



An investigation of digital skills of therapeutic radiographers/radiation therapists: A european survey of proficiency level and future educational needs

Barbosa, B., Oliveira, C., Bravo, I., Couto, J. G., Antunes, L., McFadden, S., Hughes, C., McClure, P., Rodrigues, J., & Dias, A. G. (2023). An investigation of digital skills of therapeutic radiographers/radiation therapists: A european survey of proficiency level and future educational needs. *Radiography*, 29(3), 479-488. <https://doi.org/10.1016/j.radi.2023.02.009>

[Link to publication record in Ulster University Research Portal](#)

Published in:
Radiography

Publication Status:
Published (in print/issue): 31/05/2023

DOI:
[10.1016/j.radi.2023.02.009](https://doi.org/10.1016/j.radi.2023.02.009)

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Introduction:

During the COVID-19 pandemic, there was an increasing use of digital solutions. This trend towards further digitalisation is confirmed by the growth rate in the adoption of digital technologies by European citizens. Although most countries are making progress in digital transformation, insufficient levels of digital skills undermine future growth prospects, deepen the digital divide and increase the risks of digital exclusion as more and more sectors, including essential ones are converted to digital services.^{1,2} Although most countries are making progress in digital transformation, namely in healthcare sector, insufficient or low level of proficiency can compromise competent and safe practices in the use of clinical technologies.^{1,2,3} In the healthcare sector, This digital shift poses increasing challenges to health professionals, making continuous education of these professionals necessary to keep up with these new demands.

Radiotherapy (RT) is a scientific field demonstrating significant technological advances, where the introduction of new technologies has also demanded a broader set of skills from Therapeutic Radiographers/Radiation Therapists (TR/RTTs).^{3,4} The successful implementation of digital technology in RT is dependent on the digital skills of the TR/RTTs, as a lack of expertise can reduce the safety and quality of patient care. The successful digital technology usage in patient care is dependent on the digital skills of the TR/RTTs, as an inadequate skill can undermine patient safety and increase the incidence of errors. (Healthcare professionals' competence in digitalisation: a systematic review; Salahuddin & Ismail, 2015). However,

differences in regulation and education of TR/RTTs, and differences in access to technology in European countries, leads to gaps in these same skills. In addition, the lack of a specific reference education standard regarding the training needs of digital skills of TR/RTTs prevents their development in initial and lifelong training programmes.^{2,5,6} Although a recent study presents a list of relevant digital skills which should be included in the educational curriculum and continuous professional development (CPD) programmes for TