCOMES AT THE NATIONAL LEVEL

In most countries, the learning outcomes are defined by law or regulation (11 out of 16). Regarding registration, this was mandatory in 12 countries, not available in two countries, and optional in two others. Three countries did not reply to these questions.

7.1.2 LEAST AND MOST DEVELOPED COMPETENCIES ACROSS THE EU

The Friedman test ($X^2(13)=131.86$, $p<0.001$) demonstrated that some competencies are less developed than others (Figure 7.8). The pairwise comparisons showed that *Pharmacology, Equipment quality assurance, Research and education,* and *Management and leadership* are significantly less developed than *Teamwork and multidisciplinarity, Professional and ethical practice, Radiotherapy treatment delivery* and *Positioning and immobilisation* (p<0.05). Figure 7.8 also shows discrepancies in the level of development of the different competency dimensions across the EU.

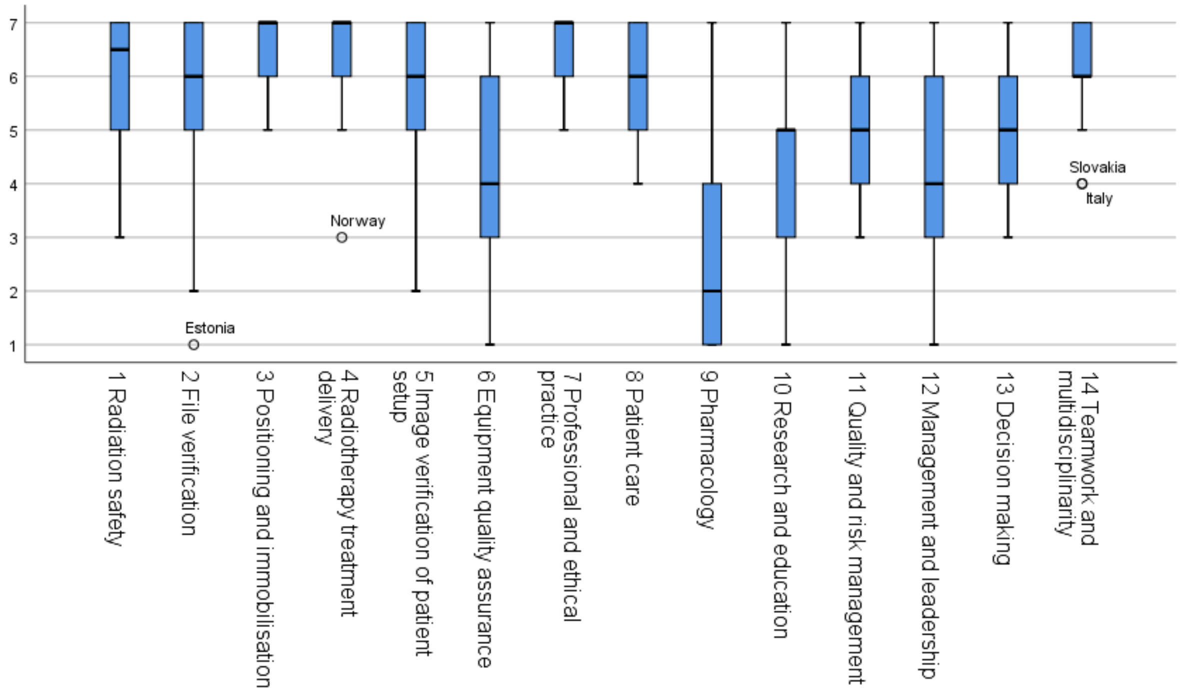


Figure 7.8 – Distribution of the competency scores across EU member states

7.1.3 Comparison and correlation of competency level with course characteristics across the EU

The replies from the 50 respondents were used to analyse the effect of programme characteristics on the level of the competency dimensions. The results of the comparison and correlation tests are shown below.

7.1.3.1 Academic level and specialisms

The competency level was compared between i) courses with academic levels below EQF6, ii) courses at EQF6 and iii) courses higher than EQF6. The groups showed statistically different levels of competency regarding *Quality and risk management* (H(2) = 6.043, p = 0.049). The *post hoc* test showed that courses below EQF6 have a significantly lower competency level (mean = 3.778) when compared with courses above EQF6 (mean = 6.056) (z = -21.167, p=0.042). The groups did not show significant differences in any other competency dimension.

The specialisms included in the programme seem to be associated with significantly different competency levels regarding *File verification* (H(2) = 6.057, p = 0.048) and *Equipment quality assurance* (H(2) = 6.764, p =0.034). RT-only programmes (mean = 5.889) developed higher *Equipment quality assurance* competency than dual-qualification programmes (mean = 3.965) (Z = 13.194, p = 0.044). The pairwise comparisons showed no significance for the *File verification* dimension.

7.1.3.2 DURATION OF PROGRAMME AND PLACEMENT (ALL SPECIALISMS)

The duration of the course programme and placement were correlated with an increase in some competency scores (significant results highlighted in Table 7.2).

Figure 7.9 and Figure 7.10 show the relationship between these course characteristics and the competency dimensions that have a significant correlation: a linear fit line was plotted to better understand the relationship between the programme characteristic and the competency level.

Table 7.2– Correlation between course characteristics and the competency score (significant results highlighted)

		Programme duration	Duration of clinical placement	Proportion of programme dedicated to RT	Proportion of clinical placement dedicated to RT	Duration of clinical placement dedicated to RT	Proportion of RT clinical placement on skills lab
1 Radiation safety	r_s	-.010	.392	.485	.444	.434	.170
	p	.948	.017	.000	.001	.007	.249
	N	49	37	49	50	37	48
2 File verification	r_s	.070	.414	.544	.489	.564	.112
	p	.635	.012	.000	.000	.000	.453
	N	48	36	48	49	36	47
3 Positioning and immobilisation	r_s	-.035	.235	.435	.474	.353	.058
	p	.811	.161	.002	.001	.032	.696
	N	49	37	49	50	37	48
4 Radiotherapy treatment delivery	r_s	.053	.402	.565	.569	.552	.062
	p	.719	.015	.000	.000	.000	.678
	N	48	36	48	49	36	47
5 Image verification of patient setup	r_s	.198	.370	.011	.074	.268	-.091
	p	.173	.024	.941	.608	.109	.539
	N	49	37	49	50	37	48
6 Equipment quality assurance	r_s	-.021	.326	.538	.487	.474	.263
	p	.887	.049	.000	.000	.003	.071
	N	49	37	49	50	37	48
7 Professional and ethical practice	r_s	.113	.264	.425	.457	.476	-.073
	p	.446	.115	.003	.001	.003	.625
	N	48	37	48	49	37	47
8 Patient care	r_s	.017	.231	.378	.364	.322	.007
	p	.907	.169	.007	.010	.052	.961
	N	48	37	49	49	37	47
9 Pharmacology	r_s	-.092	.048	.107	.114	.095	-.300
	p	.542	.785	.472	.447	.586	.045
	N	46	35	47	47	35	45
10 Research and education	r_s	.327	.098	.119	.163	.244	.017
	p	.023	.563	.414	.262	.145	.911
	N	48	37	49	49	37	47
11 Quality and risk management	r_s	.292	.071	.246	.251	.229	.062
	p	.044	.677	.089	.082	.174	.679
	N	48	37	49	49	37	47
12 Management and leadership	r_s	.299	-.124	.080	.111	-.029	.139
	p	.039	.466	.583	.450	.863	.352
	N	48	37	49	49	37	47
13 Decision making	r_s	.374	.071	.154	.212	.166	.053
	p	.010	.680	.295	.147	.333	.727
	N	47	36	48	48	36	46
14 Teamwork and multidisciplinarity	r_s	.166	.118	.153	.246	.246	.036
	p	.259	.485	.294	.088	.142	.812
	N	48	37	49	49	37	47

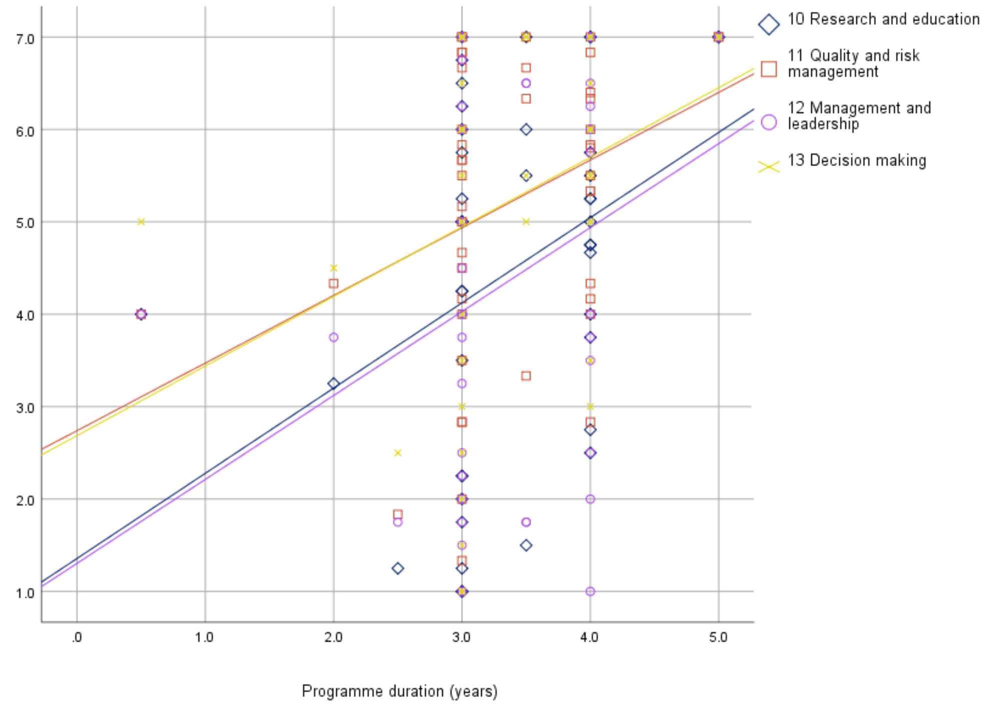


Figure 7.9 – Bivariate scatter plot of programme duration (in years) with competency scores that showed significant correlations. The linear fit line is also shown.

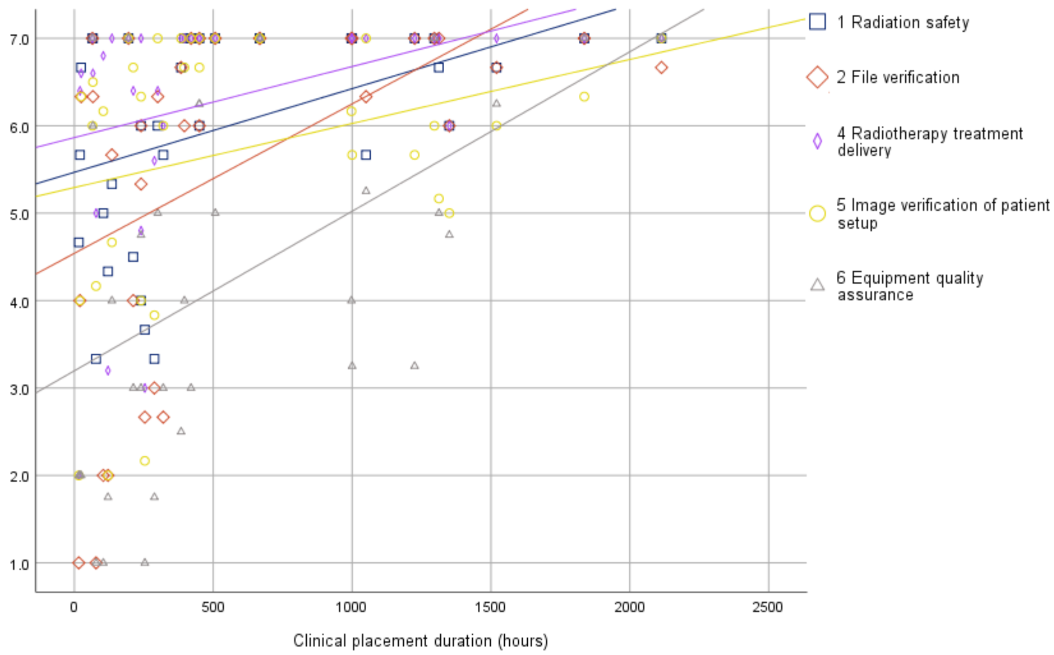


Figure 7.10 – Bivariate scatter plot of Placement duration (in hours) with competency scores that showed significant correlation. The linear fit line is also shown.

7.1.3.3 PROPORTION OF THE PROGRAMME AND PLACEMENT DEDICATED TO RADIOTHERAPY

The proportion of the course and of the placement dedicated to RT seems to correlate with an increase in several competency dimensions (significant correlations were highlighted in Table 7.2). Figure 7.11 to Figure 7.13 illustrate the correlation between these characteristics and the competency scores.

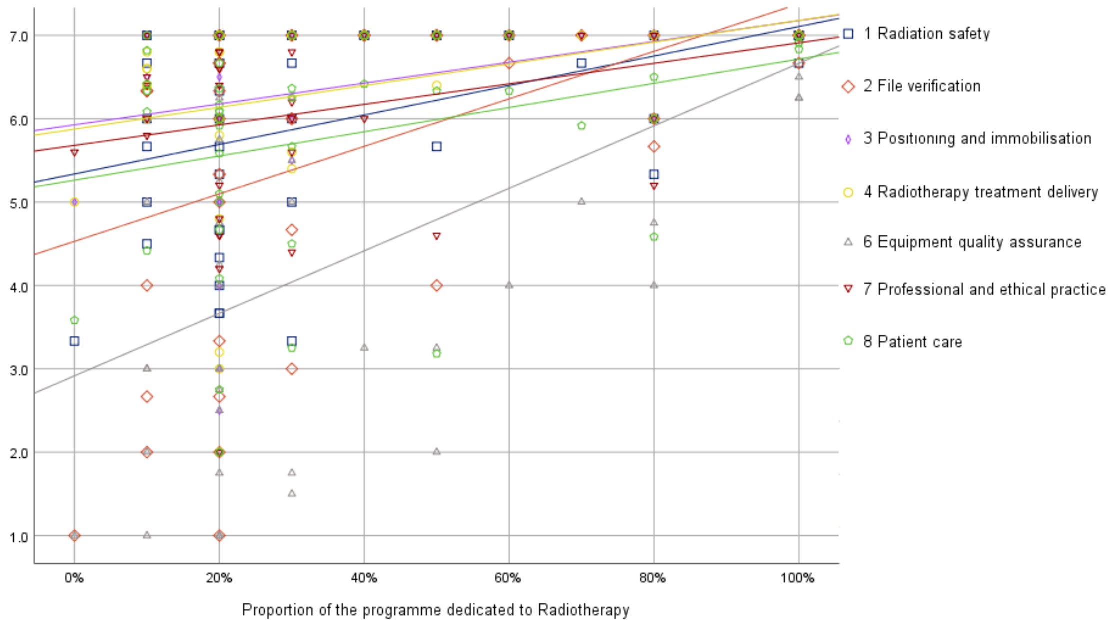


Figure 7.11 – Bivariate scatter plot of the proportion of curriculum dedicated to RT with competency scores that showed statistically significant correlation. The linear fit line is also shown.

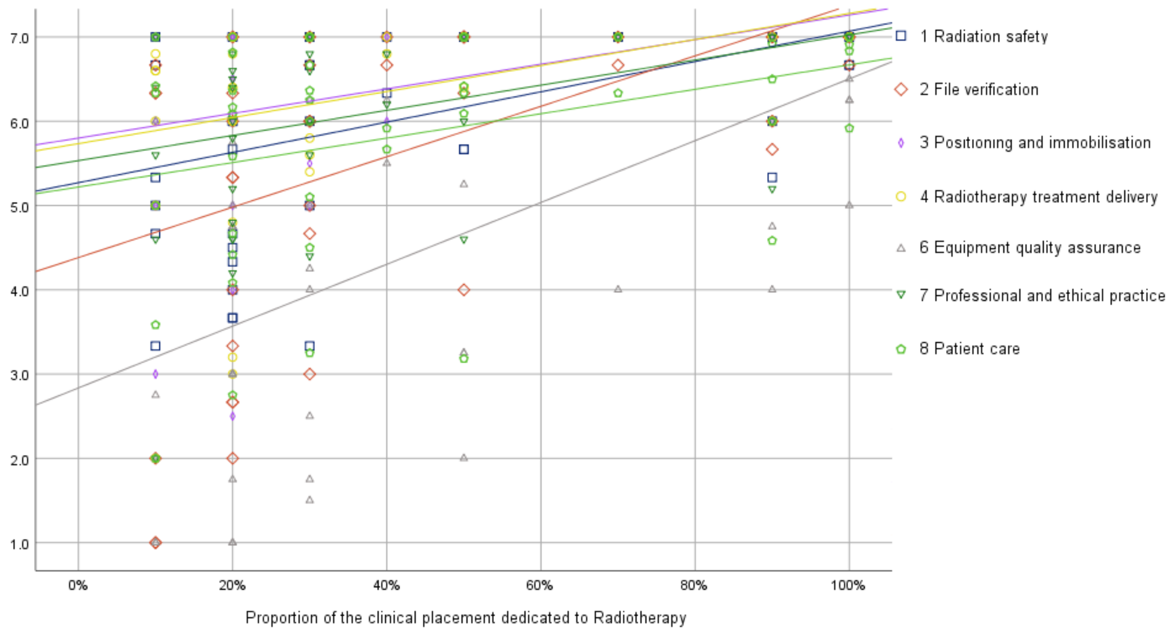


Figure 7.12 – Bivariate scatter plot of the proportion of clinical placement dedicated to RT with competency scores that showed statistically significant correlation. The linear fit line is also shown.

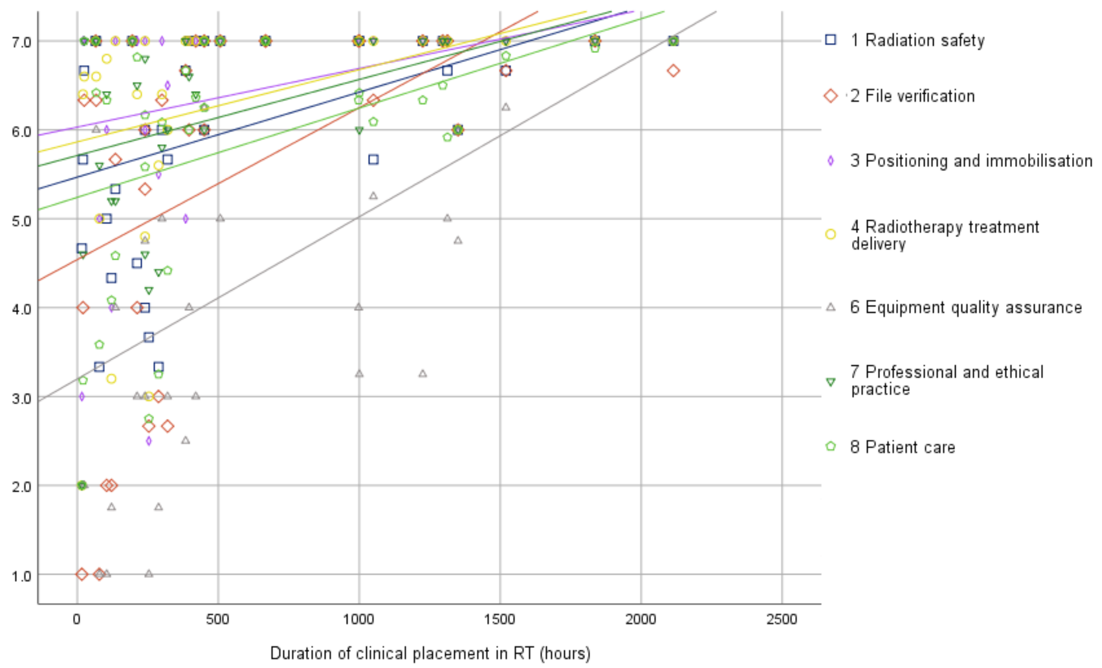


Figure 7.13 – Bivariate scatter plot of the duration of RT placement with competency scores that showed statistically significant correlation. The linear fit line is also shown.

From the data collected, it seems that the proportion of RT clinical placement delivered in skills labs correlates negatively with competency scores in *Pharmacology* (r = -.300, p = 0.045). The correlation between these variables can be seen in Figure 7.14.

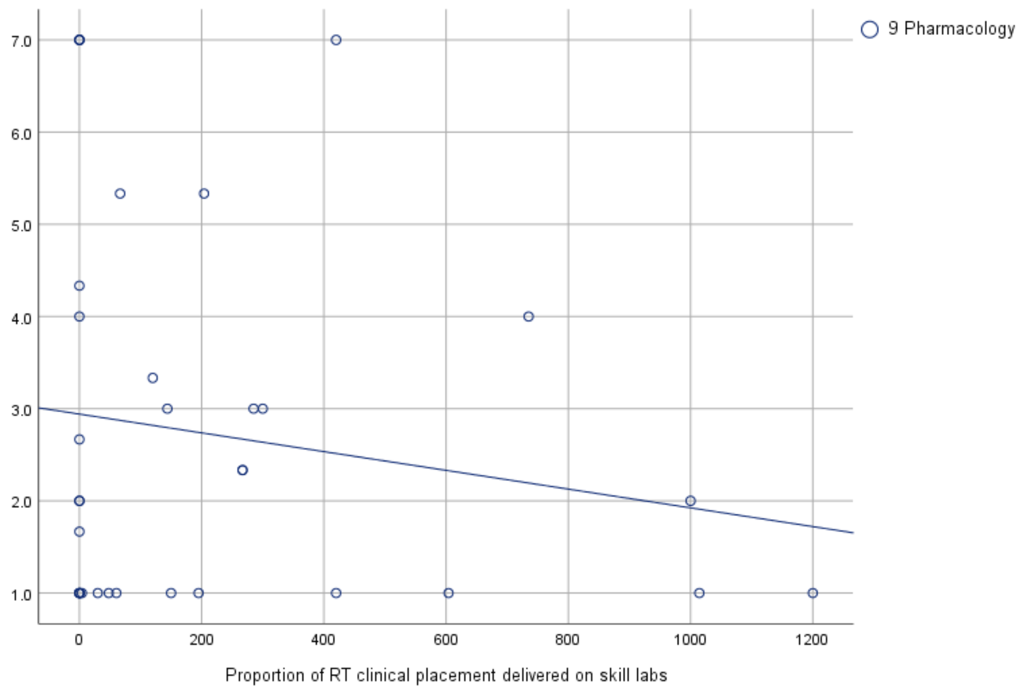


Figure 7.14 – Bivariate scatter plot of the proportion of RT placement delivered in skills labs with Pharmacology competency scores. The linear fit line is also shown.

7.1.3.4 REGULATION AND DESIGN OF LEARNING OBJECTIVES

Registration to practise seems to affect various competency dimensions significantly. Table 7.3 shows the mean scores according to the registration process. *Post hoc* tests were run, and the pairwise comparison of the groups showed that courses from countries where there is no registration have lower competency levels regarding *Positioning and immobilisation, Radiotherapy treatment delivery, Image verification of patient setup, Equipment quality assurance, Professional and ethical practice, Research* *and education, Quality and risk management, Management and leadership* and *Teamwork and multidisciplinarity* when compared with mandatory registration, optional or both (p<0.05). In addition, mandatory registration showed higher *Pharmacology* competency levels when compared with programmes in countries with optional registration (Z=16.081, p=0.006).

Table 7.3 – Mean competency score according to the country's registration process

	There is no registration at national level (n=7)	Registration at national level is mandatory (n=33)	Registration is optional (n=7)	
	Mean	**Mean**	**Mean**	**Kruskal Wallis**
1 Radiation safety	5.143	6.056	6.095	H(2) = 2.580 p = 0.275
2 File verification	4.190	5.844	6.333	H(2) = 3.417 p = 0.181
3 Positioning and immobilisation	**5.071**	**6.606**	**6.786**	**H(2) = 7.779 p = 0.020**
4 Radiotherapy treatment delivery	**5.057**	**6.613**	**6.857**	**H(2) = 6.610 p=0.037**
5 Image verification of patient setup	**4.476**	**5.934**	**6.738**	**H(2) = 7.951 p = 0.019**
6 Equipment quality assurance	**2.536**	**4.735**	**4.893**	**H(2) = 6.317 p = 0.043**
7 Professional and ethical practice	**4.733**	**6.467**	**6.343**	**H(2) = 10.603 p = 0.005**
8 Patient care	4.457	6.113	6.311	H(2) = 4.842 p = 0.089
9 Pharmacology	**2.714**	**3.118**	**1.000**	**H(2) = 10.014 p = 0.007**
10 Research and education	**2.679**	**4.703**	**5.595**	**H(2) = 9.158 p = 0.010**
11 Quality and risk management	**3.619**	**5.459**	**5.952**	**H(2) = 8.518 p = 0.014**
12 Management and leadership	**2.893**	**4.422**	**5.714**	**H(2) = 6.347 p = 0.042**
13 Decision making	4.357	5.266	5.786	H(2) = 3.301 p = 0.192
14 Teamwork and multidisciplinarity	**4.607**	**5.969**	**6.571**	**H(2) = 8.027 p = 0.018**

Thirty-eight programmes included competencies in their learning objectives, while ten of the respondents stated that the learning objectives do not include competencies. Nevertheless, it seems that including the competencies in the learning objectives does not affect the competency level perceived by the respondents (p>0.05). Programmes from countries where the learning outcomes are defined by the national regulation (n=34) also did not show any significant difference from those that do not (n=13) (p>0.05).

Regarding which guidelines are followed in the course design, most respondents stated that they followed at least one international guideline (24 out of 36), and from these, most programmes follow the European Federation of Radiographer Societies (EFRS) (n=18) and the European SocieTy for Radiotherapy and Oncology (ESTRO) guidelines (n = 14).

Programmes that use at least one international guideline showed significantly higher levels of development for some competency dimensions (Table 7.4). Further analysis was performed to assess how the use of each of the documents mentioned in the questionnaire (EFRS, 2018; ESTRO, 2014; HENRE, 2008b; IAEA, 2014) related to competency level. It was observed that courses that use EFRS (2018) and ESTRO (2014) reference documents have higher levels of development for certain competency dimensions (Table 7.5). The use of IAEA (2014) or HENRE (2008b) recommendations did not significantly influence the competencies scores (p > 0.05).

Table 7.4 – Mean competency score according to the use of international reference documents

	The course follows at least one reference document (n=24)	The course does not follow any reference document (n=12)	
	Mean	Mean	Kruskal Wallis
1 Radiation safety	6.146	5.833	H(1) = 0.783 p = 0.376
2 File verification	5.764	4.917	H(1) = 0.649 p = 0.420
3 Positioning and immobilisation	6.542	6.125	H(1) = 0.354 p = 0.552
4 Radiotherapy treatment delivery	6.558	5.900	H(1) = 1.308 p = 0.253
5 Image verification of patient setup	**6.160**	**4.889**	**H(1) = 9.036 p = 0.003**
6 Equipment quality assurance	4.115	4.125	H(1) = 0.000 p = 0.987
7 Professional and ethical practice	6.274	5.683	H(1) = 0.485 p = 0.486
8 Patient care	**6.089**	**4.954**	**H(1) = 4.292 p = 0.038**
9 Pharmacology	3.097	2.139	H(1) = 0.312 p = 0.576
10 Research and education	**4.986**	**3.229**	**H(1) = 5.889 p = 0.015**
11 Quality and risk management	**5.619**	**4.083**	**H(1) = 6.292 p = 0.012**
12 Management and leadership	**5.073**	**3.000**	**H(1) = 7.479 p = 0.006**
13 Decision making	**5.833**	**4.125**	**H(1) = 6.227 p = 0.013**
14 Teamwork and multidisciplinarity	6.115	5.375	H(1) = 2.166 p = 0.141

Table 7.5 - Mean competency score according to whether the programme uses EFRS's and ESTRO's benchmarking document in the course design

	The course follows EFRS's reference document (n=18)	The course does not follow EFRS's reference document (n=18)	
	Mean	Mean	
5 Image verification of patient setup	**6.278**	**5.194**	**H(1) = 7.410 p = 0.006**
8 Patient care	**6.254**	**5.168**	**H(1) = 5.449 p = 0.020**
10 Research and education	**5.134**	**3.667**	**H(1) = 4.398 p = 0.036**
11 Quality and risk management	**5.780**	**4.435**	**H(1) = 5.518 p = 0.019**
	The course follows ESTRO's reference document (n=14)	The course does not follow ESTRO's reference document (n=22)	
	Mean	Mean	
10 Research and education	**5.304**	**3.826**	**H(1) = 4.911 p = 0.027**
12 Management and leadership	**5.607**	**3.602**	**H(1) = 7.792 p = 0.005**

7.2 DISCUSSION

7.2.1 UNIFORMITY OF RADIOTHERAPY EDUCATION IN THE EU (OR LACK THEREOF)

Some level of harmonisation can be observed since the majority of countries seem to offer dual-qualification programmes at EQF level 6 with a duration between 3 and 4 years, corroborating previous studies (McNulty et al., 2017, 2016; Prentakis et al., 2016). These similarities facilitate movement between EU countries since these are the characteristics most often verified before granting recognition of qualifications abroad (Chapter 4). However, not all member-states offer programmes with these characteristics: the programmes vary between 1 semester and 5 years in duration; EQF level between 4 and 7; and programmes can be either dedicated to radiotherapy; dual-qualifications (imaging and radiotherapy); or even include additional specialisms (such as electrophysiology).

However, programmes which, at face value, may seem similar (same academic level, programme duration and specialisms) presented considerable variation in terms of duration of clinical placement, the proportion of the programme and of clinical placement dedicated to RT, duration of RT-specific placement and the use of skill labs. As such, an appropriate comparison of programmes (such as for the recognition of qualifications abroad) must include the assessment of more than just the academic level, duration and specialisms. Even though some countries have a very comprehensive process of verifying foreign graduates' applications, with an extensive list of criteria for registration, this does not happen in all EU countries (Chapter 4); therefore, the competencies developed may not match those practised in the destination country.

The lack of homogeneity was also evident in terms of the competency level. Even though some competency dimensions seem to be well developed across member-states, in other dimensions, the competency can be fully developed in one country and not developed at all in others. Even though this disparity is more evident in non-technical competencies (such as *Management and leadership*), it was also observed in technical competencies (such as *Equipment quality assurance* and *Image verification of patient setup*). These results showed that some competencies identified in the literature as being the responsibility of the TRs (Chapter 5) are not fully developed across the EU. As such, these disparities have the potential to become an issue when movement occurs, and so further research should be performed.

Harmonisation of education would ensure that graduates are prepared to practise the profession safely and competently in any other country. EU member states may benefit from harmonisation in education in many ways: professionals can move from countries with a surplus of TRs to countries with a lack of these professionals; the same level of care may be offered to patients irrespective of the country; sharing of educational resources between countries; faster evaluation of foreign applications for registration in the profession; patient safety when TRs move to a different member state, amongst others.

However, harmonisation limits the production of new knowledge and development since all graduates would exit with the same set of abilities and expertise (Sam and Sijde, 2014). Additionally, the programmes may not be in tune with the actual needs of the society since the needs vary between countries (Gellert, 1999; Sam and Sijde, 2014). Also, changes in education often face resistance from stakeholders in education, whilst stakeholders in clinical practice may be resistant to changes in education since these often bring about changes in the profession (Kurelić, 2009).

7.2.2 Factors associated with the level of graduates' competency in linear accelerator tasks

Most course characteristics showed an association with graduates' competency level regarding linear accelerator tasks. However, the different features of the programmes seem to be related to different competency dimensions. Programmes with higher academic levels and longer programme durations were associated with better developed non-technical competencies (such as *Quality and risk management*). In addition, more extended programmes showed improved *Research and education* competency, agreeing with previous literature, which suggested that there is a relationship between education programmes and research (England and McNulty, 2020; Malamateniou, 2009). Also, Figure 7.9 shows the impact that programme duration has on *Research and education* competency levels.

On the other hand, the results suggest that more extended clinical placement (general and RT-specific) and a more substantial proportion of RT in the educational programme allow the graduates to develop better technical competencies related to the linac (such as *Equipment quality assurance* or *Patient care*). The bivariate plots (Figure 7.9 to Figure 7.14) depict examples of the influence of these factors on different competencies. These figures also show that even for significant correlations, the impact of the various programme characteristics is not the same.

Since very few countries offer courses with academic levels different from EQF6 and specialisms other than dual-qualification, it may be challenging to see statistical significance even if there is a difference. RT-only programmes only showed statistically higher levels of competency in *Equipment quality assurance*, however, since these programmes also presented a statistically higher proportion of the curriculum and placement devoted to RT, which are correlated with increased development of other technical competencies.

There was a lack of prior research on the relationship between linac-specific competencies and training at the undergraduate level. However, the existing literature agreed that adequate training is of utmost importance to develop image verification competencies (Cox and Jimenez, 2009; Friel and Mullaney, 2014). This particular subject is possibly more discussed in scientific publications because the role of TRs in this task is not yet well established everywhere.

This study also demonstrated that courses with a large proportion of the clinical training in skill labs have a lower development of *Pharmacology* competencies. A possible explanation is that simulation may reduce the contact with actual clinical practice, suggesting that pharmacology applied to radiotherapy may be mostly learned in clinical practice. Even though ample literature showed the learning benefits of simulated training (Bleiker et al., 2011; Jimenez and Lewis, 2018), there is also literature which agreed, that despite the benefits of simulation, there is no improvement in learning (Cheung et al., 2021).

The current educational paradigm is that course objectives should be defined in terms of learning outcomes (instead of teaching objectives) (CEDEFOP, 2015; European Centre for the Development of Vocational Training, 2017; Harden, 2002; Walton, 1993; Winterton, 2009). The EQF for lifelong learning recommends that the *competencies* should be defined in the learning outcomes, reflecting responsibility and autonomy in the tasks performed (European Parliament and European Council, 2008). However, the results showed that neither the inclusion of competencies in the learning objectives nor the regulation of the learning outcomes at the national level affects the competency level of graduates. However, the lack of registration to practise significantly affects the development of both technical and non-technical competencies.

The use of international reference guidelines for the design of the course curriculum improves both technical (such as *Image verification of patient setup*) as well as non-technical competencies (such as *Decision making*), especially reference documents produced by EFRS and ESTRO. *Research and education* competencies are also more developed in courses that follow these guidelines.

The results showed how programme characteristics influence competency level. As such, besides hindering the movement of professionals between countries, the differences in course characteristics can arguably have an impact on the care that is provided to RT patients. It is essential to highlight that these results do not aim to identify which countries have less or more developed competencies since some countries show lower levels of specific competencies and higher levels of others. However, the misalignment between EU countries with regards to the competency of TRs and the potential to compromise patient safety is crucial to note. Further studies are recommended to assess this relationship.

In most countries, the professional regulatory body dictates most course characteristics, while others are decided by the educational institutions (Chapter 4). As such, this study presents evidence that can be used by these stakeholders to facilitate decision-making when trying to achieve excellence in radiotherapy education. Nevertheless, this data is vital for the whole professional community, including TRs, employers, students, researchers, individuals wishing to move across the EU, professional bodies or anyone interested in these professional issues.

7.2.3 LIMITATIONS

Not all EU countries are represented in the study. The margin of error is 12.98%, and including more countries would further decrease this error. A margin of error could not be calculated for the radiotherapy programmes since there is no information available on how many programmes exist in the EU.

Whenever statistical tests are done, there is the possibility that statistical significance can result from chance. When a high number of tests are done, the probability that the p-value is above or below the significance value (0.05) due to chance increases. As such, values close to 0.05 should be interpreted with care, and further studies would be useful to corroborate (or otherwise) these results.

Although it is expected that the academic staff of the programmes can provide accurate data, there may be some respondent bias. Due to the nature of the data collected, respondents may feel pressured to give more acceptable answers. The researcher tried to minimise this effect by keeping the questionnaire anonymous.

Since this study focuses on tasks related to the linac, the effect on other roles in RT or specialisms was not assessed. However, it is understood that specific changes, such as increasing the proportion of RT in the programme, may reflect a decreased competency in other areas, and these should be further studied.

Education is a very complex phenomenon, and it is acknowledged that there may be other confounding factors that were not assessed and may influence competency level, such as the number of RT academic staff in the education institution and their expertise, the use of feedback from stakeholders in the programme design, course entry requirements, amongst others. Also, the economic implications of changing these characteristics were not assessed; however, since the data was collected from existing programmes across member-states, applying changes within the limits of the data collected should be feasible.

The scope of this research was to study the competencies developed during the education programmes. However, it is acknowledged that training of TRs is a lifelong process, and under-developed competencies can be acquired after graduation.

7.3 CONCLUSION

This is the first study to investigate the impact of course characteristics on the development of radiotherapy competencies across the EU. This study shows that most of the programmes training radiotherapy professionals across the EU are 3 to 4-year, dual-qualification programmes (in both radiotherapy and medical imaging) at EQF level 6. However, variations can be found: different specialisms, such as RT-only or programmes that include electrophysiology; different academic levels, from EQF level 4 to level 7; and different durations, from one semester to five years. This discrepancy is also significant in terms of duration of clinical placement, the proportion of the programme dedicated to radiotherapy and the duration of RT-specific clinical placement.

Ultimately, these differences in course structures manifested as differences in competencies. Fundamental competency dimensions in the linear accelerator (such as *Radiotherapy treatment delivery, Positioning and immobilisation* and *Professional and ethical practice*) seem to be developed at the highest level across the EU, however, some others were very poorly developed (such as *Pharmacology, Equipment quality assurance* and *Research and education*). Also, a considerable variation between countries is observed in the level of many competencies related to the linac.

It was found that some programme characteristics (such as the academic level or duration of the programme) influence mostly non-technical competencies. In contrast, technical competencies depended on other features (such as specialisms in the programme, duration of placement and proportion of programme dedicated to RT). Interestingly, extensive use of skills labs showed a lower competency level in *Pharmacology*.

The factors that affected the largest number of competency dimensions (both technical and non-technical) were the existence of a mandatory registration process at the national level and the use of international guidelines in the design of the programme. Therefore, both are recommended to be applied at the national and the individual programme level.

7.4 BRIDGING SECTION

This study established the relationship between course characteristics and competency levels of TRs practising on the linear accelerator. The discrepancies in education across the EU previous identified in the literature were again confirmed. The differences in course characteristics identified in the survey may affect professional mobility, while the different competency levels may impact patient care. Chapter 8 will further explore the impact of education on these two phenomena.

CHAPTER 8. RESULTS OF THE CROSS-CASE STUDY EVALUATING THE COMPETENCY LEVEL IN RADIOTHERAPY ACROSS EU EDUCATIONAL PROGRAMMES AND ITS IMPACT ON PATIENT CARE AND PROFESSIONAL MOBILITY

This chapter presents the results of the cross-case study, which used interviews to collect stakeholders' perceptions regarding the competency level, patient care and professional mobility of graduates from four EU member states. A detailed description of the methodology can be found in section 3.2.3, "Cross-Case study (Phase 3)".

This cross-case study aimed to further explore the findings of the survey (Chapter 7) and answer the following research questions:

- Why are some competencies less developed across Europe?
- Are these competencies essential, and at what level should they be developed?
- What is the impact of TRs' education and competency levels on professional mobility and patient care and safety?

8.1 RESULTS

A total of 27 stakeholders with different roles and backgrounds from four different countries (Finland, Poland, Portugal, and the UK) participated in the study (Table 8.1). The participants' characteristics described are limited to the country and their role to avoid identification.

Table 8.1 – Participants' characteristics

Country studied	Participant characteristics
Finland (individual interviews)	FL1 – Local TR FL2 – Student FL3 – RT lecturer FL4 – Local TR FL5 – Local TR FL6 – Student
Poland (group interview)	PL1 – Clinical manager, professional body representative, RT lecturer PL2 – RT lecturer, local TR PL3 – Local TR PL4 – Student PL5 – Local TR PL6 – Local TR, professional body representative PL7 – Local TR, professional body representative
Portugal (group interview)	PT1 – Local TR, clinical educator PT2 – Local TR, clinical educator PT3 – Clinical manager PT4 – Emigrant TR PT5 – Emigrant TR PT6 – Emigrant TR PT7 – Emigrant TR PT8 – RT lecturer, ex-professional body representative
UK (individual interviews)	UK1 – Professional body representative UK2 – RT Lecturer UK3 – Local TR UK4 – Clinical manager, ex-RT lecturer UK5 – Immigrant TR, education and training leader UK6 – Local TR (newly qualified)

No migrant TRs from Poland or Finland volunteered to participate, possibly due to a low number of TRs migrating to these countries. Many TRs move out of Portugal, and many TRs move into the UK (Chapter 5); as such, it was easier to recruit migrant TRs in these countries. The participants and the Regulated Professions Database (European Commission, n.d. h) confirmed these migration patterns (Chapter 5).

Stakeholders with education roles, migrant TRs and professional body representatives provided the richest information about mobility while practising TRs offered a good understanding of the relationship between competence and patient care. Clinical managers provided an insight into the employers' point-of-view, and students and lecturers offered detailed descriptions of the course programmes.

Data saturation was achieved well before the end of the data collection. The thematic framework (Table 8.2) summarises the themes arising from the interviews.

Table 8.2 – Thematic framework.

Theme	Sub-theme
Least developed competencies	- Pharmacology - Management and leadership - Equipment quality assurance (QA) - Image verification - Research - Critical thinking
Factors influencing professional mobility across Europe	- Education programmes characteristics - Lack or excess of graduates - Registration process - Other factors
Factors influencing patient care and safety	- Education (competency level) - Lack of standardisation of practice - Professional mobility - Other factors
Education characteristics affecting competency level	- Programme structure: o Regulation of learning outcomes at the national level o Academic level o Programme duration o Specialisms o RT-specific training - Lack of academic staff in RT - Teaching methods

8.1.1 Least developed competencies

The stakeholders (Table 8.1) discussed the four competencies found to be developed in Chapter 7: *Pharmacology*, *Quality Assurance (QA)*, *Management and Leadership*, and *Research and Education*. Additionally, the participants stated that *image verification* competencies were also underdeveloped, especially in new modalities, and *critical thinking* competencies were also at risk across Europe. The participant codes found in Table 8.1 were used to identify the origin of the quotes in the results.

8.1.1.1 PHARMACOLOGY

Pharmacology subjects are often delivered to multiple healthcare professionals in generic study units but "*not in radiotherapy*" (FL3). Pharmaceuticals used for side-effect management, chemotherapies or other procedures related to oncology were poorly covered. Pharmaceuticals used to manage common side-effects are covered, but the pharmacological properties are very superficially discussed.

This learning is often undertaken during clinical placements in an unstructured fashion: *"When they're in placement […] They'll be in the presence of people when conversations are being had about those drugs"* (UK2). However, this results in students with different exposures and skills.

These competencies were also seen as *"nurse stuff"* (PL1) or other professionals in some countries and that *"maybe, we are always going to be less involved in pharmacology"*[1]

[1] "se calhar, nós vamos sempre estar sempre menos envolvidos em farmacologia" (PT4)

(PT4). This contrasts with countries where *"at an advanced practitioner level, […] you're in a position to […] move towards independent prescribing"* (UK1).

RT-specific pharmacology was considered "*important*" (UK1). The main reason was that TRs have frequent contact with oncology patients with various therapies and side effects.

Some stakeholders believed *that "you can learn [pharmacology] on the job"* (FL6). However, the theory must be covered in the qualifying degree (EQF6) since patients' outcomes depend on the competency level of TRs to provide advice. Moreover, theoretical foundations are necessary for graduates to progress into advanced roles on patient review and prescription.

8.1.1.2 MANAGEMENT AND LEADERSHIP

Management and leadership skills were considered somehow intrinsic characteristics of the individual; yet they can be developed by specific training. Even though management skills applied to RT were considered "*essential*" (UK1) "*at any level of the organisation*" (UK5), this is considered "*a very weak area*" (UK2).

Similarly to pharmacology, these competencies are often covered in generic study units, and the specifics of RT management are often left out. RT management is complex and includes multiple dimensions: equipment and human resources management, cancer pathways, and research management, among others.

Stakeholders agreed that these competencies *"should be developed by everybody"* (UK2) in their qualifying degree (ideally EQF6). Further training at EQF7 may be beneficial if TRs take management roles. However, some stakeholders stated that TRs may also develop management and leadership skills without formal education. Since some stakeholders (including employers) do not consider management skills essential, these are often transferred to post-graduation programmes.

8.1.1.3 EQUIPMENT QUALITY ASSURANCE (QA)

Competencies in QA of equipment used to treat patients are underdeveloped due to professional boundaries since "*the QA for the machines is done by the physicists*" (UK3); consequently, they have more training in these tasks. TRs are often limited to "*very basic QA*" (UK2). Multi-professional teamwork in equipment QA was deemed essential to ensure patient safety. Time restrictions in TRs' education programmes was also a reason for this underdeveloped competency.

In the UK, *"students do have to get signed off as having assisted in those procedures"* (UK2) and have *"practical-type sessions"* (UK6). While other countries do not specify QA as part of the practical learning: *"the knowledge was acquired on the job"*[2] (PT2) or that *"it's something we have in the course. It's not so big"* (FL3).

Equipment QA skills were deemed essential since "*if we do not have knowledge of QA […] how can we be sure that […] we are doing the correct thing*"[3] (PT5). Some stakeholders from multiple-specialism programmes believe that these competencies

[2] "o conhecimento foi adquirido on the job" (PT2)

[3] "se não temos noção dos "QA", […] como é que podemos ter certeza de que […] estamos a fazer algo que é benéfico" (PT5)

should be developed "*after [graduation] because then it's unnecessary if you do diagnostic*" (FL5).

8.1.1.4 IMAGE VERIFICATION

Image verification is the process of acquiring radiologic imaging to measure and correct differences between the patient's setup in the linear accelerator and the setup used for planning. Education institutions may not be up-to-date with these competencies since many modalities were introduced in the recent past, such as verification using Cone-Beam Computed Tomography (CBCT) or 4D imaging.

Curricula are not updated frequently, and there is a lack of equipment and academics with training in the new modalities. Also, universities may struggle to update their teaching methods due to issues in "*information sharing. […] Even anonymised data is very difficult to share"* (UK4).

In some countries, image verification tasks are considered part of advanced roles and students "*weren't allowed to try matching […] for the real treatment*" (FL2). This is even more pronounced for the new imaging modalities.

TRs' autonomy in performing and evaluating verification images varies across the countries interviewed. The general agreement was that these competencies must be developed in the undergraduate programme (EQF6) to allow TRs to perform these tasks autonomously and safely. Nevertheless, due to the limitations mentioned above, on-the-job training may be necessary.

8.1.1.5 RESEARCH AND EDUCATION

Research competencies are underdeveloped in the countries interviewed and across Europe. Educational institutions often do not develop this competency because of a lack of resources (human and equipment), lengthy ethical procedures, and difficulties obtaining clinical data.

These barriers limit students' options, and often they "*opt for the review article*" (UK2) or "*a research proposal*" (UK4). As such, graduates may not be fully competent in performing research themselves, and consequently, they may be unable to create new knowledge to support their practice.

On the positive side, there is "*a strong emphasis on evidence-based practice*" (UK3), preparing graduates to apply research results into their practice. Also, most courses cover research methods theory during their programme.

Stakeholders agreed that research competencies are "*very important*" (PL1), but graduates require further education in research as part of their lifelong learning (EQF7 and EQF8). However, it may be *"a personal decision"*[4] (PT6) if TRs develop these competencies later on or not. Furthermore, their research experience in the undergraduate programme (EQF6) affects the decision since *"without a basic set of skills with regards to research would make any future studies particularly difficult"* (UK2).

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[4] "é uma opção pessoal" (PT6)

Employers may not consider research as an essential competence for all TRs. Therefore, employers do not push universities to develop them. Furthermore, students also stated that they felt overwhelmed and *"already had so much stuff to do that adding research to it would mean extra work"* (FL2), compromising the overall learning experience. The significant students' workload emphasises that some competencies may need to be developed at a later stage.

Stakeholders did not sufficiently discuss education competencies. When discussing the "*research and education"* theme, participants often diverged to the research theme, even when prompted by the interviewer, indicating that the lack of research skills greatly impacted practice and overshadowed educational competencies.

8.1.1.6 CRITICAL THINKING

Stakeholders believed that multidisciplinary curricular units are substituting RT-specific content in education programmes to cut costs. As a consequence, if this trend continues, participants believe that "*critical thinking [applied to RT] will reduce*" (UK4). However, the development of all essential competencies is safeguarded if the learning outcomes are regulated.

Critical thinking is also an issue when the academic level is below EQF6: "*Somebody who's trained to a level beneath the level six, potentially in a very narrow area, is only ever skilled to undertake a task*" (UK1). Participants agreed that this competence must be developed in the qualifying degree because *"being a professional is about that commitment to lifelong learning, the critical thinking, the ability to appraise"* (UK4).

In some cases, "*the last decision goes to the doctor*" (PL2) and "*some of the radiotherapists are content to do what they are told to do instead of questioning*" (FL4) — indicating that autonomous decision-making and critical thinking may not be well-established across Europe because of professional traditions.

Participants agreed that due to the use of ionising radiation in humans, safety is well covered in most programmes, and TRs apply these concepts into practice. As such, TRs can identify common risks and take the necessary actions. Nevertheless, critical thinking was deemed essential to deal with new and unexpected situations, for which RT-specific knowledge is essential.

8.1.2 Factors influencing professional mobility across Europe

Despite stakeholders stating that **differences in education** *'definitely hinders movement'* (FL5), these differences are only significant when the programme characteristics hinder registration abroad. Most stakeholders stated that they would achieve registration to practice RT in another country (all stakeholders were at academic level EQF6 or higher). Only one participant speculated about the need to '*take another course*' (FL2) due to the small proportion of RT in their programme.

Some countries lack TRs, while others struggle with unemployment due to an excess of graduates. This **workforce imbalance** is a significant driver for professional movement, despite the educational differences across Europe. Some countries heavily rely on a foreign workforce: *'We had five agency members of staff, and only one of them was a UK national'* (UK3).

The complexity of the **registration process** abroad is a barrier to movement, not the education itself. The main issues are the cost, the lengthy and complicated process, the bureaucracy, and the lack of information available: *'it's quite complicated'* (FL1); *'A lot of red tape-like and a lot of money'* (UK2). Except for migrant TRs and professional association representatives, most stakeholders acknowledged that they did not know enough about the registration process abroad.

Registration is facilitated when there is high mobility between two specific countries because both countries are better prepared: *'I noticed that the school was more prepared when it was me [a few years after another participant]. […] they even had the forms'*[5] (PT7). In other cases, employers, colleagues or an '*agency has looked after them with getting registered*' (UK3).

However, some countries do not require registration (such as Poland), relying on the employer to check adequate training. Other countries ask '*neither for certification nor the professional warrant*'[6] (PT6) to practise specific TR roles, such as research posts. However, registration and checks are necessary to practise on the linac in all other countries (Portugal, Finland, UK, Switzerland and Belgium).

Standardisation of education or a **pan-European approach to registration** '*would help the movement across Europe*' (FL5) since there would be an '*immediate transferability*

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[5] 'notei que a escola estava mais preparada quando foi na minha altura. […] já tinham os formulários e tudo' (PT7)

[6] 'Nem certificação nem cédula profissional' (PT6)

of skills' (UK5), facilitating the recognition of qualifications and '*[foreign TRs] could come and work straight away [...]. That would alleviate my concerns, knowing that we do have a reduced workforce'* (UK3). Examining and recognising the knowledge of core subjects at an international level would also promote mobility.

8.1.2.1 OTHER FACTORS

Language issues were the most mentioned factor influencing mobility – more important than training, according to many participants. TRs tend to move '*to a country where they know the language*'[7] (PT7), often English-speaking countries. Nevertheless, as long as a basic command of language is acquired, mobility is not affected since language skills '*improve with time*'[8] (PT5). Some employers accept TRs with poorer language skills due to a severe lack of workforce, offering the necessary support, yet, this does not happen everywhere.

Personal reasons such as family, including a '*significant other*' (FL2), children or '*an elderly relative*' (UK3); stakeholders who felt that a previous '*exchange wasn't a beautiful experience*' (FL2); or **personal finances** impact the decision to move: '*with a mortgage, it's slightly more difficult*' (UK3). The Finnish stakeholders have little interest in moving '*it's in the **culture**. We want to stay in Finland*' (FL3).

[7] 'para um país onde saberia falar a língua' (PT7)
[8] 'melhora com o tempo' (PT5)

Since the data collection occurred during the transition period, Brexit was considered a factor affecting mobility into the UK. The '***political*** *uncertainty*' (UK2) may dissuade people from moving because '*it's going to be perhaps expensive and risky*' (UK2), and the UK '*may appear a potentially less welcoming or desirable place to live'* (UK4).

Salary and career progression affect the decision to leave and destination country choice: countries with higher income were mentioned as attractive destinations. Cost of living and taxation were identified as aspects to be considered when moving.

8.1.3 Factors influencing patient care and safety

Lower **competency levels** lead to inferior patient care. When graduates do not develop the essential RT competencies, their ability to provide high-quality care becomes compromised and raises patient safety concerns. Additionally, a misalignment between competencies developed in the courses and those needed in practice may compromise patient safety. When TRs move to other countries, '*some people might find it very dangerous*' (FL2); *'when education is different, we can't do the same thing'* (FL1). Participants stressed the role of regulatory bodies and employers in checking TRs' competency to practice, irrespective of their origin. The factors influencing the competency level are discussed below in section 8.1.4 "Education characteristics affecting competency level in RT tasks".

Despite the educational differences in RT, stakeholders agreed that **patient safety subjects** are included across all programmes, given the use of ionising radiation in humans: *'Patient safety is probably always on your mind […] always at the forefront, top of the list'* (UK3). This perception also reassured the stakeholders regarding safety when movement occurs: *'I don't think that it could be any problem. Patient safety is [developed] in all of the courses'* (PL5).

Professional mobility does not seem to compromise patient safety because foreign TRs must comply with the practice requirements of the destination country. '*I've worked with therapeutic radiographers that have come from […] Europe and beyond. There's no reason to believe that […] Europeans are going to cause a risk to patients'* (UK4). A diverse workforce can actually improve care by having TRs with various skill sets (and languages) working together to improve care. Nevertheless, '*it's very much down to the individual*' (UK4) and '*you do sometimes see people having restrictions put on their practice, or in the worst-case scenario being struck off*' (UK2). Employers' were considered vital in identifying and reporting cases of unsafe practice.

Standardisation of competencies across the EU would ensure patient safety and adequate care by guaranteeing that all graduates '*met a certain standard*' (UK5), irrespective of their country of education. The lack of standardisation at the national level leads to variation between universities within the same country.

Standardisation of education is complex and may only be possible in an '*ideal world*' (UK2) since TRs' roles vary considerably between countries due to tradition. Despite these difficulties, stakeholders believed that agreement on the **common core RT competencies** would improve harmonisation while leaving enough **flexibility** for countries to adapt the programme to the local needs. A **minimum EQF6 academic level** across the EU was also suggested since most countries already established this minimum, which provides an autonomy and responsibility level adequate to the critical roles undertaken by TRs. Nevertheless, other aspects are necessary to ensure a complete alignment across the EU.

8.1.3.1 OTHER FACTORS

One stakeholder stated that professional mobility could be an issue if there is a *'**language** barrier, but in other ways, I don't think so.'* (PL5). However, language issues seem to be rare: *'I've only ever really encountered [language] to be a problem in one individual.'* (UK4).

It is also crucial to establish intra-departmental **risk management** mechanisms. Some of the procedures mentioned included reporting accidents and near misses, implementing measures to prevent future incidents, and transfer this knowledge to educational institutions.

Research is also vital to create the necessary evidence to improve TRs' practice, improving patients' care and outcomes: '*we've got to continually improve patient care. The only way you can do that is to understand your professional practice and research it*' (UK1).

Lastly, all professionals have limitations that can be overcome by **teamwork**. Working collectively was considered particularly important when RT competencies are poorly developed and roles are shared with other professionals.

8.1.4 Education characteristics affecting competency level in RT tasks

Although every model '*has its downsides and upsides*' (FL2), stakeholders agreed that the **education programme characteristics** strongly influence graduates' competency level. In turn, competency levels have an impact on patient care.

Despite being clear that '*there's always bias to the models that you know*' (UK1), stakeholders frequently discussed alternative models to the more traditional EQF6 degree. The programme structures discussed and countries identified by stakeholders were as follows:

- Programmes below BSc (EQF4 and EQF5) – Germany, Poland and Spain;
- RT-only BSc programmes (EQF6) – Portugal (before 2014) and the UK;
- Multiple-specialism BSc programmes (EQF6) – Finland, Malta and Portugal (after 2014);
- RT-only apprenticeships (EQF6) – UK;
- Multiple-specialism BSc followed by an MSc programme (EQF6 → EQF7) – Poland;
- Integrated Master's (EQF7) – no country identified by stakeholders;
- RT-only pre-registration MSc (EQF7) – UK;
- 'Common trunk' model (EQF6 or EQF7) – The Netherlands.

Most of these models are commonplace, but the less common models may need explanation. In the '*common trunk*' model discussed by the participants, the student starts a programme that covers all radiography specialisms (common trunk) and, at some point, they specialise in one specialism/modality. The benefits identified for this model included:

i. Increased RT-specific competencies (lacking in some multiple-specialism programmes):

> *it's very important that you know a lot of radiation and patient safety, but then, for example, one last year, you can focus in radiotherapy. (FL1)*

ii. Increased imaging competencies (lacking in some RT-only programmes):

> *It would make sense to have a common trunk because we would increase the knowledge of MRI, CT… and then, yes, choose an option*[9] *(PT2)*

iii. Expose students to different specialisms before choosing their specialisation while developing their area of expertise at a deeper level:

> *they should go through everything to see what's done […] but after all, it would be good to focus on something (FL4)*

The *'common trunk'* model can be used at any academic level, including in *integrated master's* model: an EQF6 programme that automatically progresses into an EQF7 programme. Since the *'common trunk'* is not widely implemented, participants discussed several variations in the duration; specialisms included; when students start specialising; if they can start practising after the completion of the EQF6; which specialisms can graduates practise; or if they have immediate access to advanced roles. Stakeholders agreed that this model could increase the competency level, but there are financial and political barriers since these programmes are longer and more expensive.

The *pre-registration Master's degree* is an EQF7 post-graduation programme that allows non-radiography EQF6 degree holders to train and be eligible to register as a radiographer. These degrees may develop specific skills (such as research) at higher levels than the traditional EQF6. However, these graduates cannot be equated to a

[9] 'Faria sentido termos um tronco comum, porque ganhamos em termos de conhecimento de RM, TC, e depois sim, escolher uma opção' (PT2)

person who followed both EQF6 and EQF7 programmes in RT since *'they will only have actually two years [of RT training]'* (UK4).

8.1.4.1 REGULATION OF LEARNING OUTCOMES AT THE NATIONAL LEVEL

Tradition affects competency development, yet education has the power to change this tradition. To change tradition, *"you have to change the education [first] because you've got to empower the people"* (UK1) and equip TRs with the skills necessary to take new roles *"because otherwise […] it takes a long time to change the profession"* (UK1).

Regulation of standards of practice (learning outcomes) is the best way to ensure that all EIs develop the necessary competencies. In the UK, all graduates must achieve the same standards of proficiency established by the regulator (HCPC) irrespective of the educational model (Bachelor's degree, master's degree, or apprenticeship). While Portuguese and Polish stakeholders confirmed that the TRs' learning outcomes (skills and competencies) are not regulated. As a result, competency level varies between graduates from EQF5 and EQF6 degrees (in Poland), between graduates of the RT-only and the multiple-specialism programmes (in Portugal) and between graduates from courses with different amounts of RT-specific training (Poland and Portugal).

8.1.4.2 ACADEMIC LEVEL

Stakeholders unanimously agreed that the ideal minimum '*education training should be to degree [EQF] level six*' (UK1), developing competencies at an **academic level** that allows TRs to take responsibility for the critical tasks performed by them. This academic level also allows TRs to act as professionals rather than technicians.

The stakeholders considered academic levels below EQF6, available in Germany, Poland and Spain, as dangerous to patient safety. An emigrant stakeholder observed errors that would be *'unthinkable that a [TR with EQF6] would do this error'*[10] (PT7) due to a lower academic level in that country. In Poland, the academic level affects the responsibility taken since *'some activities […] we could do only when we have a Master's [EQF7]'* (PL5).

8.1.4.3 PROGRAMME DURATION

An increase in **programme duration** was considered beneficial to develop more competencies or develop them at a higher level. However, it would increase costs and delay the output of graduates, worsening the workforce issues in some countries.

Stakeholders expressed their concern for short programmes when these are at a lower academic level: *'As they do in Spain, they study two years and go to the [treatment] units [upset tone of voice]. They have no knowledge of dosimetry, […] of physics, they have no knowledge at all'*[11] (PT5). Shorter courses at higher academic levels were less of a concern; for example, the 2-year pre-registration Master's degree was considered to have '*the same standards of education and training*' (UK4). However, in the UK, graduates must achieve the same competencies irrespective of the educational model, agreeing with the statement that '*time in years doesn't necessarily equate to an output*' (UK1). This shows how education characteristics are intertwined. The course duration

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[10] 'É impensável que um técnico [com nível EQF6] fizesse este erro' (PT7)

[11] 'como fazem em Espanha, estudamos dois anos e vamos para as unidades. Eles não têm noção de dosimetria, não têm noção de física, não têm noção nenhuma' (PT5)

was interlinked with other characteristics such as academic level, teaching methods (passive vs active), and the number of specialisms in the programme.

8.1.4.4 SPECIALISMS IN THE PROGRAMME

In all programmes, the contents must be carefully selected due to time limitations. However, stakeholders identified that programmes with **multiple specialisms** struggle more with this issue and often cover the subjects only superficially (‘*you know a little bit of everything, but you don’t know everything about one thing*’ – FL2) or dedicate the majority of time to MI with little RT content: *‘There were like 20 [credits in radiotherapy] when whole school [programme] was 210 [credits]’* (FL5). Multiple-specialism graduates seem to be more competent in imaging-related competencies, being this the main argument in favour of this model.

The impact of specialism was evident in the Portuguese interviews, where a change from an RT-only to a multiple-specialism course led to a significant reduction in RT-specific competencies and stakeholders pointed out the misalignment between graduates’ competencies and those practised by TRs with the previous course. Stakeholders stated that patient safety is at risk if these graduates practise RT, both ‘*abroad and within the country*’[12] (PT2) and that *‘it shouldn’t be possible for people to practise without a post-graduation or a Masters’ degree in the area they choose to practise’*[13] (PT3). The new

[12] ‘lá fora e cá dentro’ (PT2)

[13] ‘mas não deveria ser possível as pessoas exercerem sem fazer uma pós-graduação ou um mestrado na área que escolherem como eleição’ (PT3)

programme also seemed to decrease graduates' job competitiveness nationally and internationally: *'I do not understand why a UK employer would offer a job to a student with this training'*[14] (PT4).

RT-only programmes appear to develop more RT-specific competencies and '*equips professionals well, at practitioner-level, so they can then build on that in their areas of expertise at advanced practice, and then consultant level*' (UK1). The RT-only model was considered essential to support the UK's four-tier career structure, which requires high competency levels in RT, preparing graduates to undertake advanced roles in this specialism. However, this model may not be suitable when workforce needs are not sufficient to have a separate education programme for each specialism: '*you would need to have a four-year programme with both components mixed-in because the output that you need for Malta is much smaller*' (UK1)

8.1.4.5 RT-SPECIFIC TRAINING

The amount of **RT-specific training** seems to be the main factor affecting RT-specific competencies. This depends on available time, which is contingent on the academic level, programme duration and specialisms. However, other factors play a role: '*curriculum is becoming more diluted. […] there's been a lot more emphasis on multi-*

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[14] 'não percebo porque e que um empregador no reino unido iria dar trabalho a alunos com esta formação' (PT4)

professional working […] but it does mean that […] content that relates to radiotherapy […] is being lost' (UK4).

In Poland, *'some universities focus more […] on diagnostic aspects or radiotherapy aspects'* (PL1) depending on their proximity to an RT department. As such, some graduates are more competent despite having the same academic level. This variation is caused by a lack of regulation of learning outcomes. A British stakeholder responsible for the induction of newly employed TRs stated that, despite the regulations, *'there are still very much large differences'* (UK5) due to variation in students' exposure to different practices during clinical placements.

Portuguese and Finnish stakeholders identified the lack of time in their multiple-specialism programmes as the main cause for the reduced RT-specific content. Finnish students '*can take six weeks [of placement] more on whatever they want to*' (FL3), allowing them to develop their RT competencies if they chose this specialism. In Portugal, the main concern was that *'the internships are becoming shorter and shorter'*[15] (PT3). However, a considerable reduction in the theory underpinning RT also occurred with this change.

The decrease in RT-specific education may compromise the professionals' ability to perform RT-specific tasks or grow into advanced practice: *'my concern is […] will future therapeutic radiographers, who are coming through the current training programmes*

[15] 'os estagios sao cada vez mais curtos' (PT3)

[…], have that skillset and knowledge to be able to take on those [advanced] tasks in the longer-term?' (UK4). This decrease also compromises research in this area, compromising the production of evidence that supports TRs' daily practice.

8.1.4.6 LACK OF LECTURERS WITH EXPERTISE IN RT

Some RT lecturers are *'quite alone'* (FL3) while clinical educators are missing: *'We do have hospitals here that don't employ people who are focused on education. […] That can pose a bit of a challenge in terms of the experience students get.'* (UK2). This **lack of expertise** affects both theoretical and practical learning. If the RT team is small, they cannot be qualified in the numerous areas of expertise within the RT science, keep updated in this '*fast-paced changing environment'* (UK4), or attend to all students as needed.

8.1.4.7 TEACHING METHODS

Teaching methods impact competency levels and were discussed by stakeholders. Learning through clinical practice improves graduates' competence since students '*come and see and do themselves*' (FL5) and learn from the diverse practices across multiple RT centres. Nevertheless, clinical placements come with challenges: lack of communication between clinics and universities, link between theory and practice, staff willingness to support students, or adequate assessment criteria to ensure RT competencies are developed.

Stakeholders suggest that **'active' teaching** can improve training efficiency and replace the 'passive' observation and copy method. This can be further improved with **simulation**, which *'could reduce the amount of time on clinical placement provided for* *the students'* (UK4). However, there are some caveats: the upkeep of simulation equipment is expensive, difficulties obtaining clinical data, simulations do not perfectly match reality, and requires an increase in academic staff input.

8.2 DISCUSSION

Figure 8.1 describes the complex interactions between the themes identified in the thematic analysis. Starting from the top of figure 8.1: regulation of the education or the professional entry requirements often define the characteristics of the educational programmes offered in the country. These course characteristics directly affect TRs' ability to register abroad, influencing graduates' mobility. Course characteristics also affect the competency level, which in turn influences the care that graduates provide to RT patients.

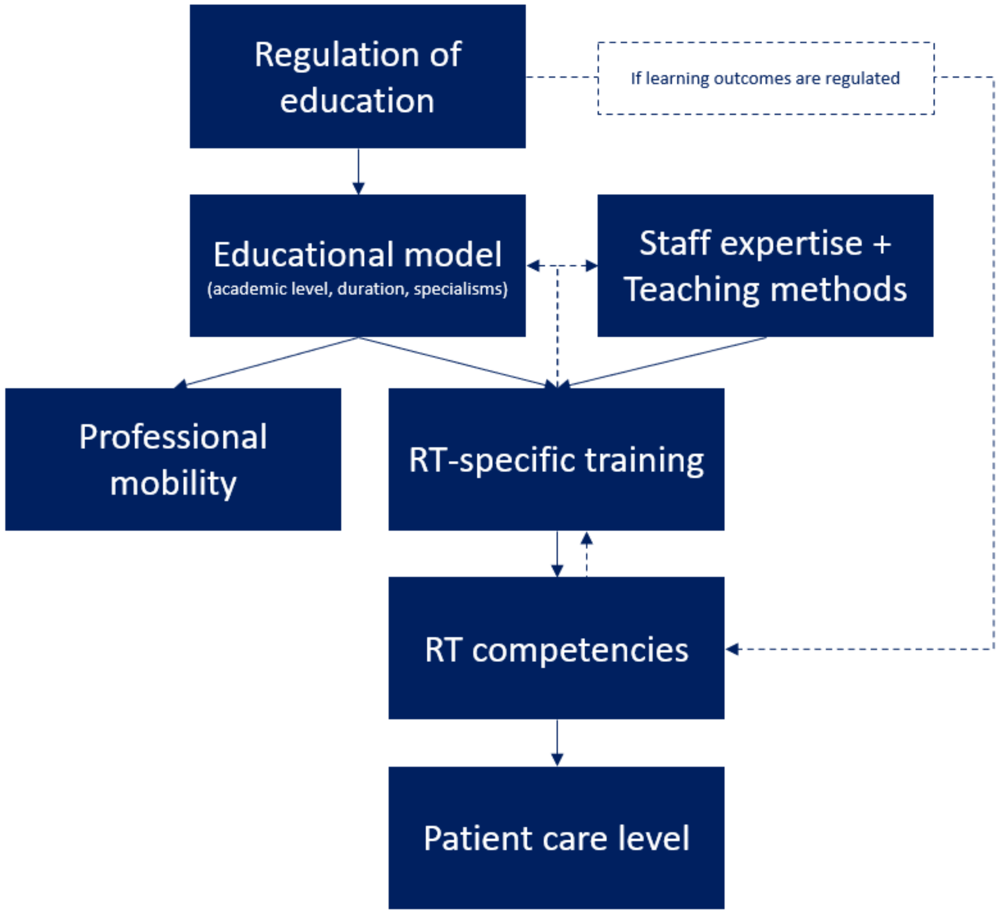

Figure 8.1 – The impact of education characteristics on professional mobility, competency level and patient care

However, when learning outcomes are regulated (represented by the dashed lines in Figure 8.1) they directly influence competencies that must be developed by students. Instead of the course characteristics defining which competencies are developed, the competencies that need to be developed define the course characteristics that must be implemented to achieve these goals.

It is important to note that despite regulation, EIs normally have enough autonomy to develop competencies above those required to practise. However, EIs tend to develop only the competencies required by the national regulation.

Course characteristics impact the competency level, which consequently affect the quality of patient care. Courses with a lack of RT-specific training have lower RT competency levels, confirming results from the survey (Chapter 7). As such, adequate attention must be given to the programme characteristics, such as academic level, programme duration and specialisms, and the curriculum design to ensure adequate RT-specific competencies.

The ideal programme duration seems to be the right balance between developing the necessary competencies to practise safely in the shortest period. This period can be shortened if the programme is delivered at a higher academic level since students have already developed some transferable skills. The use of active teaching and simulations may also improve learning efficiency, but these have a high financial cost. Therefore, education quality should not be measured in terms of programme duration but in outcomes achieved.

Stakeholders also stated that when graduates' training is not aligned with the tasks performed in clinical practice, patient safety is compromised. Therefore, graduates must be equipped to practise in their country but also abroad, given the current international job market.

Regulation of professional practice at the national level is crucial to ensure the necessary competencies are developed irrespective of the education model used, such as in the UK. While the lack of regulation observed in Portugal and Poland allows different education models to graduate professionals with varying competency levels.

International regulation of the learning outcomes would further standardise the level of care across Europe.

It became clear that there is a gap between the competencies developed in European courses and those considered essential for practice. Therefore, there is potential to close this gap and improve patient care by continuously improving TRs' education.

Course design is complex due to time restrictions within the programme. Therefore, choices must be made regarding which subjects are included in the curriculum (White, 2017). Consequently, some competencies cannot be fully developed in the qualifying degree and should be further developed at postgraduate levels – for example, research competencies.

Nevertheless, a consensus is difficult due to differences in stakeholders' priorities depending on their country's tradition, background, and roles. For example, the employers' training priorities are not the same as educators' priorities.

Tradition also varied between countries, especially regarding TRs' autonomy, showing that the competency needs may be country-specific. While Polish and Portuguese TRs are less involved in pharmacological patient care, these roles can be taken by TRs in the UK (at advanced levels but still requiring the underpinning knowledge). Another example is the limited decision making autonomy in certain countries, which leads to critical thinking skills being perceived as non-essential.

Tradition is a barrier for TRs to develop specific competencies, and since TRs are not trained in these competencies, the tradition is maintained in a vicious cycle. However, if the cycle is broken and TRs are equipped with the necessary skills to perform roles usually undertaken by other professions, there is potential to change practice.

8.2.1 Underdeveloped competencies of TRs

There were multiple reasons for the lack of development of the competencies identified. A lack of RT-specific study units was a significant factor affecting *Pharmacology*, *Management and Leadership*, *Image Verification* and *Critical Thinking* competency level. Curiously, stakeholders believed that an excess of multidisciplinary training hinders the development of RT-specific competencies despite evidence that this type of training can be beneficial (Mercieca et al., 2019). Not because multidisciplinary learning is harmful, but because of the reduction in RT-specific knowledge, which is essential to apply the competencies above to RT situations (Chapter 7). For example, graduates must have enough RT lectures to learn about the different types of errors (random, systematic, intra-, inter-fraction) so they can critically evaluate verification images and take informed decisions.

Pharmacological management of side effects may be developed in an unstructured fashion during placements; as such, students graduate with different competency levels, even within the same country or institution. This phenomenon of unstructured learning was previously observed in an earlier survey (White, 2017).

Management and leadership skills are essential at all levels of RT practice. Participants also emphasised that these are crucial to achieve advanced practice, agreeing with the findings from Hilder et al. (2018). It is also essential that these competencies are developed in the RT-specific context rather than in generic study units.

Regarding image verification, other authors also agreed that these competencies are not fully developed at the end of the initial degrees, especially advanced modalities, and graduates require on-the-job training after graduation (Burnet et al., 2010; Cox and Jimenez, 2009). However, it is acknowledged that TRs can safely take this role after training (Cox and Jimenez, 2009). Technological advances such as the introduction of artificial intelligence in image verification and other tasks performed by TRs (Francolini et al., 2020) require the development of the necessary digital skills. Digital skills and advanced roles are being further researched in other work packages of the SAFE EUROPE project.

Traditional roles taken by TRs and other professions seem to be one of the causes of inadequate *Equipment QA* competencies. In 2014, in the UK, only 6% of the QA of advanced RT procedures were performed by TRs (while physicists performed 88%) (Abolaban et al., 2016). This tradition was identified as the main reason why TRs only develop basic QA competencies (such as daily QA).

Inter-professional issues also affect *critical thinking* when TRs do not have the autonomy to make decisions, as mentioned by Finnish and Polish stakeholders. The lack of autonomy to take decisions removes the justification to include these competencies in the education programmes. Autonomy is an essential characteristic that distinguishes a profession from an occupation (Hughes, 1984; Jackson, 2010). In the interviews, it was clear that TRs are still under dominance from other professions, removing their autonomy and authority necessary to apply critical thinking (Adams, 2008; Foucault and Faubion, 2002; Freidson, 1994).

Lack of time, resources and access to clinical data seem to be the main reason for the underdeveloped *Research* competencies, even though research methods are well developed in theoretical study units. Of all the competencies mentioned, research competencies are the best studied, and many publications confirm the need to invest in developing these skills among radiographers (ACORRN Research Radiographer Working Party, 2007; Ooi et al., 2012; Probst et al., 2015). Despite being an underdeveloped competency, there is also evidence that these competencies can be developed after graduation, and an increase in TR-led research has been observed in recent years (Duffton et al., 2020). TRs-led research is essential to develop the body of knowledge of the profession and improve patient outcomes (Malamateniou, 2009).

Safety subjects (including radiation safety and professional and ethical practice competencies) are well developed across Europe (England et al., 2016 and Chapter 7). This may have led stakeholders to state that safety is well covered. In addition, the European Commission established guidelines on radiation protection training which may help harmonise this domain of education (Directorate-General for Energy, 2014). However, patient safety does not stop there, and stakeholders confirmed that the underdeveloped competencies discussed in this research directly impact patient safety. Furthermore, ensuring patient safety, meaning that no harm is caused (Vincent, 2010), is only the first step in achieving the highest level of care possible.

As such, developing these competencies have a great potential to improve safety and quality of care; some examples may include: QA competencies ensure that the equipment is safe to deliver ionising radiation to patients; critical thinking prepares them to evaluate patients’ condition or setup before irradiation; pharmacology skills allows them to identify adequate medication to deal with symptoms of disease or RT side effects. Therefore, despite the differences in tradition across Europe, patients would benefit from increased competency levels.

8.2.2 Professional mobility

Course characteristics only affect mobility when the graduates' academic level, programme duration, and developed competencies do not comply with minimum requirements at the destination country. This agrees with the results of Chapter 5, which showed a low rate of rejected applications across Europe, but a high rejection rate when radiographers come from countries with i) unregulated profession (only Romania in EU), ii) low academic level radiography programmes, or iii) countries with different specialisms (European Commission, n.d. h).

The lack of standards of practice in some countries may also hinder the movement to other countries since each programme may develop different competencies. Therefore, it is recommended that member-states develop their national standardisation of education. Ideally, the national standards should be at EQF6 using the multiple international guidelines available (Directorate-General for Energy, 2014; EFRS, 2018; ESTRO, 2014; IAEA, 2014) since there is evidence that the use of these guidelines improves graduates' competency (Chapter 7).

Course characteristics are not the only factor affecting mobility. Other factors include language, complex registration processes, personal reasons, political factors, salary, and career progression.

8.2.3 STANDARDISATION OF EDUCATION

Standardisation of education seems to be the ‘silver bullet’ that would improve professional mobility and patient safety by ensuring equal competencies across European courses. Standardisation would facilitate radiographers’ mobility from countries with mass unemployment to countries with a lack of workforce, which is already a significant factor in promoting mobility (European Commission, n.d. h). This harmonisation would also ensure that competencies developed match the tasks practised across Europe, supporting patient safety.

However, standardisation is difficult due to different national needs and traditions, such as working practices and team configurations. Stakeholders suggested that the common core RT-competencies should be standardised to facilitate international recognition while providing flexibility for the courses to adapt to local needs. Some flexibility would also allow for a skill mix in the workforce that is beneficial for the profession.

The EU issues regulations and recommendations related to RT practice and education, which helps standardising TRs’ education directly or indirectly (Directorate-General for Energy, 2014; European Council, 2013; European Higher Education Ministers, 1999; European Parliament and European Council, 2008). However, since countries have autonomy to adapt the transposition of these regulations, differences are still created.

Standardisation could be implemented through a European exam, which would require a standardised education, so all TRs across the EU would achieve the same outcomes. Both Canada and the USA require an exam to access the profession, showing that this method is not unprecedented (ARRT, 2021; CAMRT, 2020). Some professions (such as medicine and nursing, but not radiography) are regulated at the European level and can attain automatic recognition of qualifications across the EU (European Parliament and European Council, 2005). This automatic recognition is very close to the pan-European registration suggested by one stakeholder. Nevertheless, TRs can apply for the general system of recognition of qualifications (same directive), which is not as efficient, but allows for professional mobility after checking of the applicants' qualifications.

8.2.4 ALTERNATIVE EDUCATION MODELS

Despite most European courses consisting of EQF6 multi-specialism education programmes (McNulty et al., 2016 and Chapter 7), stakeholders believed that other models could benefit the RT workforce. Multi-specialism programmes have considerably reduced RT-specific content caused by the limited amount of time to cover all specialisms, compromising RT competency. These results support the findings from Chapter 7. Various stakeholders defended the RT-only EQF6 degrees as beneficial due to the high RT-specific training.

A 'common trunk' model was also recommended, combining the benefit of multiple-specialism training while allowing students to specialise in one area. The 'common trunk' model was often associated with an integrated Master's model, requiring longer educational programmes (4 or 5 years). This model is used in the Netherlands, where students choose a 'profile theme' (such as CT, MRI, RT) in the last two years of their four-year programme (EUNICAS, 2011; Janaszczyk and Bogusz-Czerniewicz, 2011).

The term 'common trunk' was previously used to describe the educational model that aggregated general and special education in the USA, allowing students to develop common core competencies followed by a specialisation in different areas of general or special education (such as visual impairment or significant support needs) (Educator Preparation Committee, 2018). This model is also a 5-year Integrated Master's degree (Attallah College of Educational Studies, 2018).

Other models are appropriate for developing the RT workforce depending on national situations, including the multi-specialism Bachelor's degree, the apprenticeships and the pre-registration Master's degrees. However, irrespective of the education model, the essential competencies must be developed to ensure mobility and adequate care.

8.2.5 Recommendations for practice and further studies

Education institutions should revise their programmes if they believe that these competencies are underdeveloped and that developing them benefits the professionals or the patient. Alternatively, postgraduate education or Continuing Professional Development (CPD) can be available to all European TRs, to ensure that these competencies can be developed after graduation. Research is recommended to identify possible methods to develop these competencies in initial and postgraduate degrees. Programmes must also be continuously revised and updated to keep up with the technological and clinical advances.

Education institutions should ensure that their curriculum does not develop these competencies (solely) as part of generic curricular units; application to RT is essential to prepare students for safe practice. This is important since the knowledge underpinning the application of these competencies to RT differs considerably from other specialisms and professions.

Students should be allowed longer time-frames and sufficient resources to perform their research projects by starting a research project earlier in their course. This may require an increase in academic staff able to support this research. Agreements between education and clinical institutions could be established to facilitate access to data.

Based on the results, it seems vital that all countries regulate the essential competencies to be developed in the degrees. Additionally, a pan-European standardisation of the curriculum for the education of TRs would be beneficial to avoid the discrepancies observed between counties. Additional research may be necessary to identify a curriculum that is consensual between parties while allowing flexibility and time to develop other competencies which are required in each country.

Since education and research competencies were discussed together, stakeholders preferred to focus on research. As such, it is recommended that further research is done focusing on stakeholders' perception of education competencies.

8.2.6 Limitations

Only four out of 28 EU countries were included in the study. Even though the countries were carefully selected for maximum variation, extrapolation is possible but carries some limitations if the country to which we aim to extrapolate markedly differs from the selected countries (Table 3.2). This qualitative study aimed for a deeper exploration of the results from the survey distributed across 19 EU countries; as such, the results complement each other.

Stakeholders' perceptions and opinions are subjective, and not all stakeholders addressed financial and organisational aspects of course design. As such, the implementation of the recommendations may not always be feasible.

Education of TRs, professional regulation, mobility of graduates and patient safety are incredibly complex phenomena. Their interaction is even more complex. Best efforts were made to ensure that the implications of these phenomena were adequately identified and discussed; however, the existence of other interactions or other factors cannot be excluded. Continuous research into this subject is recommended.

Language may have been a limitation since some participants found it challenging to express themselves in English. The interviewer kept a supportive attitude and asked to repeat until the message was clear. The Portuguese interviews, performed in Portuguese, were analysed in the original language to avoid translation issues.

Limitations inherent to the data collection tool, the interviews, include response bias such as providing answers they believe are more acceptable (social desirability bias) or drive the answers to a particular personal message (demand bias). Multiple interviews and triangulation with previous phases were done to reduce its impact on the results.

The methodology also aimed to identify the least developed competencies and possible causes, not establish a consensus. Further research is necessary to achieve this.

8.3 CONCLUSION

Standardisation of education can significantly impact RT training across Europe by facilitating registration abroad and professional mobility. It would also ensure that mobility is safe by ensuring that professional standards are met across Europe.

However, this standardisation must be flexible enough to be accepted by individual countries due to different national needs. Furthermore, some level of diversity (beyond the core competencies) may actually improve the skills mix of the workforce.

Considering that many EU countries do not yet regulate the learning outcomes at the national level, leading to discrepancies in graduates' competencies, it is strongly recommended that each member-state standardise education within the country, ideally using international guidelines.

The current education of TRs does not fully develop all essential competencies identified in this study. There is great potential to improve patient care by improving TRs' competencies, especially those considered of concern across Europe: pharmacology, equipment QA, management and leadership, research, image verification and critical thinking. Adequate RT-specific training in the programme is essential to develop essential RT competencies. However, education institutions must also equip TRs with the skills necessary to perform roles beyond the traditional scope of practice in their country.

Lastly, but importantly, the level of care provided to RT patients depends on the course characteristics. Careful selection of the education model and curriculum design is vital to ensure high-quality patient care. Programmes should be at least EQF6 to develop an adequate level of professional autonomy and responsibility. Additionally, the programme characteristics (duration, specialisms and RT-specific training) must allow the development of the core RT competencies. Further research into alternative education models which may allow for improved education is also recommended.

CHAPTER 9. GENERAL DISCUSSION AND CONCLUSIONS

At the start of this project, only a few publications existed addressing the education of radiography from a European-wide perspective (EFRS, 2015; England et al., 2017; HENRE, 2008b; McNulty et al., 2017, 2016), with a few more dedicated specifically to radiotherapy education (Bibault et al., 2018; Eriksen et al., 2012; Janaszczyk and Bogusz-Czerniewicz, 2011; Pötter et al., 2012). Therefore, this research increased the body of knowledge in this scientific area.

This project's research question, "How do education characteristics (and other education-related factors) affect competency level, professional mobility and patient care?" was answered at the end of this multiphase study. The answer to this question was split into two parts, addressing the impact on competency level and patient care in section 9.1 and the impact on professional mobility in section 9.2. Secondary objectives that deserve a dedicated discussion include the underdeveloped competencies across Europe (section 9.1.1), the impact of regulation on RT education (section 9.3) and professional titles across Europe (section 9.4).

9.1 HOW DO EDUCATION CHARACTERISTICS IMPACT COMPETENCY LEVEL AND PATIENT CARE?

This section answers part of the main research question, "how do education characteristics affect competency level and patient care?". The impact of education on competency level and patient care will be discussed together since education affects competency, which in turn has an impact on patient care. While lower competency levels may lead to lower-quality care, a misalignment between the competencies developed and those practised also puts patient safety at risk (Chapter 8).

The notion that course characteristics influenced graduates' competencies have been previously identified (Sá dos Reis et al., 2018), but a relationship between course characteristics and RT competencies was unclear before the current study. The survey data established a quantitative relationship between course characteristics and competency levels (Chapter 7); this was further explored during the interviews with stakeholders, who identified other factors influencing competency levels (Chapter 8). Table 9.1 summarises these factors in no specific order.

Table 9.1 – Factors affecting competency level of graduates.

Factors identified in the survey	Factors identified in the interviews

- Academic level
- Number of specialisms
- RT-specific training
  o Proportion of the programme dedicated to RT
  o Duration of RT placement
- Existence of national professional registration (national regulation)
- Programme duration
- Duration of clinical placement
- Proportion of placement in skills labs (teaching methods)
- Use of international recommendations in course design
	- Academic level
	- Number of specialisms
	- RT-specific training
	- Regulation of learning outcomes
	- Programme duration
	- National tradition
	- Lack of resources (time, human, financial)
	- Lectures with RT expertise
	- Teaching methods

The survey showed that courses often develop different competencies despite having similar academic levels, duration and specialisms. In other words, course characteristics do not equate to competence. As such, recognition of qualifications between countries cannot be limited to comparing course characteristics, and regulation of the profession should include more than these basic characteristics.

Stakeholders further identified that the different course characteristics are strongly interlinked, and their relationship is complex. For example, higher academic levels or active teaching methods can compensate for shorter courses or courses with multiple specialisms. These factors and their connections must be considered when designing courses.

Prior literature showed that European TRs are mostly taught as part of multi-specialism programmes, often with RT being a short component of the whole curriculum (Coffey et al., 2018; Eriksen et al., 2012; McNulty et al., 2016). Authors argued that pre-registration programmes are often insufficient to practise RT specialisms, requiring additional training (Coffey et al., 2018; Katzman et al., 2013; Kivistik, 2018). The current study confirmed that multi-specialism programmes have less RT-specific curriculum and placements than RT-only programmes ($p<0.05$). A pronounced lack of RT training was observed in multiple-specialism programmes, with an average of only 25% of the programmes dedicated to RT. Indeed, most multi-specialism programmes (7 out of 13) provided less than 250 hours of placements in RT. Nevertheless, graduates from these courses can practise RT despite the limited training in this specialism, confirming McNulty et al.'s (2021) findings. This study also confirmed a strong correlation between the amount of RT-specific training with the level of various RT-specific competencies, radiation safety, professional and ethical practice, and patient care competencies ($Rs>0.4$, $p<0.05$) (Chapter 7). Stakeholders also associated a lack of RT-specific content with low competency levels in pharmacology, management and leadership, image verification and critical thinking applied to RT. An increase in RT content is strongly recommended in many radiography courses across Europe to ensure adequate competency levels so graduates can practise this specialism at an adequate level to provide RT patients with the best possible outcomes.

Stakeholders agreed with international recommendations that an EQF6 academic level should be required to practise as a TR (Directorate-General for Energy, 2014; EFRS, 2018; ESTRO, 2014; IAEA, 2014). Courses below EQF6 showed a significantly lower competency level for only one of the competency themes, Quality and risk management ($p=0.042$). However, by definition, the EQF academic level is linked with the level of autonomy and responsibility (European Parliament and European Council, 2008); as such, stakeholders emphasised that an EQF6 level is recommended given the autonomy and responsibility required to practise the roles of these professionals.

Programme duration was moderately correlated ($0.2>Rs>0.4$, $p<0.05$) with the level of some transverse skills, such as research and risk management. Stakeholders agreed that extending the programmes' duration would be favourable, yet this would delay the supply of workers and increase the programmes’ cost. They also stated that shorter programmes are less problematic if the course includes substantial active teaching, is dedicated to RT, or is delivered at post-graduation levels since students have already developed some competencies at the undergraduate level.

The survey showed a correlation between the use of skills labs with a decrease in pharmacology competencies. Stakeholders believed this may be due to simulation replacing clinical placements, also observed in previous research (Chaka and Hardy, 2021; McNulty et al., 2021; Vestbøstad et al., 2020). Nevertheless, stakeholders identified that simulation could be used as an active teaching method, improving students’ competencies, especially in short courses and multiple-specialism programmes. The use of active learning through simulation is encouraged, making learning more efficient. However, all teaching methods should be validated to confirm that they achieve the learning goals (Bridge et al., 2020; Chaka and Hardy, 2021; England et al., 2017; Kane, 2018). The use of simulation should complement patient contact, not replace it. Programmes using simulation extensively must assess if competencies that are developed in clinical practice, such as pharmacology, are still developed adequately.

9.1.1 Underdeveloped Radiotherapy competencies and competency variation across Europe

This section answers three of the research sub-questions that aimed to guide the individual phases:

- What are the competency levels of EU graduates with regards to linac tasks?
- Why are some competencies less developed across Europe?
- Are these competencies essential, and at what level should they be developed?

Numerous competencies were identified from the literature as being the responsibility of TRs working on the linear accelerator. However, these competencies were scattered across multiple publications, including guidelines and benchmarking documents relevant to RT education. A systematic search of the literature collated these competencies (Chapter 6), which were used in the survey to evaluate at which level these competencies were developed across Europe (Chapter 7). The survey showed that none of the European guidelines for the education of TRs were fully implemented across all education institutions, and countries develop different competencies at different levels.

Pharmacology, equipment quality assurance, research and education, and management and leadership competencies were the most underdeveloped competencies identified across Europe by the survey. The stakeholders confirmed that these competencies are underdeveloped across Europe and added image verification and critical thinking to the list of underdeveloped competencies. Even though patient safety was considered well developed across Europe by the stakeholders, all other RT competencies are necessary to provide patients with the highest levels of care. Many stakeholders considered these underdeveloped competencies as essential, showing the potential to improve RT treatments by enhancing TRs' education.

Research is a critical competency in TRs' education since performing research allows the profession to create the necessary evidence to improve their practice (Malamateniou, 2009). Research methods are usually covered in the countries where the interviews were conducted. However, students do not always perform research as part of their first degree, leading to underdeveloped competencies. The main reasons were lack of resources: supervision/human resources, time, equipment and access to data. Funding is necessary to provide the necessary resources; access to data could be facilitated through bilateral agreements with clinical departments; and students could start the supervised research project earlier in their courses, allowing enough time for study design, ethical review, and data collection and analysis. Research competencies are often further developed during post-graduation programmes, which should be encouraged by universities and employers.

Given the importance of competent TRs in providing the best care to RT patients, the inclusion of these competencies in current programmes is strongly recommended.

However, it may be impossible to include all competencies in the primary degree due to time constraints. Pathways must be available to allow students to develop all essential competencies, either in their first degree or through additional training, such as postgraduate education, on-the-job training, or CPD. Nevertheless, the underpinning concepts must be developed during the first degree because not all students pursue post-graduation education. The primary degree is also essential to establish the basic concepts needed to undertake post-graduation training.

The SAFE EUROPE project provides free webinars to address these underdeveloped competencies, which can be used as teaching material in existing educational programmes.

9.2 IMPACT OF EDUCATION ON PROFESSIONAL MOBILITY

This section answers the research question: “How do education characteristics affect professional mobility?". No literature was found discussing the movement of radiographers across the EU. As such, the patterns of movement of these professionals and the implications of education to this movement were unknown. A key document regarding this topic was the 2005/36/EC directive (European Parliament and European Council, 2005), which establishes the requirements to obtain recognition of qualifications in other member states: i) the profession must be regulated in both origin and destination country, ii) the academic level must be similar, and iii) any differences in “professional qualifications” must not compromise the population’s health or safety.

According to the survey, substantial variation exists in the programme characteristics and professional qualifications between European countries required for the automatic recognition of qualifications. In addition, the data collected from the RPD confirmed that movement is not always automatic (Chapter 5). Possible explanations for the professional mobility difficulties included low academic levels, differences in professional qualifications and lack of professional regulation in certain countries. Stakeholders confirmed these factors. Harmonisation of education would remove barriers and facilitate movement.

In most countries, national regulation is in line with the 2005/36/EC directive. They often establish educational requirements to practise in terms of academic level, programme duration, ECTS, and other objective course characteristics. Only a few countries regulate competencies, some countries regulate other types of learning outcomes (skills, knowledge), and a few countries do not regulate learning outcomes at all (Chapter 4). Course programmes characteristics are often designed to comply with the countries' national requirements. However, according to the EU vision, programme design should also ensure that graduates are eligible to register abroad.

Stakeholders confirmed that registration procedures are complex, lengthy and costly, and information is restricted, hindering movement (Chapter 8). Easy-to-access, clear information should be made available for TRs wishing to move across Europe. Simplification of the registration process would facilitate movement. This can include harmonising standards, better communication between regulatory bodies, pan-European registration, or European exams to access the profession, all of which have their challenges, benefits and disadvantages.

According to some stakeholders, language was another main factor influencing mobility, possibly more than education differences (Chapter 8), influencing radiographers' choice of the destination country. Language learning should be encouraged across the EU as recommended by the High Level Group on the Modernisation of Higher Education (2013).

Personal, financial and political factors, including salary and career prospects, also impact the individuals' decision to move and choice of the destination country. These factors were previously identified for other professions (Chiswick and Miller, 2015). Attractive working conditions, salaries, and career pathways are essential to retain or captivate radiographers.

On the one hand, stakeholders stated that when movement occurs between countries with very different competency sets, patient safety may be at risk due to a misalignment between competencies developed and practised. Once again, European-level regulation of the essential competencies would improve patient care and safety across all countries and minimise the risk of competencies misalignment when movement occurs. In contrast, they also confirmed that competency issues are rare, defending that skill diversity above the core competencies may improve patient care and emphasising the role of the regulators and employers in ensuring adequate qualifications of all practitioners. The lack of regulation of standards of practice observed in many countries (Chapter 4) may allow people with a lack of competency to practise, making national regulation instrumental in guiding employers and regulators.

The patterns of movement of radiographers within the EU were drawn from the Regulated Profession Database data (Chapter 5). Many radiographers move from south-outer to north-central Europe, often from low-income to wealthier countries. This phenomenon may be linked with another pattern identified by stakeholders: from countries with high unemployment to those lacking TRs. These patterns must be acknowledged when planning workforce education (Eyal and Hurst, 2008). Additionally, this mobility leads to brain drain and a high education cost for the supplying country (Kovács et al., 2017). Reduction of vacancies in countries with mass unemployment and increased recruitment actions in countries with a lack of graduates may be recommended. Financial compensations may help offset the supplying countries' education costs while replenishing the workforce in the receiving countries.

9.3 IMPACT OF REGULATION ON RADIOTHERAPY EDUCATION

The role of professional regulation in achieving good professional practice and patient safety is well established across healthcare professions (Short and McDonald, 2012). However, a recent narrative literature review showed the scarcity of research on the regulation of radiography (McInerney et al., 2021). Even though this was not an aim of the research, since many conclusions from this body of work related to professional and education regulation, this seemed appropriate to dedicate a section to discuss the impact of regulations on competency level, professional mobility and patient care.

Some professions are regulated at the European level (European Parliament and European Council, 2005), but not radiography. As such, variation in the regulation of the TR profession and education exists across member states (Chapter 4), which is reflected in the various educational structures found across Europe (Chapter 7 and 8), in agreement with existing literature (EFRS, 2015; HENRE, 2008a; Janaszczyk and Bogusz-Czerniewicz, 2011). These educational differences result in mobility difficulties (Chapter

5 and 8), different RT competency levels (Chapter 7 and 8), and care levels (Chapter 8), at least for the TRs' role studied here, i.e. radiotherapy delivery in the linear accelerator.

The lack of harmonisation of education regulation at the European level is due mainly to different national requirements and traditions (Chapter 8). This tradition influenced radiography in the past and will probably define the profession in the future (Decker and Iphofen, 2005; James et al., 2012; Larkin, 1978; Price, 2001).

From the current study, all EU countries except Romania were found to regulate the profession (Chapter 4); however, not all have professional registry (Chapter 7). The lack of professional registration negatively affected many competencies (both RT-specific and transversal); this was the factor that correlated with the largest number of competencies. Therefore, it is recommended that all countries establish a professional registration for TRs to improve the competency level of graduates and harmonise them across the country.

However, stakeholders identified that regulation should be made at the European level to facilitate professional movement and ensure adequate patient care. This harmonisation of education and profession must acknowledge the different needs and traditions. Standardisation across Europe must focus on the core competencies common to all countries while allowing flexibility to develop additional skills needed by individual countries. This "flexible harmonisation" could facilitate endorsement by the different countries while creating a diverse workforce that holds the core competencies but contributes with slightly different skill sets that improve the care provided. This diversity of abilities and expertise also increases knowledge production (Sam and Sijde, 2014), which is essential to provide the evidence to improve TRs' practice continuously.

Curricula design in terms of "learning outcomes" is the current educational model in Europe (CEDEFOP, 2016; European Centre for the Development of Vocational Training, 2017), replacing the previous paradigm of defining "teaching objectives". However, this educational framework is not yet fully implemented in radiography education regulation. Chapter 4 identified that some countries do not regulate learning outcomes, and even when these are regulated, different formats are used. Some countries regulate learning outcomes that reflect professional autonomy and responsibility (competencies), but others do not. It is recommended that the standards of practice are defined using Knowledge, Skills and Competencies (KSC) dimensions according to the European Qualifications Framework (European Parliament and European Council, 2008). Competencies (only) may be an alternative because they imply the application of knowledge and skills to practice and reflect autonomy and responsibility (European Centre for the Development of Vocational Training, 2017; European Parliament and European Council, 2008). The regulation of knowledge only (list of subjects) is discouraged since they are not enough to reflect autonomy or responsibility; competence would be a by-product, not the aim of the training (Zitterkopf, 1994).

Additionally, regulation of learning outcomes permits alternative educational models since all programmes would need to achieve the same competency goals irrespective of the course characteristics. These alternative education models could benefit students and the profession (Chapter 8).

The different stakeholders demonstrated different priorities regarding RT education (Chapter 8). As such, the design of the learning outcomes must be a joint effort between regulators, education institutions, professional associations, TRs, managers, students, patients, and other relevant stakeholders. This is in line with the European vision and the recommendation by the High Level Group on the Modernisation of Higher Education (2013) to design curricula based on dialogue and partnerships between all market actors.

There are various benchmarking documents of international scope for the education of TRs (Directorate-General for Energy, 2014; EFRS, 2018; ESTRO, 2014; IAEA, 2014). These documents are non-binding, have different scopes, and their recommendations are not in perfect alignment but rather complement each other. The implementation of these guidelines and their impact on graduates' competency was not studied before.

This study showed that different educational institutions follow different documents (Chapter 7), and course design is still primarily based on national requirements (Chapter 8), which often do not regulate learning objectives (Chapter 5). Therefore, the survey also showed that using any of the international benchmarking documents in course design correlated with higher competency levels in many domains ($p<0.05$). As such, education institutions should use benchmarking documents and other literature when designing educational programmes to improve the competency level of graduates, not only the national regulations. Harmonisation of European benchmarking documents among organisations may help to improve their implementation.

These international documents identify the benchmarking and ideal standards of practice. However, stakeholders acknowledged that these might be removed from reality across Europe (Chapter 8). Stakeholders stated that European standardisation is exceptionally challenging because of the different roles practised across member states. As mentioned before, the proposed European standards must include the core competencies (shared across all countries) while allowing flexibility to develop specific competencies to meet the countries' traditions and needs.

9.4 PROFESSIONAL TITLES

Another secondary finding from this research was the variation in the title used to describe the profession of TR across Europe. Many publications exist about this subject, primarily grey literature, as discussed in section "2.2.4 Title of radiographer".

The titles used across Europe were identified when researching national regulations (Chapter 4). Identification of all titles was also required to ensure that a comprehensive search strategy was employed to gather literature regarding the competencies of TRs in the linear accelerator (Chapter 6). Stakeholders also discussed the variation in titles and the associated implications during the interviews (Chapter 8).

The variation in titles found in the literature and the RPD reflects a variation of the BoK, competency, authority, autonomy and responsibility. This discrepancy may suggest that there is not one radiography profession but several professions, represented at the European level by a common title.

Some countries only have MI titles (e.g. "Radiology Technologist") with no title reflecting the RT component. Some countries have titles that reflect a lack of autonomy (e.g. "Technician" or "Assistant") (Chapter 4). During the interviews, RT stakeholders did not self-identify with the "radiographer" title used in this study (Chapter 8). Arguably, the title "radiographer" (radio- for "radiation", "graph" for image) may reflect only the medical imaging branch of the profession. Some stakeholders also do not identify with their official national title and use unofficial titles: both Portuguese and Polish prefer

“Radiotherapist” to the official “Radiotherapy Technician” and “Electroradiologist”, respectively.

Title harmonisation for these professionals may be beneficial to represent these professionals at the European level. However, national titles must be respected because they represent professionals with similar but different characteristics. Complete harmonisation of titles may only happen when there is also harmonisation of the professional characteristics mentioned above. The European title must reflect the body of knowledge, authority, responsibilities and autonomy of the titleholders; it must be generic to include all specialisms in radiography or have separate titles reflecting each specialism; and must be widely accepted so all professionals endorse them.

9.5 LIMITATIONS OF THE STUDY

Many roles of TRs were not included in the study since studying all of the TRs’ roles would make the research at the depth intended unfeasible. A more superficial data collection of all roles has been completed previously (Bibault et al., 2018; Janaszczyk and Bogusz-Czerniewicz, 2011; McNulty et al., 2021, 2016). The researcher opted to focus on the most common role of TRs and study it in depth. Many of the findings can be extrapolated to other roles, but further research is recommended.

It is acknowledged that TRs’ education is a continuous and life-long process. However, for feasibility reasons, this study assessed their competencies at the time of graduation only in order to have comparable results between countries. If post-graduation training is considered, the competency differences observed in Chapter 7 may be different. The stakeholders discussed the impact of life-long learning, explaining that some underdeveloped competencies are developed after graduation. Advanced practice and post-graduation education will be studied in more detail as part of another SAFE EUROPE study.

Difficulty accessing data across many countries and many languages was another limitation of the study. Some countries did not provide enough data to triangulate all the requirements to practise (Chapter 4), some countries did not submit updated information to the Regulated Professions Database (Chapter 5), publications about the role of TRs in languages other than English were excluded from the systematic search (Chapter 6), and only 19 of the 28 then EU countries were represented in the survey (Chapter 7). As part of the preliminary research, it was evident that the data was difficult to access; therefore, pragmatism was the selected philosophical approach since this perspective defends that research should not be stopped if the data is not complete. However, the findings should be continuously evaluated and updated as more data becomes available (Mills et al., 2010).

Education of TRs is a very complex subject, and, as observed in the interviews, the factors affecting patient care and competency level are very interlinked. Therefore, the possibility that additional factors beyond those found in this research may influence competency levels cannot be excluded.

RT patients are a central stakeholder in TRs' education. They were not included in this study since another SAFE EUROPE research work package focuses on their perspective. The findings of that study will complement these results.

The financial implications of many recommendations were not measured. For example, an increase in programme duration, active teaching or academic staff, the conversion of multiple-specialism into single-specialism programmes, and even the research needed to have an evidence-based European-wide regulation may be costly and a barrier for change. This was not the aim of the study, but its impact is recognised.

The UK left the EU close to the end of the research. The last data was collected during the transition period, just after the British exited the Union; as such, most responses would still reflect the UK as a member state. The UK is one of the few countries that regulate learning outcomes, has an RT programme separate from MI, and allows multiple educational models to train TRs. The UK leaving the EU does not affect the findings of this study but may affect its applicability in the future. Their exclusion from a possible harmonisation of education across Europe would impact the outcome.

9.6 RECOMMENDATIONS FOR FURTHER STUDIES

The philosophical approach used in this research, pragmatism, proclaims that research is a continuous process and no conclusions are final (Mills et al., 2010). Therefore, further research into the effect of education across Europe on competencies, patient care and professional mobility is recommended. Given the difficulties in accessing data for this research inherent to this topic, research replication would be beneficial to confirm, complement or contradict these results. A deeper exploration of the factors affecting competencies in each country, performed by local researchers with greater local insight, may be suggested to confirm these results.

Continuous research is essential to identify the common standards and keep them updated. A consensus regarding the essential competencies across the EU would be crucial to establish the core competencies implemented in a possible European-wide regulation. These essential competencies are distinguished from the ideal competencies already identified by benchmarking documents. A Delphi method, including all stakeholders and decision-makers, could be an appropriate research design. This future study would also identify which competencies should be further developed at postgraduate levels.

Regulation of the profession at the European level was one of the main themes that emerged from the study. Despite an almost unanimous agreement of the benefits of harmonisation, it seems a very challenging objective. A study focusing on the barriers to implementing such a harmonisation may be suggested. This future study must include professional associations, regulators, and decision-makers at the national and European levels.

Further research is strongly recommended to assess the benefits of the alternative educational models to train TRs mentioned by the stakeholders inChapter 8. Many stakeholders described alternative models enthusiastically and believed that they might achieve higher competency levels, resulting in improved care. A multi-dimensional evaluation should be performed, including assessing the financial implications of these models for education and healthcare services.

Research on a consensual title to be used at the European level is recommended. This could improve acceptance of a title that reflects these professionals' bodies of knowledge, competencies, autonomy, and authority.

9.7 CONCLUSION

Education has a massive impact on professional mobility and RT competencies, the latter directly affecting patient care. As such, improvements in education would impact the professional practice and also RT patients' outcomes.

Education improvements are necessary for many programmes that show low competency levels. These improvements are crucial to providing RT patients with adequate care; this change can happen at the institutional, national, and European levels.

This study provided evidence regarding which factors can be adopted by educational institutions to improve RT competency levels. However, throughout the study, it became clear that regulation of competencies is the foundation to ensure that all graduates achieve the necessary autonomy and responsibility to practise RT at an adequate level, irrespective of the educational model used. As such, regulation is essential at the national level and ideally at the European level to harmonise care and facilitate professional mobility.

PUBLICATIONS AND PRESENTATIONS

The research in this dissertation was disseminated through publications and presentations at national and international conferences. The peer-reviewed publications and the presentations (past and future) are listed below.

The PhD researcher led the study design, data collection, data analysis, findings and conclusions, the compilation of the manuscripts, abstracts and presentations, submission to journal/conference, and management of review process. All done under the guidance of the supervisory team, who were directly involved in all the steps outlined above. In specific publications and conference papers, additional authors are listed who have significantly contributed to those studies.

PEER-REVIEWED PUBLICATIONS

Couto, J.G., McFadden, S., Bezzina, P., McClure, P., Hughes, C., 2018. An evaluation of the educational requirements to practise radiography in the European Union. Radiography 24, 64–71. https://doi.org/10.1016/j.radi.2017.07.009

Couto, J.G., McFadden, S., McClure, P., Bezzina, P., Hughes, C., 2019. Competencies of therapeutic radiographers working in the linear accelerator across Europe: A systematic search of the literature and thematic analysis. Radiography 26, 82–91. https://doi.org/10.1016/j.radi.2019.06.004

Couto, J.G., McFadden, S., McClure, P., Bezzina, P., Camilleri, L., Hughes, C., 2020. Evaluation of radiotherapy education across the EU and the impact on graduates' competencies working on the linear accelerator. Radiography 27, 289–303. https://doi.org/10.1016/j.radi.2020.08.010

Couto, J. G., McFadden, S., McClure, P., Bezzina, P., Beardmore, C., & Hughes, C. (2022). Competency level in radiotherapy across EU educational programmes: A cross-case study evaluating stakeholders' perceptions. Radiography, 28(1), 180–186. https://doi.org/10.1016/j.radi.2021.10.015

PRESENTATIONS

An evaluation of the requirements to practise Radiography in the EU. **ECR 2017**, Vienna, Austria. https://doi.org/10.1007/s13244-017-0546-5

Competencies of Radiation Therapists practising on the linear accelerator. **SEETRO 2017**, Sofia, Bulgaria. http://seetro.org/2017/schedule/competencies-of-radiation-therapists-practicing-on-the-linear-accelerator/

Thematic analysis of the competencies of the therapy radiographer practising in the linear accelerator. **ECR 2019**, Vienna, Austria. https://doi.org/10.1186/s13244-019-0713-y

Competencies of radiotherapy professionals working on the linear accelerator across the European Union. **CNART 2019**, Lisbon, Portugal. https://art-radioterapia.pt/wp-content/uploads/CNART2019_GC__EN_FINAL.pdf

WP3 — Graduates' competency on linear accelerator tasks across the EU: effect of different course characteristics. **SRM's International Conference on Medical Imaging and Radiotherapy 2020**. St Julian's, Malta. https://doi.org/10.14614/RADINTCONFMALTA/2020/

A review of the recognition of professional qualifications across the EU: how the 2005/36/EC directive affects the movement of radiographers across Europe. **SRM's International Conference on Medical Imaging and Radiotherapy 2020**. St Julian's, Malta. https://doi.org/10.14614/RADINTCONFMALTA/2020/

Patterns of movement of radiographers and professional qualifications recognition across the European Union. **ECR 2020**, online. https://doi.org/10.1186/s13244-020-00851-0

Radiotherapy education in the EU: impact on practitioners' mobility and patient safety. **ECR 2021**, online.

National regulations and its impact on quality and competency level of Radiation Therapists. **SAFE RADIOTHERAPY WebART 2021**, online. https://art-radioterapia.pt/webart2021/

The impact of tradition and national requirements on radiotherapy education. **UKIO 2021,** online. www.ukio.org.uk/

Education of therapeutic radiographers in EU: competency and recognition of qualifications between member states. **CNATARP 2021**, Peniche, Portugal.

Competencies and Regulations. **Final SAFE EUROPE Radiotherapy conference**, May 2022, Copenhagen, Denmark

AWARDS

Radiographer Research Presentation Abstract Award. ECR2021, online. www.myesr.org/awards

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APPENDIX 1. TRADITIONAL EUROPEAN HE MODELS

THE NAPOLEONIC MODEL

This model was created to distinguish between university and vocational education. It was first developed in France, and a strong centralised approach characterises it. The *Grandes Ecoles* were the utmost representatives of these elite institutions and essential for professional formation (Sam and Sijde, 2014; The National Committee of Inquiry into Higher Education (UK), 1997). In addition to the French universities, the Napoleonic model was used in Eastern countries, such as Russia, Romania, Hungary, and South European countries, such as Italy, Portugal, and Spain. (Jakab et al., 2005; Le Feuvre and Metso, 2005; The National Committee of Inquiry into Higher Education (UK), 1997).

The HEIs were considered public entities: governments controlled the curricula, the assessment methodologies and teaching procedures (Sam and Sijde, 2014) and divided faculties by subject, giving them very low autonomy (Le Feuvre and Metso, 2005). This strict type of model ensured that all students across the country would be provided with the same content and were equally qualified (Le Feuvre and Metso, 2005; Sam and Sijde, 2014).

When applied to radiography, every radiographer across the country would have the same competencies. If this method were applied across the EU, it would ensure that all European radiographers would have the same knowledge and the same competencies facilitating professional movement.

In the golden age of the Napoleonic model, the government was the only stakeholder. Universities had to comply with the educational regulations directly issued by the government but also with the professional regulations issued by the professional regulators, but heavily influenced by the government. Non-compliance with the educational regulation or the professional regulation would result in a denial to practise (Sam and Sijde, 2014).

Another aspect of this model is the separation of universities from research institutions. Research institutions were independent institutions with multidisciplinary research staff. In contrast, universities conducted minimal research, confined to their disciplines (Le Feuvre and Metso, 2005). The HEIs were a high-level vocational education with the single aim of training professionals (Sam and Sijde, 2014). Traces of this model can still be observed in the contemporary education of radiographers since these courses emphasise the development of a set of knowledge, skills, and competencies to practise a specific profession.

THE HUMBOLDTIAN MODEL

The Humboldtian model named after the founder of the University of Berlin, Wilhelm von Humboldt, was devised in Germany but also applied in the Netherlands, Czechoslovakia, Hungary, Poland, Sweden and Finland (Keskinen and Silius, 2005; Le Feuvre and Metso, 2005; The National Committee of Inquiry into Higher Education (UK), 1997; Vasilache et al., 2012).

The Humboldtian model is characterised by the HEI complete independence from the government. This independence includes the freedom to design course curricula and decide research topics and methodology, publishing their results even if they are not in the best interest of the governments. This model promoted the fusion of education and research activities inside HEIs. Although the HEI has freedom and autonomy, they are exclusively funded by the state, which indirectly profited from the knowledge production (Le Feuvre and Metso, 2005; Sam and Sijde, 2014).

Humboldt stated that “the professors are not there for the students, but rather both are there for science” (Humboldt, 1809/1990, p. 274 as cited in Ash, 2006, p. 246). This means that students and professors work together to create new knowledge, as this production of new information is the system’s primary objective (Sam and Sijde, 2014).

In this model, there is a clear separation between the two possible pathways that the students can follow: vocational education, where the objective is to develop a skillset to execute a job; or university education, to produce knowledge by research and by educating students so they can also produce knowledge on their own (Sam and Sijde, 2014).

Elements of this model are still observed, with HEIs being crucial sources of knowledge production. This research is also often funded by national governments and international organisations such as the EU, which indirectly benefit from knowledge production.

THE ANGLO-SAXONIC MODEL

The Anglo-Saxonic model, also known as the Personality Development model, is more market-centred. This model emphasises the achievements of the student and the needs of the stakeholders, such as employers, service users, students and the government (The National Committee of Inquiry into Higher Education (UK), 1997). This model was driven by social usefulness, measured by the willingness of the market to buy the product (Le Feuvre and Metso, 2005).

The model has its origin in the UK (Oxford and Cambridge universities). However, other countries, such as Norway and Ireland, also followed this model (Le Feuvre and Metso, 2005; Sam and Sijde, 2014). The term “Anglo-American model” can also be found since the model is extensively applied in the USA (Le Feuvre and Metso, 2005). However, North-American HEIs also have traits of the other models discussed before (Ash, 2006; Carlsson et al., 2009; Sam and Sijde, 2014).

Universities are autonomous in managing curricula, staff, institutional aims, and even organisational structure, but they need to answer the society needs as identified by multiple stakeholders (Le Feuvre and Metso, 2005; Sam and Sijde, 2014). Additionally, the government can oversee the HEIs activities through regulation and quality control, often performed through independent institutions (Sam and Sijde, 2014). The need to self-manage while answering stakeholders’ needs makes the model highly competitive.

This model focuses on developing the personality of the student. The students are frequently exposed to different problems, and the objective of the Anglo-Saxonic model is to develop problem-solving skills to be applied when practising their profession (Sam and Sijde, 2014). In radiography, it is impossible to prepare the students for every possible situation they will face in practice, largely because it is a constantly changing discipline influenced by continuous technological evolution. The development of personal skills prepares graduates to evolve with standards of practice even when the practice is no longer what they have learned.

This model is divided into two cycles. The undergraduate cycle is considered the cycle that prepares students to enter the job market by giving them the necessary skills to practise (Kurelić, 2009). This first cycle also prepares students to proceed to the second cycle: postgraduate programmes such as Master's and doctoral programmes. (Sam and Sijde, 2014).

APPENDIX 2. SURVEY

Competencies developed in European educational institutions for radiographers working in the linear accelerator

Invitation and information Letter

Dear participant,

I am currently reading for a PhD in Education of Radiographers in Europe at Ulster University in Belfast, UK. This survey is part of my dissertation and is the result of a collaboration between the European Federation of Radiography Societies (EFRS) and the Ulster University research team, reflecting the importance given by both groups to the education of radiographers in their diverse roles.

This study is of utmost importance for the development of the profession that has the ultimate goal of providing our patients with the best care possible.

Aim and Objectives

The aim of this survey is to investigate differences in competencies developed by educational institutions across the Europe for radiographers practising in the Linear Accelerator. The specific role on the Linear Accelerator is being studied since this is the most common role of the radiographer in radiotherapy. Across this questionnaire, “radiographer” is understood as the professional performing tasks in the linear accelerator. Other titles for "radiographer" can be found including Radiation Therapist, Radiology Technologist, Radiology Technician, Radiologist's assistant amongst others.

Besides identifying the level at which the competencies are developed across Europe, this study has the objective to the determine differences between educational programmes and their influence in the development of competencies. This study will be performed at European level, providing information that will help to also understand the impact of these differences in migration.

Rationale of the study

This research is of utmost importance for all actors in our profession since it will allow to identify the existence of gaps in education, allowing education institutions to close those gaps and improve the movement of radiographers. It is also relevant for the radiographers themselves as they can become aware of which are the competencies developed across Europe and develop those required to be able to practice in other countries. The employers benefit from this research since they can use it as a reference for the in-house training and when employing a non-national radiographer. National and international professional associations can also use this information in order to promote the development of the profession at an European level. The regulators can use the information collected to develop the requirements to practise the profession using a standard that is appropriate for all European countries. Ultimately, the patient will benefit from this study by an improved education of radiographers across Europe resulting in a better practice and improved outcomes.

Ethical considerations

The identity of the respondents and institution will be kept confidential at all times. No identification of the institution or any information that allows the indirect identification of the educational organisation will be published. For example, if only one institution in the country answers the questionnaire, the country will not be identified as it may allow identification of the institution.

All data collected will be safely stored through password protected software, will be assessed exclusively by the researcher and will be used solely for the purpose of this study.

At the end, you will have the option to provide your email to receive the results (also on voluntary and confidential basis) and this will not be associated with the responses given in this questionnaire. Furthermore, the results will be published in an international journal and in the dissertation submitted as part of this PhD.

The submission of this questionnaire indicates that you have read this information letter and that you consent for the data to be collected and used from this study.

The questionnaire will take approximately 20 minutes to complete. You can withdraw from from the study at any moment before submission. In addition, the respondents that opt to submit the institution name can also withdraw from the study at a later stage by contacting the researcher. Data provided by a respondent who withdraws will not be included within the analysis. Participants who complete the questionnaire anonymously will not be able to withdraw from the study once they submit their data.

I want to take this opportunity to thank you for your participation which is of utmost importance for the success of this research.

If you have any questions about the study or you wish to withdraw from the study please do not hesitate to contact me using the following contact details:

Mr. Jose Guilherme Couto
Room 15, Faculty of Health Sciences, University of Malta,
MSD2080, Msida, Malta
Jose.g.couto@um.edu.mt
(00356) 2340 1846

Regards,
J Guilherme Couto

*Required

Part A – Educational institution characteristics

1. **Country:** *

Mark only one oval.

- Austria
- Albania
- Belgium
- Bulgaria
- Croatia
- Cyprus
- Czech Republic
- Denmark
- Estonia
- Finland
- France
- Germany
- Greece
- Hungary
- Iceland
- Ireland
- Italy
- Latvia
- Liechtenstein
- Lithuania
- Luxembourg
- Macedonia (FYROM)
- Malta
- Montenegro
- Netherlands, The
- Norway
- Poland
- Portugal
- Romania
- Serbia
- Slovakia
- Slovenia
- Spain
- Sweden
- Switzerland
- Turkey
- United Kingdom
- Other (questionnaire ends here) *Stop filling out this form.*

Part B - Educational programme information

2. **Institution:**

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3. **Course programme title (in English):** *

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4. **Course duration in years:** *
Mark only one oval.

- ( ) 2 years
- ( ) 2.5 years
- ( ) 3 years
- ( ) 3.5 years
- ( ) 4 years
- ( ) Other: _______________

5. **Does this course allow the graduates to practise radiotherapy in your country?** *
Mark only one oval.

- ( ) Yes
- ( ) No (this questionnaire ends here) *Stop filling out this form.*

Part B - Educational programme information (Cont.)

6. **Besides radiotherapy, which other areas are included in your course programme?** *
(more than one choice allowed) Please identify any other specialisms, besides those mentioned below, that are included in the course programme.
Tick all that apply.

- [ ] Medical Imaging
- [ ] Nuclear Medicine
- [ ] Other: _______________

7. **How much of the workload of the course is...** *
Mark only one oval per row.

	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Dedicated to radiotherapy	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
Dedicates to other specialisms	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
General/common subjects	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )

8. **How much of the clinical placement is...** *

Mark only one oval per row.

	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Dedicated to radiotherapy	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Dedicated to other specialisms	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
General/common subjects	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

9. **Total workload in ECTS for the whole programme:**

(optional) NOTE: 1 ECTS is equivalent to 25 to 30 hours of workload (example: 1 ECTS is equivalent to 5 to 7 hours of lectures or 25 to 30 hours of clinical placement)

Mark only one oval.

- ◯ 120 ECTS
- ◯ 150 ECTS
- ◯ 180 ECTS
- ◯ 210 ECTS
- ◯ 240 ECTS
- ◯ Other: ____________

10. **Academic level achieved at the end of the programme according to the European Qualification Framework (EQF):** *

Mark only one oval.

- ◯ Lower than EQF 4
- ◯ EQF 4 – Secondary course
- ◯ EQF 5 – Short higher education programme
- ◯ EQF 6 – Bachelor's degree
- ◯ EQF 7 – Master's degree
- ◯ Higher than EQF 7
- ◯ I don't know

11. **Are the learning outcomes defined in terms of competencies?** *

NOTE: According to the Recommendation of the European Parliament and of the Council on the establishment of the European Qualifications Framework for lifelong learning, "competency" is related to the ability to perform a task autonomously and take responsibility for it.

Tick all that apply.

- ☐ Yes
- ☐ The subject areas to be covered in the programme are identified
- ☐ The aims and objectives are identified
- ☐ The knowledge to be developed is identified
- ☐ The skills to be developed are identified
- ☐ Other: ____________

12. **Are the learning outcomes of the course in line with EFRS benchmarking document for EQF level 6?** *

Mark only one oval.

- Yes
- No
- Other: ____________________

13. **Are there any legal requirements for the learning outcomes that must be achieved in the course programme?** *

Mark only one oval.

- Yes
- No
- Other: ____________________

14. **Is registration in a professional/regulatory body mandatory to practice in radiotherapy in your country?** *

Mark only one oval.

- Yes
- No
- Other: ____________________

Part C – Specific technical competencies of the radiographer working on the linear accelerator

Competency is related to the ability to perform a task AUTONOMOUSLY and take RESPONSIBILITY for it, however, during education and training, each competency can be developed at different levels.

From the list of competencies below, identify the level of competency of the graduate (at the end of the course programme). Please remember that this is applied to the competencies used during practice in the linear accelerator.

Below you can find the description of the different levels of competency presented:

NOT DEVELOPED: The graduate competency is not developed.

PARTIALLY DEVELOPED: The competence was developed but the graduate does not achieve autonomy or responsibility.

COMPETENT: The competence was developed and the graduate is responsible and autonomous in all cases (very complex cases may still require a higher level of expertise).

DEVELOPED IN CLINICAL PRACTICE OR POST-GRADUATE: Some competencies can be developed further in clinical practice or post graduate education. Please choose this option in this case.

15. **Radiation safety on the linear accelerator** *

For each competency, please identify the level at which this is developed in the education programme.
Mark only one oval per row.

	Not developed	Partially developed (No autonomy/ responsibility)	Competent (Autonomous/ responsible)	Developed in the clinical practice or post-graduate education
Perform risks and hazards analysis and reduce risk to patients, public and staff	◯	◯	◯	◯
Be able to justify a treatment based on own analysis and refuse to carry out unjustified exposures	◯	◯	◯	◯
Maintain ALARA principle in daily practice	◯	◯	◯	◯

16. **Comments regarding "radiation safety on the linear accelerator" competencies or additional competencies developed.**

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17. **File verification prior to daily treatment** *

For each competency, please identify the level at which this is developed in the education programme.
Mark only one oval per row.

	Not developed	Partially developed (No autonomy/ responsibility)	Competent (Autonomous/ responsible)	Developed in the clinical practice or post-graduate education
Go through the patient's file prior to irradiation and report any inconsistencies	◯	◯	◯	◯
Critically assess plans for clinical acceptability (plan report, dose distribution and dose-volume histograms)	◯	◯	◯	◯
Carry out necessary data transfer checks	◯	◯	◯	◯

18. **Comments regarding "file verification prior to daily treatment" competencies or additional competencies developed.**

19. **Positioning and immobilisation on the linear accelerator** *

For each competency, please identify the level at which this is developed in the education programme.

Mark only one oval per row.

	Not developed	Partially developed (No autonomy/ responsibility)	Competent (Autonomous/ responsible)	Developed in the clinical practice or post-graduate education
Confirm that the appropriate immobilisation is selected for the patient being treated	⬭	⬭	⬭	⬭
Accurately position the patient according to treatment plan and simulation	⬭	⬭	⬭	⬭

20. **Comments regarding "positioning and immobilisation on the linear accelerator" competencies or additional competencies developed.**

21. **Radiotherapy treatment delivery on the linear accelerator** *

For each competency, please identify the level at which this is developed in the education programme.

Mark only one oval per row.

	Not developed	Partially developed (No autonomy/ responsibility)	Competent (Autonomous/ responsible)	Developed in the clinical practice or post-graduate education
Confirm the choice of therapeutic, imaging and ancillary devices is appropriate for the patient	◯	◯	◯	◯
Check if appropriate treatment parameters were selected	◯	◯	◯	◯
Administer treatment accurately and safely	◯	◯	◯	◯
Constantly observe the patient during treatment	◯	◯	◯	◯
Interrupt treatment, if required, in an emergency	◯	◯	◯	◯

22. **Comments regarding "treatment delivery on the linear accelerator" competencies or additional competencies developed.**

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23. **Image verification of patient setup on the linear accelerator** *

For each competency, please identify the level at which this is developed in the education programme.

Mark only one oval per row.

	Not developed	Partially developed (No autonomy/ responsibility)	Competent (Autonomous/ responsible)	Developed in the clinical practice or post-graduate education
Acquire planar (2D) images	⬭	⬭	⬭	⬭
Acquire volumetric (3D) images	⬭	⬭	⬭	⬭
Analyse and assess planar (2D) verification images	⬭	⬭	⬭	⬭
Analyse and assess volumetric (3D) verification images	⬭	⬭	⬭	⬭
Make decision regarding the action to take following image analysis, within the protocols	⬭	⬭	⬭	⬭
Develop patient setup verification protocols	⬭	⬭	⬭	⬭

24. **Comments regarding "image verification of patient setup on the linear accelerator" competencies or additional competencies developed.**

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25. **Equipment quality assurance (QA) of the linear accelerator** *

For each competency, please identify the level at which this is developed in the education programme.
Mark only one oval per row.

	Not developed	Partially developed (No autonomy/ responsibility)	Competent (Autonomous/ responsible)	Developed in the clinical practice or post-graduate education
Perform daily QA procedures of treatment units	⬭	⬭	⬭	⬭
Report and take corrective actions in view of QA results	⬭	⬭	⬭	⬭
Carry out in vivo dosimetry	⬭	⬭	⬭	⬭
Perform daily QA of imaging systems	⬭	⬭	⬭	⬭

26. **Comments regarding "equipment quality assurance (QA)" competencies or additional competencies developed.**

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Part D – Generic technical competencies

The following list corresponds to technical competencies that may NOT be SPECIFIC to the linear accelerator radiographer, however, are still tasks performed by the radiographer working in the linear accelerator.

This part of the questionnaire is optional, however, your answers are of utmost importance for our study and for that reason I would appreciate the time taken to answer this part of the questionnaire.

27. **Professional and ethical practice on the linear accelerator**

For each competency, please identify the level at which this is developed in the education programme.

Mark only one oval per row.

	Not developed	Partially developed (No autonomy/ responsibility)	Competent (Autonomous/ responsible)	Developed in the clinical practice or post-graduate education
Recognise limitations of their scope of practice and seek advice when necessary	⬭	⬭	⬭	⬭
Accurately prepare, document and administer radiotherapy	⬭	⬭	⬭	⬭
Practise using scientific, ethical and moral standards as established within the institution	⬭	⬭	⬭	⬭
Maintain confidentiality at all times	⬭	⬭	⬭	⬭
Document all relevant information as per protocols	⬭	⬭	⬭	⬭

28. **Comments regarding "professional and ethical practice on the linear accelerator" competencies or additional competencies developed.**

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9. **Patient care on the linear accelerator**

For each competency, please identify the level at which this is developed in the education programme.

Mark only one oval per row.

	Not developed	Partially developed (No autonomy/ responsibility)	Competent (Autonomous/ responsible)	Developed in the clinical practice or post-graduate education
Adopt a holistic approach with the patient	⬭	⬭	⬭	⬭
Act as an advocate for the patient and empower the patient	⬭	⬭	⬭	⬭
Perform appropriate patient identification	⬭	⬭	⬭	⬭
Continuously assess patient physically, psychologically and socially	⬭	⬭	⬭	⬭
Give advice to patient in regards to management of side effects	⬭	⬭	⬭	⬭
Perform patient review after last treatment (follow-up)	⬭	⬭	⬭	⬭
Give appropriate information prior, during and after treatment	⬭	⬭	⬭	⬭
Develop patient information material	⬭	⬭	⬭	⬭
Seek consent prior to any procedure	⬭	⬭	⬭	⬭
Provide first aid to patients, if necessary	⬭	⬭	⬭	⬭
Perform appropriate infection control prior, during and after each procedure	⬭	⬭	⬭	⬭
Report a change in a patient condition/concern which will impact on treatment	⬭	⬭	⬭	⬭

30. **Comments regarding "patient care on the linear accelerator" competencies or additional competencies developed.**

31. **Pharmacology applied to the linear accelerator**

For each competency, please identify the level at which this is developed in the education programme. ADDITIONAL NOTE: This question refers to any type of pharmaceutical, including but not limited to: pharmaceuticals for patient preparation for radiotherapy or to manage side-effects.
Mark only one oval per row.

	Not developed	Partially developed (No autonomy/ responsibility)	Competent (Autonomous/ responsible)	Developed in the clinical practice or post-graduate education
Administer pharmaceuticals to patient	⬭	⬭	⬭	⬭
Respond to complications of the administration of pharmaceuticals	⬭	⬭	⬭	⬭
Take responsibility for pharmaceuticals-related tasks	⬭	⬭	⬭	⬭

32. **Comments regarding "pharmacology applied to the linear accelerator" competencies or additional competencies developed.**

33. **Research and education**

For each competency, please identify the level at which this is developed in the education programme.

Mark only one oval per row.

	Not developed	Partially developed (No autonomy/ responsibility)	Competent (Autonomous/ responsible)	Developed in the clinical practice or post-graduate education
Carry out research as part of a multidisciplinary team	⬭	⬭	⬭	⬭
Participate in national and international clinical trials	⬭	⬭	⬭	⬭
Present, publish and implement results of research	⬭	⬭	⬭	⬭
Be able to teach and supervise students and staff	⬭	⬭	⬭	⬭

34. **Comments regarding "research and education" competencies or additional competencies developed.**

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Part E – Generic non-technical competencies

The following list corresponds to NON-TECHNICAL competencies that may NOT be SPECIFIC to the linear accelerator radiographer, however, are still tasks performed by the radiographer working in the linear accelerator.

This part of the questionnaire is optional, however, your answers are of utmost importance for our study and for that reason I would appreciate the time taken to answer this part of the questionnaire.

35. **Quality and risk management**

For each competency, please identify the level at which this is developed in the education programme.

Mark only one oval per row.

	Not developed	Partially developed (No autonomy/ responsibility)	Competent (Autonomous/ responsible)	Developed in the clinical practice or post-graduate education
Take decisions and perform daily tasks based on scientific evidence	◯	◯	◯	◯
Continuously assess own competencies and ensure professional development	◯	◯	◯	◯
Contribute to the development of the profession	◯	◯	◯	◯
Construct and implement institutional protocols based on national and international standards, guidelines and regulations	◯	◯	◯	◯
Develop and implement audit programmes	◯	◯	◯	◯
Report radiation incidents and near-misses	◯	◯	◯	◯

36. **Comments regarding "quality and risk management" competencies or additional competencies developed.**

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37. **Management and leadership with relevance to the linear accelerator**

For each competency, please identify the level at which this is developed in the education programme.
Mark only one oval per row.

	Not developed	Partially developed (No autonomy/ responsibility)	Competent (Autonomous/ responsible)	Developed in the clinical practice or post-graduate education
Plan the workload of the treatment unit and manage the use of resources (including human resources)	⬭	⬭	⬭	⬭
Contribute to team development and promote the expertise of colleagues	⬭	⬭	⬭	⬭
Contribute to conflict resolution and openness to discussion	⬭	⬭	⬭	⬭
Lead new initiatives and projects	⬭	⬭	⬭	⬭

38. **Comments regarding "management and leadership with relevance to the linear accelerator" competencies or additional competencies developed.**

____
____
____
____
____

39. **Decision making and critical analysis with relevance to the linear accelerator**

For each competency, please identify the level at which this is developed in the education programme.
Mark only one oval per row.

	Not developed	Partially developed (No autonomy/ responsibility)	Competent (Autonomous/ responsible)	Developed in the clinical practice or post-graduate education
Critically analyse practice, research and literature	⬭	⬭	⬭	⬭
Take decisions in order to improve patient outcome and safety	⬭	⬭	⬭	⬭

40. **Comments regarding "decision making and critical analysis with relevance to the linear accelerator" competencies or additional competencies developed.**

41. **Team work and multidisciplinarity**

For each competency, please identify the level at which this is developed in the education programme.

Mark only one oval per row.

	Not developed	Partially developed (No autonomy/ responsibility)	Competent (Autonomous/ responsible)	Developed in the clinical practice or post-graduate education
Work as part of a team and promote collaboration	⬭	⬭	⬭	⬭
Recognise limits of the radiographers' roles	⬭	⬭	⬭	⬭
Communicate effectively with radiographers and other professionals	⬭	⬭	⬭	⬭
Participate in peer-review processes	⬭	⬭	⬭	⬭

42. **Comments regarding "team work and multidisciplinarity" competencies or additional competencies developed.**

Thank you!

If you would like to be contacted to receive the results of this study or participate in future developments, please click on the link below.

PLEASE MAKE SURE YOU SUBMIT THIS QUESTIONNAIRE

https://goo.gl/forms/QB07a52MW2Wz16Ns2

Google Forms

APPENDIX 3. ETHICS APPROVAL SURVEY

RG3 Filter Committee Report Form

Project Title	Education of radiographers in the European Union
Chief Investigator	Dr Ciara Hughes
Filter Committee	Nursing and Health Research

This form should be completed by Filter Committees for all research project applications in categories A to D (*for categories A, B, and D the University's own application form – RG1a and RG1b – will have been submitted; for category C, the national, or ORECNI, application form will have been submitted).

Where substantial changes are required the Filter Committee should return an application to the Chief Investigator for clarification/amendment; the Filter Committee can reject an application if it is thought to be unethical, inappropriate, incomplete or not valid/viable.

Only when satisfied that its requirements have been met in full and any amendments are complete, the Filter Committee should make one of the following recommendations:

The research proposal is complete, of an appropriate standard and is in

- category A and the study may proceed* ☑
- category B and the study must be submitted to the University's Research Ethics Committee** Please indicate briefly the reason(s) for this categorisation ☐
- category C and the study must be submitted to ORECNI along with the necessary supporting materials from the Research Governance Section*** ☐
- category D and the study must be submitted to the University's Research Ethics Committee** ☐

Signed: [redacted] Date: 6th February 2018
Chairperson of Filter Committee

***The application form and this assessment should now be returned to the Chief Investigator. The Filter Committee should retain a copy of the complete set of forms.**

**** The application form and this assessment should now be returned to the Chief Investigator so that he/she can submit the application to the UUREC via the Research Governance section. The Filter Committee should retain a copy of the complete set of forms for their own records.**

***** The application form and this assessment should now be returned to the Chief Investigator so that he/she can prepare for application to a NRES/ORECNI committee. The Filter Committee should retain a copy of the complete set of forms for their own records.**

<u>For all categories, details of the application and review outcome should be minuted using the agreed format and forwarded to the Research Governance section</u>

Please complete the following

The application should be accompanied by an appropriate and favourable Peer Review Report Form (if not, the Filter Committee should be prepared to address this as part of its review). Please comment on the peer review (include whether or not there is evidence that the comments of the peer reviewers have been addressed).

Peer review is complete and there are no outstanding issues of ethical concern.

Please provide an assessment of all component parts of the application, including questionnaires, interview schedules or outline areas for group discussion/unstructured interviews.

This is a well-prepared online survey to be distributed to educational institutions through the European Federation of Radiographers' Societies, to assess the different educational structures across Europe and identify the competencies developed by the professionals.

Please comment on the consent form and information sheet, in particular the level of language and accessibility.

Acceptable arrangements have been made to address implied consent through appropriate information given to participants.

Please comment on the qualifications of the Chief and other Investigators.

Well qualified investigators for the proposed research.

Please comment on the risks present in conducting the study and whether or not they have been addressed.

No risks of any harms have been identified. Minor inconvenience associated with data collection is acceptable.

Please indicate whether or not the ethical issues have been identified and addressed.

Overall risk is far outweighed by the likely benefits to be gained in terms of new knowledge; justice is served through the wide application of the survey; no harmful disclosure of sensitive data is likely. The study is likely to lead to enhancements in quality.

Please comment on whether or not the subjects are appropriate to the study and the inclusion/exclusion criteria have been identified and listed

Appropriate subjects have been identified through the professional body with appropriate criteria.

UNIVERSITY OF ULSTER

RESEARCH GOVERNANCE

UU Ref No:

Form RG6 **Notification of a proposed substantial amendment**

Chief Investigator: Dr Ciara Hughes

Approved Study Title:

Education of radiographers in the European Union

New/Amended Title (if appropriate):

Type of Amendment (please indicate any that apply):

- Amendment to application form [ ]
- Amendment to description/protocol [x]
- Amendment to the information sheet/consent or other supporting information [x]

Please submit the appropriate amended documentation in each case, ensuring that new text is highlighted to enable comparison with the previous version to be made.

Summary of Changes:

Minor changes were made to the methodology and the questionnaire. The questionnaire is attached to this document and the changes are highlighted.

<u>Multiple respondents per institution</u>
Within the first submission, the questionnaires were going to be submitted to a single person per education institution (EI): the head of department or a representative. However, a variance in the perception of the level of competence between respondents was noticed during the inter-rater reliability test. To reduce the influence of inter-rater variability, the use of repeated measurements is recommended (Atkinson and Murray, 1987), therefore, all

Summary of Changes (continued):

academic staff involved in the teaching of Radiotherapy will now be invited to participate. The invitation will be performed by professional associations/federation (see below).
Two questions were added to the questionnaire regarding their involvement in teaching Radiotherapy students and their role in the institution.
The respondent can only withdraw from the study before submission because the questionnaire is anonymous and there may be multiple respondents per institution. Therefore, it is not possible to identify the response following submission.

Distribution of the survey by three professional associations/federations
According to the original submission, the questionnaires were going to be distributed to the EI affiliated with EFRS (European Federation of Radiographers' Societies). However, two other associations have now agreed to distribute the questionnaire to EIs within their remits (ART – Associação Portuguesa dos Radioterapeutas and TNTMR - Towarzystwo Naukowe Technikow Medycznych Radioterapii), reducing the margin of error.

Integration of the PhD into the SAFE EUROPE project
This project was integrated into the SAFE EUROPE project, funded by the ERASMUS+ Sector Skills Alliances grant. This funding has now been acknowledged within the questionnaire.

Change to the title of the professional
The title used on the questionnaire is now "therapeutic radiographer", since this is the title used in the UK (country leading the SAFE EUROPE project and where I am enrolled on the PhD programme).

Questionnaire amendments following the pilot study
The information letter was simplified. This is because it was considered by the respondents of the pilot study that there was too much information that could demotivate people from answering the questionnaire. The points regarding ethical considerations (e.g. anonymity) were all retained.
Clarification that the name of the institution is optional and should only be submitted if it does not affect the respondent's answers.
Minor typos (e.g. "Dedicated" instead of "Dedicates")
Questions added: "How much of the clinical radiotherapy placement is based in a simulated skills lab rather than in a real clinical environment?" answer between 0% and 100% (10% steps). "What is the number of hours in your course programme dedicated to clinical placements?"
More answer options in some questions (e.g. "I don't know")
Simplification of the possible answers to the question "Are the learning outcomes of the course defined in terms of competencies?". Possible answers: "Yes", "no" and "I don't know"
Question amended to include all benchmarking documents used in the construction of the questionnaire. New question: "Are the learning outcomes of the course in line with any of the following guidelines or benchmarking documents?"
The answer format for parts C, D and E was changed into a 7-point Likert scale (previously a 3-point Likert scale). This is because a larger scale reduces inter-rater variability, by reducing the impact of slightly different perceptions. This also allowed to simplify the introduction to this sections.

Additional ethical considerations:

There are no additional ethical issues.

List of enclosed documents:

- Amended questionnaire
- Amended protocol

Declaration:

I confirm that the information in this form is accurate and that implementation of the proposed amendment will benefit the study appropriately.

Signed ....C. Hughes.... Date ....27/03/19....
(Chief Investigator)

Filter Committee Decision

This amendment:

is appropriate to the needs of the study, is in category A and should be implemented [✓]
is appropriate to the needs of the study, is in category B and should be considered by the University REC [ ]
is NOT appropriate and should be reconsidered or withdrawn [ ]

Signed .... [redacted] Date ......27/03/19..............
(Chair of Filter Committee)

UU Ref No:

UNIVERSITY OF ULSTER

RESEARCH GOVERNANCE

Form RG6 **Notification of a proposed substantial amendment**

Chief Investigator: Dr Ciara Hughes

Approved Study Title:

Education of radiographers in the European Union

New/Amended Title (if appropriate):

Type of Amendment (please indicate any that apply):

- Amendment to application form [ ]
- Amendment to description/protocol [x]
- Amendment to the information sheet/consent or other supporting information [ ]

Please submit the appropriate amended documentation in each case, ensuring that new text is highlighted to enable comparison with the previous version to be made.

Summary of Changes:

We are requesting permission to distribute the previously approved questionnaire through social media. This will allow to reach a larger number of participants, increasing the strength of the results. The link to the questionnaire will be posted on the social media of the SAFE EUROPE project consortium (European funded project linked to this PhD) and on radiotherapy professional groups on the social media platforms.

Additional ethical considerations:

There will be no coercion of participants since they need to voluntarily click on the link to participate. In addition, there will be no direct communication between the researchers and the participants, unless the participant contacts the researcher (as described on the information letter). This change will not comprise confidentiality of the participants.

List of enclosed documents:

- Amended protocol (changes highlighted)

The following documents are also attached for your reference:

- Previous permission to proceed with the study (RG3 – Feb 2018)
- Previously approved changes (RG6 – March 2019)
- Previously approved questionnaire (no changes – for your reference)

Declaration:

I confirm that the information in this form is accurate and that implementation of the proposed amendment will benefit the study appropriately.

Signed ………………………………………………………… Date ……20.08.19……………………
(Chief Investigator)

Filter Committee Decision

This amendment:

is appropriate to the needs of the study, is in category A and should be implemented	[ ]
is appropriate to the needs of the study, is in category B and should be considered by the University REC	[ ]
is NOT appropriate and should be reconsidered or withdrawn	[ ]

Signed ……………… [redacted] Date …20/08/19………..
(Chair of Filter Committee)

APPENDIX 4. INTERVIEW PROTOCOL

Aim/research question:

How do differences in linear accelerator competencies affect the movement of therapy radiographers (TRs) and patient safety across Europe?

Objectives:

- Assess stakeholders' perceptions on education and competency of TRs across Europe
- Assess stakeholders' perceptions on the process of recognition of qualifications and movement of TRs across Europe
- Assess stakeholders' perceptions on patient safety

Main methodology points:

- Audio-recorded
- Assistant to take notes
- Focus-group interviews or one-to-one interviews
- Focus-group interviews of maximum 7 people
- Focus-group interviews should be homogeneous (same country) but can include different stakeholders (national TRs, emigrant TRs, immigrant TRs, clinical managers, education staff, students, professional association representatives)
- Invited by professional associations.
- Invitation letter sent at least 2 weeks prior to interview
- Focus-group to be run during scientific events
- Individual interviews can be run at any time in presence, via videoconferencing or phone.

Ethical considerations to be discussed with participants

- Consent letter to be collected by the researcher at the time of interview
- Inducement will be offered to participants (25eur voucher)

Welcome

Introduce moderator and assistant

Our topic is Education of Therapeutic Radiographers in Europe

The results will be used for my PhD and as part of the SAFE EUROPE project

You were selected because you were identified as a stakeholder who may be able to help us answer the question how do differences in linear accelerator competencies affect the movement of therapy radiographers (TRs) and patient safety across Europe?

Guidelines

- There are no wrong answers, but people may have differing points of view, you must listen respectfully
- The interview will be recorded, please try to speak one at a time
- Confidentiality is guaranteed through the application of the Chatham House Rule: "participants are free to use the information received, but neither the identity nor the affiliation of the speaker(s), nor that of any other participant, may be revealed."
- I will be addressing you on a first name basis. Is this acceptable for everyone?

- Please turn off your phones. If you really must answer a call, please do so as fast and quietly as possible and re-join when ready.
- My role is to moderate and guide this session; my assistant will help me keep on track
- Feel free to address each other, but please talk one at a time

Interview Guide:

1. Can you briefly describe your education and experience?
   1.1. RT only or dual-qualified? duration, academic level?
   1.2. Do you work in clinical or academic? What are your main roles?
2. How do you find education of TRs in [name of the country]?
   2.1. What are the strengths and the weaknesses of the education in [name of the country]?
   2.2. How do you think it compares with other European countries?
3. This list shows the areas of competency of the linac-TRs. What do you think about this list?
   3.1. Is there any theme that you think is missing? Or any that you don't agree?
   3.2. Which ones do you think that TRs in [name of the country] are stronger and which ones could be improved?
   3.3. Which ones do you think that TRs from other European countries are stronger and which ones could be improved?
4. What do you know about the movement of TRs across Europe?
5. Did you have any personal experience of movement in Europe? Or you know someone? (either in or out of [name of the country]).
   5.1. What do you know about the process of getting the competencies recognised?
   5.2. Was there any process of verifying your qualifications? Was there an exam, adaptation period, etc.?
   5.3. What do you think that are the main barriers/difficulties for the movement?
      5.3.1. Was language a barrier?
6. What is your opinion regarding patient safety when movement occurs?
   6.1. When TRs move to [name of the country]
   6.2. When TRs move to another country
7. Is there anything else you would want to discuss regarding education and movement of TRs across Europe?

APPENDIX 5. ETHICS APPROVAL INTERVIEWS

ULSTER UNIVERSITY **RESEARCH GOVERNANCE**

RG3 Filter Committee Report Form

Project Title	*Education of radiographers in the European Union*
Chief Investigators	Dr Clara Hughes
Filter Committee	Nursing and Health Research

This form should be completed by Filter Committees for all research project applications in categories A to D (*for categories A, B, and D the University's own application form – RG1a and RG1b – will have been submitted; for category C, the national, or ORECNI, application form will have been submitted).

Where substantial changes are required the Filter Committee should return an application to the Chief Investigator for clarification/amendment; the Filter Committee can reject an application if it is thought to be unethical, inappropriate, incomplete or not valid/viable.

Only when satisfied that its requirements have been met in full and any amendments are complete, the Filter Committee should make one of the following recommendations:

The research proposal is complete, of an appropriate standard and is in

- category A and the study may proceed* ☑
- category B and the study must be submitted to the University's Research Ethics Committee** Please indicate briefly the reason(s) for this categorisation ☐
- category C and the study must be submitted for external approval along with the necessary supporting materials from the Research Governance Section*** ☐
- category D and the study must be submitted to the University's Research Ethics Committee** ☐

Signed: [redacted] Date: 25-Oct-2019

*The application form and this assessment should now be returned to the Chief Investigator. The Filter Committee should retain a copy of the complete set of forms.

** The application form and this assessment should now be returned to the Chief Investigator so that he/she can submit the application to the UUREC via the Research Governance section. The Filter Committee should retain a copy of the complete set of forms for their own records.

*** The application form and this assessment should now be returned to the Chief Investigator so that he/she can prepare for application to an external committee. The Filter Committee should retain a copy of the complete set of forms for their own records.

<u>For all categories, details of the application and review outcome should be minuted using the agreed format and forwarded to the Research Governance section</u>

Please complete the following

The application should be accompanied by an appropriate and favourable Peer Review Report Form (if not, the Filter Committee should be prepared to address this as part of its review). Please comment on the peer review (include whether or not there is evidence that the comments of the peer reviewers have been addressed).

Peer review is complete and there are no outstanding issues of serious ethical concern.

Please provide an assessment of all component parts of the application, including questionnaires, interview schedules or outline areas for group discussion/unstructured interviews.

This is a qualitative study with stakeholder involvement using standard focus group intervews. The materials were deemed acceptable by filter committee to proceed.

Please comment on the consent form and information sheet, in particular the level of language and accessibility.

The arrangements for consent are acceptable. Personal details will be kept securely and not made public.

Please comment on the qualifications of the Chief and other Investigators.

The investigators are qualified to carry out the study.

Please comment on the risks present in conducting the study and whether or not they have been addressed.

Filter committee agreed that there were no serious risks associated with data collection, storage, analysis and reporting. The risk of distress associated with the investigation is low and has been adequately addressed. The risk of disclosure of relevant issues has been addressed. Adequate planning has taken place to ensure satisfactory study completion.

Please indicate whether or not the ethical issues have been identified and addressed.

Overall study benefits, in new knowledge gained, outweigh the potential for harm or inconvenience. Common principles associated with this type of study have been addressed: in particular data protection. Committee saw no potential for injustice. No new duty of care is likely to be identified.

Please comment on whether or not the subjects are appropriate to the study and the inclusion/exclusion criteria have been identified and listed

Yes, appropriate subjects have been identified.

L-Università ta' Malta

Jose Guilherme Araujo Seara Couto <jose.g.couto@um.edu.mt>

Query regarding consent - online interviews

3 messages

Jose Guilherme Araujo Seara Couto <jose.g.couto@um.edu.mt> 27 March 2020 at 20:12
To: [redacted]@ulster.ac.uk
Cc: "Hughes, Ciara" <cm.hughes@ulster.ac.uk>

Dear Dr [redacted],

As part of my PhD studies, we got ethical approval to run interviews with radiotherapy stakeholders on the selected countries (attached for your reference).

We also requested permission to run these interviews online if in-person interviews were not feasible. As a result of COVID19, all interviews are now going to be done online.

Since this is going to be recorded, can we replace the signed consent form by a verbal recorded consent? each of the aspects mentioned on the consent letter would be read by the researcher and confirmed with each participant. or shall request participants to sign and scan the consent form?

The consent form (attached) was sent to the participants at least 2 weeks in advance (together with the information letter).

Thanks,
Guilherme Couto

Best regards,
J Guilherme Couto

(BSc Radiotherapy, MSc Medical Physics)
Assistant Lecturer - Radiography Department
Room 15 - Faculty of Health Sciences - University of Malta
Msida - MSD 2080 - Malta
Tel: +356 2340 1846

Radiography department social media:

SAFE EUROPE project:

3 attachments

RG3_010_3_3a.pdf
93K

RG1a interviews compiled files 22102019.pdf
5095K

consent form focus group poland.pdf
0K

[redacted]@ulster.ac.uk> 28 March 2020 at 12:54
To: Jose Guilherme Araujo Seara Couto <jose.g.couto@um.edu.mt>
Cc: "Hughes, Ciara" <cm.hughes@ulster.ac.uk>

Hi Guilherme

Either arrangement is fine, so you could use an e-mailed/online consent process or recorded consent.

All the best

[redacted]

UU Ref No:

UNIVERSITY OF ULSTER

RESEARCH GOVERNANCE

Form RG6 **Notification of a proposed substantial amendment**

Chief Investigator: Dr Ciara Hughes

Approved Study Title: Education of radiographers in the European Union

New/Amended Title (if appropriate):

Type of Amendment (please indicate any that apply):

- Amendment to application form [ ]
- Amendment to description/protocol [x]
- Amendment to the information sheet/consent or other supporting information [ ]

Please submit the appropriate amended documentation in each case, ensuring that new text is highlighted to enable comparison with the previous version to be made.

Summary of Changes:

In the previously approved protocol, the method was to interview stakeholders in 4 European countries. We are now requesting permission to add a focus-group interview to members of an European Professional organisation (EFRS). The same methodology will be used for recruitment and for the interview process. This interview will compliment the stakeholders from the 4 countries.

Additional ethical considerations:

There will be no coercion of participants since the participants will be invited through one of the organisations mentioned in the previous protocol (EFRS).

List of enclosed documents:

- Amended protocol (changes highlighted)

The following documents previously sent are also attached for your reference (without changes):

- Previous permission to procced with the study (RG3 oct 2019)
- Previously approved procedures (RG1a sep 2019)

Declaration:

I confirm that the information in this form is accurate and that implementation of the proposed amendment will benefit the study appropriately.

Signed .... Date ......15/07/2020......................
(Chief Investigator)

Filter Committee Decision

This amendment:

is appropriate to the needs of the study, is in category A and should be implemented [✓]
is appropriate to the needs of the study, is in category B and should be considered by the University REC [ ]
is NOT appropriate and should be reconsidered or withdrawn [ ]

Signed .... Date 27/07/2020 ....
(Chair of Filter Committee)

APPENDIX 6. DETAILED DISCUSSION OF THE REQUIREMENTS TO PRACTISE RADIOGRAPHY IN EACH EU COUNTRY

AUSTRIA

The reply from the General Legal Affairs and Health Professions indicated that there was no registration of radiographers in Austria. However, the profession is regulated, and the qualifications need to be recognised by the Austrian Ministry of Health. After the first contact, updated legislation regulating radiographers in Austria was approved by the Austrian Federal Council and obtained by the researcher. Two critical legal documents were collected referring to the registration of radiographers in Austria. The most recent amendment to the Health Professions Registration Act (Federal Council (Austria) [in German], 2016a) and the Legal Provision for Paramedical Services Federal Law (Federal Council (Austria) [in German], 2016b).

As identified in the legislation (Federal Council (Austria) [in German], 2016a), the candidate must provide information and corresponding proof of identity, nationality and residence. The candidate must provide proof of qualifications “according to professional rules” which are established in the Federal Law (Federal Council (Austria) [in German], 2016b). The same document states that the applicant needs to submit evidence of trustworthiness, medical fitness to practise the profession and language skills. Also, it identifies applicability and means of proof.

The Federal Law on the regulation of the higher-level paramedical services (Federal Council (Austria) [in German], 2016b) establishes, amongst other things, the job profile of the paramedic professions. The radiographer can execute functions in diagnostic radiography, nuclear medicine and radiotherapy autonomously, as prescribed by a physician, and perform research. It is explicit in the legislation that the use of contrast agents and radiopharmaceuticals can be practised only in collaboration with the physician. This information matches the data available in the RPD (European Commission, n.d. c).

The requirements established by the Health Professions Registration Act refer that a higher-level diploma is required to practise a paramedical profession. For radiographers, the required 3-year programme must include theoretical and practical training in a set of subjects established in this legislative document. This training corresponds to an EQF6 and a Level 4 according to 2005/36/EC, which confirms the data on the RPD (European Commission, n.d. c; Federal Council (Austria) [in German], 2016a).

The RPD identifies another role under “Radiographer/Radiotherapist”: the Radiology Assistant. This occupation was not considered in the data analysis because the role description states that the professionals always work under supervision (European Commission, n.d. d).

BELGIUM

The Belgian Public Federal Service for Public Health, Food Safety and Environment was identified as the contact point for the registration of radiographers. They referred to the Royal Decree for the qualification requirements for the exercise of the profession of “technologist in medical imaging” (Minister of Public Health and Pensions (Belgium) [in French], 1997). The competencies of a radiographer are also laid down in this document.

Only individuals who satisfy the following conditions can use the professional title of *Technologue en Imagerie Médicale*:

- Hold a HE diploma;
- Completed a minimum of three years of study (full-time);
- Developed the skills outlined in the same Royal Decree;
- Completed an internship in the following areas:
    - Radiology;
    - Ultrasound;
    - Magnetic resonance;
    - Interventional procedures in medical imaging;
    - In vivo nuclear medicine.

The Decree does not mention the therapeutic branch of radiography on the skills to be developed nor the internship areas. Nevertheless, the competent agency and radiographers confirmed that graduates can still practice RT. Besides, the title ("technologist in medical imaging") is also suggestive of a diagnostic-only speciality. Furthermore, the competent authority stated that nurses can, "in specific cases", practise as TRs.

The legislation, the course descriptions identified by the regulator (see below) and the information available in the RPD confirm that the academic level in Belgium is a Level 4 according to 2005/36/EC directive and a Level 6 according to EQF (European Commission, n.d. e; Haute Ecole Leonard de Vinci, 2021; Minister of Public Health and Pensions (Belgium) [in French], 1997).

To complement this subject, the course programmes showed that radiotherapy is covered in Bachelor's courses (Haute Ecole Leonard de Vinci, 2021) and postgraduate specialisation courses (ISSIG, 2016) together with medical imaging. However, only 6 out of 180 ECTS and 4 out of 60 ECTS, respectively, were specific theoretical lectures in the radiotherapy field. A Bachelor's degree in nursing is a requirement to undergo the postgraduate specialisation course. It is useful to note that the title of the Bachelor course that allows the graduate to practise both diagnostic imaging and radiotherapy does not reflect the therapy branch: *Bachelier-Technologue en Imagerie Médicale* (Bachelor's in medical imaging technologist).

BULGARIA

No reply was obtained either from the contact point nor the competent authority identified in the RPD. The president of the Bulgarian Society of Radiation Therapy Technicians was contacted; the documents submitted were used to collect the data.

According to the Bulgarian Health Law (Ministry of Health (Bulgaria) [in Bulgarian], 2016), to practise health care professions, the individual must have a Bachelor degree from an HEI that received accreditation under the Higher Education Act. The ordinance (Bulgarian Council of Ministers, 2008), issued and approved by decree by the Bulgarian Council of Ministers, identifies the following requirements to accredit a Bachelor in Radiography:

- Hold at least a three-year course (6 semesters);
- Developed the following theoretical training:
    - Minimum of 3200 academic hours;
    - Compulsory subjects defined in the same ordinance;
- Developed the following practical training:
    - Minimum of 1 semester in an accredited institution;
    - Minimum of 1095 academic hours;
    - Minimum of 600 hours in each specialism;

The academic level in Bulgaria is an EQF6 and a Level 3 according to 2005/36/EC directive confirming the information available on the RPD (European Commission, n.d. f). The training to acquire the degree ends with a state exam on the following:

- Complex examination in methods and techniques of imaging - practical and theoretical;
- Nuclear medicine and radiotherapy;
- Radiobiology and radiation protection.

The accreditation of a radiography course in Bulgaria comprises criteria in diverse aspects: academic level; programme duration (with specifics for theoretical and practical learning); specific subjects to be covered; and a final state examination that includes both theoretical and practical assessment. The subjects covered in the final exam described in the legislation clearly show that both diagnostic and therapy branches of Radiography are required. However, the legislation does not specify the modalities developed; such as ultrasound or radiotherapy treatment planning.

CROATIA

On the RPD (European Commission, n.d. g) the title identified under the generic name of “Radiographer/Radiotherapist” for Croatia is “Radiation Technician”. This title was used in the letter requesting information sent to the competent authority. However, in their reply, the researcher was informed that radiation technicians “cannot work in radiation technology healthcare” according to current legislation. Instead, the requirements to register as a “Radiation Technologist” were identified.

In terms of education requirements, the applicant must show proof of completion of a Bachelor’s degree in Radiation or Radiologic Technology, in one of the three Croatian Universities. Additionally, the graduates should undergo a state exam after finishing one-year probation. The contact point identified that the Bachelor's degree corresponds to a 3-year programme. Additional requirements are proof of nationality and the payment of a registration fee.

A HE 3-year programme corresponds to an academic level 3 according to 2005/36/EC directive and an EQF6, confirming the data collected from the RPD. Further information retrieved from the RPD was that the professional activities include both diagnostic and therapy (European Commission, n.d. g). However, this information was not confirmed by any other source. Further contact was initiated twice, requesting the legislation that identifies the subjects to be covered; however, no further replies were obtained.

CYPRUS

Cyprus does not have an entry in the RPD (European Commission, n.d. h). In this case, the researcher contacted the Cypriote Ministry of Health to confirm that the profession was regulated and requested to provide the requirements to practise the profession.

The profession is regulated at national level, and the requirements were identified. To be able to register as a radiographer, the applicant must comply with the following criteria:

- Pay the registration fee;
- Be fit to practise, as certified by a member of the Pancyprian Medical Association;
- Be 21 years old or over;
- Provide proof of trustworthiness through a criminal record check;

The applicants must hold a degree with the following characteristics:

- From a university or HEI of comparable level;
- Minimum three years duration;

- In “radiation therapy technology” or “radiation technology” course, or equivalent;
- The course must be recognised both in the country of training and by the Cyprus Qualifications Recognition Council.

Although it was not possible to validate the information in the email due to lack of documentation and other sources, the course description corresponds to an academic level 4 according to 2005/36/EC directive and an EQF6. Since, in the email reply, details on the education programmes were scarce, the Ministry was contacted twice again to request the legislation that regulates the registration of radiographers, with no further replies.

CZECH REPUBLIC

The competent authority identified in the database (European Commission, n.d. i) is the Ministry of Education, Youth and Sports. An email reply by this authority refers two stages of registration for the radiographer: 1) Certification of professional competence and 2) certification for the performance of the profession without supervision. The following requirements were identified by the Ministry as stated by Czech legislation (Czech Republic Parliament, 2004):

- Bachelor in Radiography:
    - Minimum of a three-year programme;
    - At a higher paramedical school;
- Proof of trustworthiness;
- Proof of fitness to practise.

Following the certification of “professional competence”, in order to be able to practise without supervision, the radiographer must apply for a certificate, according to the time since “professional competence” certification. The application options and requisites are as follows:

- If the application takes place less than 18 months since “professional competence” was granted:
    - The professionals must submit documentation that demonstrates that they are competent to practise without supervision;
- If the application takes place more than 18 months since “professional competence” was granted:
    - The professionals must have at least one year’s experience and 40 lifelong learning credits in the last ten years; or
    - Undergo an examination.

The legislation clearly identifies that the “Radiology Assistant” practises both MI and RT; however, it does not specify the subjects to be covered to explore the details of the professional qualifications.

DENMARK

The Danish contact point mentioned in the EC database (European Commission, n.d. j) was the National Coordinator for Professional Recognition Directive 2005/36/EC. They identified the regulator and relevant legislation.

The Act on the Authorization of Health Professionals and Health Business (Ministry of Health (Denmark) [in Danish], 2011) establishes that only licensed radiographers can use this title. The compulsory characteristics of the radiography programmes offered in Denmark are laid down on the Order on the Bachelor of Science in Radiography (Agency for Higher Education (Denmark) [in Danish], 2016). From these two documents, we can determine the requirements to practise the profession: the Bachelor’s programme must have 210 ECTS in three and a half years, out of which 90 ECTS must be clinical education.

The course is organised into three parts. The first part (120 ECTS) is characterised by education and training in common core subject areas that take place in the first two years, where knowledge and skills are gradually developed mainly in diagnostic imaging (X-rays, CT, MRI and NM). All Danish institutions offering the course agreed on the curriculum for this part. The second part is composed of one of the three optional study areas: nuclear medicine, radiological imaging or radiotherapy, and it constitutes a total of 45 ECTS. The last part of the programme refers to obligatory clinical education that must include the core and optional areas of study and constitutes a total of 45 ECTS. A list of mandatory subjects covered in the Bachelor degree is established in the same legislation in terms of knowledge, skills and competencies developed. The academic level, according to 2005/36/EC directive, corresponds to a Level 4 and according to the EQF corresponds to a Level 6, confirming the information available on the RPD (European Commission, n.d. j).

ESTONIA

There are no entries in the RPD for Estonia. However, the *Eesti Radioloogiatehnikute Ühing* was identified as a national society through the EFRS webpage. This association identified the relevant documentation.

The professional must have at least Estonian Qualification Level 6 (EstQF) in Radiography (EQF6). To achieve it, the graduate must undergo a Bachelor's degree at a HEI (Estonian Parliament, 2008; Qualifications Authority (Estonia), 2014a). The radiographer should develop general competencies, which include team-work, patient communication and general radiologic procedures and develop competencies in the following specialisms:

magnetic resonance imaging, computed tomography, interventional/angiography, conventional radiography or mammography with corresponding titles recognised: MRI Radiographer/Technician, Computed Tomography Technologist/Radiographer, Interventional Radiology Radiographer, (Medical) Diagnostic Radiographer and Mammographer (English titles as presented in the document). Some specialisms require EstQF level 7 (EQF7). These are radiotherapy, ultrasound and nuclear medicine (Qualifications Authority (Estonia), 2014b) with corresponding regulated titles: Radiation Therapist, Sonographer and Specialist in Nuclear Medicine or Nuclear Medicine Technologist/ Technician.

In addition to the general subjects, the specific content of the programme is described in terms of KSC (for level 6 and 7). Specific competencies for the sub-specialisms were also identified (Radiotherapy, Nuclear Medicine, Mammography).

The contact point also identified the curriculum of the single radiography course currently being delivered in Estonia, which was confirmed by the National Higher Education Quality Assurance Agency database (Estonian Quality Agency for Higher and Vocational Education (EKKA), n.d.). This course is a 3.5-years HE programme, corresponding to 210 ECTS. All the modules in the course have the learning outcomes clearly defined. These training characteristics match the standards for an academic level 6 according to EQF and a level 4 according to 2005/36/EC directive.

FINLAND

The National Supervisory Authority for Welfare and Health (Valvira) directed the researcher to the official website of this authority from where the information was collected. On the website two classes of healthcare professionals were identified: Licensed Professionals and Protected Occupational Titles. The radiographers fall under Licensed Professionals, who can only practise after successful registration at the Authority for Medicolegal Affairs (Ministry of Education (Finland) [in Finnish], 2006; National Supervisory Authority for Welfare and Health, 2015).

According to the Health Care Professionals Act (Ministry of Social Affairs and Health (Finland), 1994), a licensed professional with specific qualifications is a Finnish or a foreign national who has completed the education required for specific qualifications in Finland (Ministry of Social Affairs and Health (Finland), 1994, p. 6). All applicants are requested to submit proof of qualifications. However, the National Authority for Medicolegal Affairs can request applicants educated outside of Finland for further information regarding their course in order to confirm that the course is equivalent to the education of radiographers in Finland. A proof of language proficiency is also required.

The education requirements to achieve a degree in Radiography (Ministry of Education (Finland) [in Finnish], 2006) and include the following:

- Minimum credits for the degree: 210 ECTS;
- Programme duration: 3.5 years.
- The competencies and skills required to be developed by the student are laid down in the document. Four specific areas are identified:
    - Radiography and radiotherapy basics;
    - Radiography and radiotherapy techniques;
    - Radiation and nuclear safety;
    - Research, development and management.
- Minimum practical training: 90 ECTS, out of which:
    - Maximum of 15 ECTS in the educational institution (e.g. skills labs);

- 15 ECTS correspond to the thesis.

The academic level defined in the RPD corresponds to a Level 4 (2005/36/EC directive) and an EQF6, matching the requisites identified above (European Commission, n.d. k).

FRANCE

The Regional Directorate for Youth, Sports and Social (DRJSCS) replied to the contact by identifying that there are two pathways to practise the profession of radiography in France by undergoing the *Diplôme d'Etat de manipulateur d'électroradiologie médicale* (Minister of Social Affairs and Health (France) [in French], 2012), or the *Diplôme de Technicien Supérieur en Imagerie Médicale et Radiologie Thérapeutique* (Ministry of Higher Education and Research (France) [in French], 2012). However, these pathways are extremely similar with the main difference is that the first is governed by the French Minister of Social Affairs and Health while the latter by the Ministry of Higher Education and Research.

France is one of the very few countries where the graduate is considered competent to practise EP (electrophysiology) in addition to MI, RT. The programmes are 3 years in duration, corresponding to 180 ECTS obtained at a HEI. Although regulated by different decrees, each one issued by the corresponding ministry, even the KSC developed in the courses are overlapping. These training characteristics correspond to an academic level 4 according to 2005/36/EC directive and an EQF6, matching the information available in the RPD (European Commission, n.d. l).

The French legislation establishes the learning objectives, contents, and evaluation for the curricular units for all course programmes across the country. This system is based on the traditional Napoleonic educational model, introduces a high level of homogeneity of education across the country.

GERMANY

German legislation defines that, in order to practise radiography, as other allied health professions, the applicants must have completed an approved course and passed the state exam (Federal Council (Germany) [in German], 2011). Proof of trustworthiness, fitness to practise and knowledge of the language are also requisites to register.

The required training can be accessed following intermediate school (Federal Ministry of Health (Germany) [in German], 2016). The course consists of a 3-year programme, with a minimum of 6-weeks clinical practice. This training corresponds to an EQF4 (Level 2 according to 2005/36/EC directive) as identified in the RPD (European Commission, n.d. m).

The subjects to be covered (theoretical and practical) are clearly defined, including the hours dedicated to each radiography specialism, which include RT and MI. Although the subjects are defined, the competencies developed are not (Federal Ministry of Health (Germany) [in German], 2016). The same legislation defines that, at the end of the programme, the student must undergo a state exam that includes written, oral and practical components.

The written part of the exam covers the following subjects (Federal Ministry of Health (Germany) [in German], 2016):

- Mathematics; Statistics; IT and documentation; Physics; Anatomy; Physiology;
- Diagnostic radiology and other imaging procedures; radiotherapy; nuclear medicine;

- Radiation physics, dosimetry and radiation protection.

The oral and the practical part of the examination are divided into the following parts (Federal Ministry of Health (Germany) [in German], 2016):

- Radiology and other imaging procedures;
- Radiotherapy;
- Nuclear medicine;
- Radiation physics, dosimetry and radiation protection.

GREECE

The database does not identify a competent authority (European Commission, n.d. n). Nevertheless, a Greek professional association provided the researcher with the relevant documents (Institute of Athens (Greece), 2011; The President of the Republic (Greece) [in Greek] et al., 1996). The degree regulated in these documents allows the graduate to practise the profession. In the role description, it is possible to identify that the profession includes the RT, MI and NM specialisms. The training of radiographers is defined in terms of competencies and the responsibilities of these professionals in the three specialisms indicated are clearly stated (Institute of Athens (Greece), 2011; The President of the Republic (Greece) [in Greek] et al., 1996).

The supplement to the diploma of the Technological Educational Institution of Athens (Greece) (Technological Educational Institution of Athens (Greece), 2015), referred to in the presidential decree, indicates further competencies developed in addition to those legally required and gave insight into other aspects of the requirements to achieve the degree. In order to graduate, the student must have completed the following:

- 4-year programme;
- 240 ECTS;

- All mandatory curricular units;
- Six months of practical training;
- Submitted a dissertation that was examined and approved.

The Greek education corresponds to an academic level EQF6 and a level 5 according to 2005/36/EC directive, confirming the information on the RPD (European Commission, n.d. n)

HUNGARY

The reply from the Hungarian contact point referred to the registration system of health workers. However, it was not specific for radiographers and lacked information on the academic requirements. Although this information was requested in a second contact, such information was not received by the researcher.

The Hungarian system has two levels of registration, basic registration (Records and Health Training Centre (Hungary) (in Hungarian], 2014) and operational registration (Records and Health Training Centre (Hungary) [in Hungarian], 2015). The operational registration requires the professional to have the basic registration and allows an individual to practise independently. However, the basic registration allows the practice of the profession under supervision.

The basic registration is done *ex officio*, within 30 days of the issuance of the certificate by the educational institution. The registration is automatic, and the applicant is required to submit the certificate, personal identification, address of the education institution awarding the degree and the payment of a fee (Records and Health Training Centre (Hungary) (in Hungarian], 2014). Proof of trustworthiness and fitness to practice are also required.

According to the RPD, four different professions fall under the generic name of "Radiographer/Radiotherapist", these are (European Commission, n.d. h):

- Radiographer
- Imaging diagnostic analyst
- Practicing diagnostic medical imaging, nuclear medicine and radiation therapy technician
- Visual diagnostic, nuclear medicine and radiotherapy assistant

While the "Imaging diagnostic analyst" requires a 2005/36/EC level 4 (EQF6), the others require a level 3 (EQF5). All professions identified include RT and MI specialisms (European Commission, n.d. o, n.d. p, n.d. q, n.d. r). Since the academic level was not possible to triangulate, such information was not taken into consideration in the publication not to compromise the trustworthiness of the study.

In the description of the professional activities, the lack of autonomy of the "visual diagnostic, nuclear medicine and radiotherapy assistant" and the "practising diagnostic medical imaging, nuclear medicine and radiation therapy technician" were evident as these occupations are clearly practising under the "control of the specialist". However, the description of the two other professions correspond to the roles of the radiographer (European Commission, n.d. o, n.d. p, n.d. q, n.d. r).

IRELAND

CORU is the competent authority for the registration of radiographers in Ireland (European Commission, n.d. s, n.d. t) and both the competent authority and the contact point replied to the contact referring to CORU's procedure for registration (CORU (Ireland), n.d.) and corresponding bylaws (Radiographers Registration Board (Ireland), 2015). According to the referred procedures, the applicant must have an approved qualification, demonstrate to be fit to practise and have knowledge of the language (CORU (Ireland), n.d.).

The Radiographers Registration Board is composed of the Radiographers' and Radiation Therapists' divisions. To achieve registration as a radiographer (Diagnostic), the applicant must hold a Bachelor of Science (Hons) Radiography degree from the National University of Ireland (University College Dublin – UCD). A Bachelor of Science in Radiation Therapy [B.Sc. [Ther.Rad.]] from the University of Dublin (Trinity College Dublin – TCD) is required to register as a Radiation Therapist. In both cases, a qualification that the Board decides as being equivalent is also accepted (Radiographers Registration Board (Ireland), 2015).

The Radiography course at UCD is a four-year programme, corresponding to 240 ECTS. The learning outcomes are available on the university webpage and describe a list KSC to be achieved by the student during the programme. Clinical training details were also published, including placement workload (1065 hours), learning outcomes and assessment modes, allowing for a comparison with other programmes for registration purposes (University College Dublin (Ireland) - School of Medicine and Medical Science, 2012).

At the time of this search the Radiation Therapy course offered by Trinity College Dublin was the only approved course in Ireland granting registration as a radiation therapist and was the basis of comparison to other courses. This programme comprises of radiotherapy-related subjects addressed throughout four years. The degree requires the completion of 240 ECTS, and 1435 hours of clinical placement (41 weeks at 35 hours per week) (Trinity College Dublin (Ireland), 2016, 2013). However, in the meantime, a pre-registration Master's degree in Radiation Therapy opened at the University College Cork, allowing a different pathway to access the profession (University College Cork, 2021).

The training in Ireland corresponds to an EQF6 and an Academic Level 5 according to the 2005/36/EC directive, confirming the information collected from the RPD (European Commission, n.d. s, n.d. t).

ITALY

The competent authority identified in the RPD (European Commission, n.d. u) did not reply to the contacts by the researcher. However, the website of the *Federazione Nazionale Collegi Professionali Tecnici Sanitari di Radiologia Medica* (FNCPTSRM) identified the relevant legislation.

According to the legislation (Minister of Health (Italy) [in Italian], 2006, 2000), an academic title is required to practise the profession. While the professional associations define the titles used and the access to the profession (Minister of Health (Italy) [in Italian], 2006), the Education Ministry defines the educational programmes that lead to the title (Minister of Health (Italy) [in Italian], 2000).

The education of Italian radiographers is then regulated by Decrees from the Ministry of Health and Education (Minister of Health (Italy) [in Italian], 1994; The Minister of the University and Scientific and Technological Research (Italy), 1996), which established that the Diploma Course is designed to train professionals capable of performing, independently or in collaboration with other health professionals, all interventions that require the use of ionizing radiation, both artificial and natural, ultrasonic imaging, magnetic resonance as well as interventions for physical and dosimetric protection.

To achieve the diploma, the student must undergo a three-year course that ends with a final examination, which includes the presentation of a thesis, a written and a practical exam (Minister of Health (Italy) [in Italian], 1994; The Minister of the University and Scientific and Technological Research (Italy), 1996). This training corresponds to an EQF6 and a Level 4, according to 2005/36/EC, confirming data collected from the RPD (European Commission, n.d. u).

Both RT and MI are part of the training and practice. The subjects to be covered, in terms of knowledge and skills are also laid down in this legislation (The Minister of the University and Scientific and Technological Research (Italy), 1996).

The objectives for the clinical placements are specified in terms of the number of times the graduate must have performed an examinations/procedures (The Minister of the University and Scientific and Technological Research (Italy), 1996). For example, the graduates are awarded the degree if they have treated 15 patients with external beam radiotherapy.

LATVIA

Latvia has two different professions that execute functions that fall under the generic name of “Radiographer/Radiotherapist” as referred in the RPD (European Commission, n.d. h): “Radiographer” and “Radiologist Assistant”.

The requirements to practise as a radiographer were requested from the Latvian Academic Information Centre, that promptly replied by identifying the main education requirements for this profession. To be able to practise, a radiographer must obtain a Bachelor’s degree through a 4-year programme (240 ECTS) corresponding to EQF6 and an academic level 5 on the 2005/36/EC directive, confirming data from the RPD (European Commission, n.d. h).

Although it is not the scope of this work to report on the training of assistants in the area of radiography, the RPD identifies Radiology Assistant under the generic name of "Radiographer/Radiotherapist". The competent authority stated that an EQF5 is required to practice as a Radiology Assistant. This level is achieved through a shorter cycle of studies, corresponding to a 3-year HE course (180 ECTS).

LITHUANIA

The title of Radiology Technologist is considered under the generic name of "Radiographer/ Radiotherapist" in the RPD (European Commission, n.d. h). The Lithuanian Ministry of Health identifies the Bachelor's degree in Radiology as a requirement to practise the profession in Lithuania. Despite the title, the course-programme allows graduates to practise RT as well. The course programme that leads to the practice of radiography in Lithuania has the following characteristics (Minister of Health (Lithuania) [in Lithuanian], 2007):

- Minimum of a three-year programme;
- EQF Level 6;
- Minimum of 120 ECTS;
    - Out of which, minimum of 10 ECTS should correspond to professional practice
- Cover a list of subjects as identified in the legislation;
- Develop skills as identified in the legislation.

This validates the information on the RPD, that identified an academic level 4 according to 2005/36/EC directive (European Commission, n.d. h).

According to the reply from the competent authority and the legislation, these graduates will be able to practise in the following specialisms of radiography:

- X-Ray;
- Magnetic Resonance;
- Angiography;
- Ultrasound;
- Densitometry;
- Nuclear Medicine (Gamma Cameras);
- Radiation Therapy;
- Interventional Radiology;
- Interventional Cardiology;
- Computed Tomography.

Only two courses were being offered in Lithuania. The first groups of students graduated in 2016 and 2017.

LUXEMBURG

The Luxembourgish legislation (Ministries of Health, Finance and Public Service (Luxembourg) [in French], 2011) established that a diploma recognised by the Minister of Education is required to practise the profession. However, details on this education were not present in the document. In addition to the required education, the applicant must be mentally and physically fit to practise, be trustworthy and knowledgeable of the essential languages to practise and understand all languages in the country.

Further information regarding the education was gathered through the competent authority, the *Centre de Documentation et d'Information sur l'Enseignement supérieur (CEDIES)*. Only one institution in Luxembourg runs a recognised course. The HEI's website identified details of this course. This programme corresponds to a 3-year programme, EQF6 (Level 4 according to directive 2005/36/EC), and includes MI, NM and RT (Lycee Technique pour Professions de Sante, 2014).

MALTA

In the Maltese legislation, the academic requirements to practise professions complementary to medicine are not specified. The legislation refers to a course that must be provided by the University of Malta (UoM) or equivalent (Ministry of Health (Malta), 2003).

The current version of the Code of Practice, issued by the Council of Professions Complementary to Medicine (CPCM), indicates that access to Diagnostic Radiography is made through the completion of a course at the UoM. While access to Therapy Radiography can only be achieved through courses offered abroad (Council for the Professions Complementary to Medicine, 2006). This information is outdated since the UoM currently offers a 4-year (240 ECTS) course, covering both MI and RT since 2010.

The UoM course achieves a EQF6 and a level 5 according to 2005/36/EC directive. The learning objectives are identified in terms of knowledge and skills that the student must achieve to obtain the degree (University of Malta, 2016).

Other requirements to register include proof of trustworthiness and fitness to practise. The applicant may be required to pass a linguistic proficiency test, according to the legislation (Ministry of Health (Malta), 2003).

NETHERLANDS, THE

The contact point informed that registration is not mandatory in the Netherlands, however, as established by law, the health care professional must have appropriate training to use the title and to practise (Ministry of Health, Welfare and Sport (Netherlands) [in Dutch], 1993). The contact point stated that the appropriate training can be obtained in an accredited education institution (Ministry of Health, Welfare and Sport (Netherlands) [in Dutch], 2006). Registration is optional; however, employers and insurance companies may attach value to it. To apply for registration, the radiographer must submit a copy of the certificate, provide the details and pay a registration fee (Ministry of Health, Welfare and Sport (Netherlands) [in Dutch], 2006).

In the Netherlands, training of radiographers includes both MI and RT. However, details on the education requisites were not provided, and so it was not possible to assess the duration, academic level or ECTS of the radiography courses in the Netherlands. From the RPD, it was possible to identify that the required academic level is classified as EQF6 and Level 4 according to 2005/36/EC (European Commission, n.d. v).

POLAND

The competent authority identified in the RPD (European Commission, n.d. h) was the Ministry of Health. They replied to the contact by informing that there is no registration or registration chamber for “Electroradiology Technicians” in Poland, who can practise MI, RT, NM and EP. These professionals would be able to practise if they hold a diploma achieved through one of the following pathways:

i. At vocational post-secondary educational level: 2.5 years training provided by the post-secondary school that trains in this profession. Training ends with a state exam.
ii. At university level: 3 years Bachelor's degree in electroradiology;
iii. At university level: 2 years Master's degree in electroradiology.

In summary, the professional can have different qualifications to perform the task where the EQF level can reach level 7 with the master's programme. However, the minimum requirements are an EQF5 (Level 3 according to the European Directive 2005/36/EC). The documentation sent by the Ministry of Health referred to the recognition of the qualifications process, however, did not provide further information regarding education or requirements to practise. Given this, further contact was established to request legislation regarding the regulation of the profession and education; however no reply was obtained.

PORTUGAL

According to the Portuguese legislation, three professions that fall under the general concept of "Radiographer" used in this study: *Tecnico de Radiologia, Tecnico de Radioterapia e Tecnico de Medicina Nuclear* (Radiology Technician, Radiotherapy Technician and Nuclear Medicine Technician). In order to practise any of these professions, the applicant must have a degree from one of the HEIs identified in the legislation or a legal equivalent (Ministry of Health (Portugal) [in Portuguese], 1999; Portuguese Government, 1999).

The courses of Radiotherapy, Radiology and Nuclear Medicine were separate until 2015. Currently, a four-year programme is delivered that comprises the three specialisms (Ministry of Health, Education and Science and Solidarity (Portugal), 2014). The three professions are still considered separate as the role of each is established by law independently (Ministry of Health (Portugal) [in Portuguese], 1999).

The legislation establishes the main characteristics of the joint course: a 4-year programme with 240 ECTS that covers RT, MI and NM. This course corresponds to a EQF6 and a Level 5 according to the European Directive 2005/36/EC (Ministry of Health, Education and Science and Solidarity (Portugal), 2014). This legislation identifies the KSC that are common to the three professions but does not specify the KSC for the different specialisms. Instead, these are defined by educational institutions and approved by a regulatory agency.

SLOVAKIA

According to the email reply from the competent authority, the requirements to practise the profession of “radiology technician” are either a Bachelor’s degree in radiology or a higher-vocational education in “radiology assistant”. The legislation regulating the registration of radiographers identified by the contact point (National Council of the Slovak Republic, 2016), only stipulates that the applicant must have qualifications in the field, with no reference to the level or any details regarding the programme. Other requisites to register and practise the profession include knowledge of the language, proof of trustworthiness and fitness to practice.

In the RPD, only “radiology technician” is considered to fit under the generic name of “Radiographer/Radiotherapist”. The qualification according to 2005/36/EC is a level 4 (EQF6), which is in line with the information provided by the competent authority. The profession includes RT and MI specialisms according to the description of activities available in the RPD (European Commission, n.d. w).

SLOVENIA

The Slovenian contact point, the Ministry of Health, was contacted. They identified two documents relevant for this work: The Health Act (Health Ministry (Slovenia), 2014a) lays down the minimum requirements to practise the profession; these include the following:

- Adequate professional education;
- Mastery of Slovenian language;
- A minimum internship of 9 months;
- A proficiency exam.

The Health Minister define the contents of the internship and the exam. The contents are specific for each profession (Health Ministry (Slovenia), 2014a).

A separate list identifies the professions encompassed by this document (Health Ministry (Slovenia), 2014b), which includes radiography. The qualifications required and the role of the professionals are also presented in the list. The list states that the professionals practise in the fields RT and MI, with no further details.

Since the contact also identified the University of Ljubljana as a provider of education compatible with the practice of the profession. The course offered is a 3-year HE programme (180 ECTS), corresponding to an EQF6 (level 4 according to 2005/36/EC directive). The subjects covered are identified in the programme description. However, these are not discriminated in terms of KSC (University of Ljubljana (Slovenia), 2015).

SPAIN

The competent authority identified in the RPD is the Ministry of Health, Social Services and Equity. However, the reply did not include any information regarding the requisites to practise in Spain. In their reply, they mentioned that registration to practise is mandatory, but it is not a centralised system, and radiographers must apply to the region where they intend to practise.

The two national professional associations provided information for the data collection. Although there is a push by the Spanish Society of Graduates in Radiology to increase the minimum level to an EQF level 6 (Spanish Society of Graduates in Radiology (Spain) [in Spanish], n.d.), the RPD defines the minimum education as level 3 according to 2005/36/EC which corresponds to an EQF5 (European Commission, n.d. x, n.d. y, n.d. z).

The courses offered in Spain correspond to 2-year post-secondary education programmes, equivalent to an EQF5 (Centro de Estudios Sanitarios, 2015a, 2015b, 2013; ITEP, 2015). However, Spanish universities established collaborations with foreign universities (e.g. Portugal) to offer Bachelor’s degrees, equivalent to EQF6. These courses are issued by institutions in the EU; therefore, these qualifications must be recognised in Spain (Spanish Society of Graduates in Radiology (Spain) [in Spanish], n.d., n.d.).

Education of specialisms are performed separately corresponding to three independently regulated professions: *Técnico especialista de medecina nuclear*, *Tecnico superior en imagen para el diagnóstico* and *Tecnico superior en radioterapia*, corresponding to the NM, MI and RT, respectively.

Since the competent authority did not reply and the researcher did not have access to the legislation, the requisites to practise in Spain were considered those available in the RPD (EQF5 and Level 3 according to 2005/36/EC) which was submitted by the competent authorities. However, information regarding curricula, course duration, ECTS could not be triangulated and were not used in the published paper.

SWEDEN

In Sweden, the protected title of *Röntgensjuksköterska* (Radiology Nurse) can be used when in possession of an identification issued by the regulatory body. To obtain the right to practise as a radiographer, the applicant must submit a copy of the certificate of qualifications and the payment of a fee (National Board of Health (Sweden), 2015).

The qualifications to work as a radiographer are obtained after the completion of 180 credits, where 60 credits correspond to an academic year (40 weeks). These requisites are established in the Higher Education Ordinance (1993:100) (2016). The same document establishes the objectives of the programmes, grouped into three categories: 1) knowledge and understanding, 2) skills and abilities and 3) evaluation ability and approach, which reflect the KSC framework. The course programmes across the country must include this list of objectives; however, the list does not specify technical details specific to radiography. An additional requirement is an independent project of at least 15 credits.

From the documentation available, it was not possible to identify the specialisms developed and practised by these professionals. However, a search on the programmes offered by Swedish universities that are affiliate members of EFRS, indicate that MI is developed at the undergraduate level, with no clear indication of the RT branch (Jönköping University, 2016; Lund University, 2012; Örebro University, 2016; University of Gothenburg, 2016). However, other HEIs, not affiliated with EFRS, may offer radiotherapy educational programmes.

UK

The regulatory body in the United Kingdom, the Health and Care Professions Council (2014), establishes that the minimum requirements to practise the profession of radiography is a Bachelor's degree with honours. The curriculum of the course must be constructed in such a way that the learning outcomes ensure that the graduate will be able to practise according to the standards of proficiency for radiographers, published in a separate document (Health and Care Professions Council (HCPC) (UK), 2013). Therefore, neither the minimum duration of the Bachelor's degree nor the number of ECTS are identified as requisites, as long as the outcomes are achieved the graduate is allowed to practise.

The subjects to be covered in the degree must allow the graduate to achieve the standards of proficiency. These are divided into three categories:

- Generic standards, which apply across most health professions;
- Specific standards for radiographers and;
- Standards specific to diagnostic and TRs, as those professionals can have different competencies.

Regarding clinical practice during the course, no details are given in terms of type or duration of the placements, as long as these are in line with the learning outcomes.

In order to apply to a radiography programme, the applicant must prove to be trustworthy, fit to practise, in possession of adequate entry qualification and good command of the English language. Since these are pre-requisites to access the education programme, they are then also a requisite to access the profession itself (Health and Care Professions Council (HCPC), 2014).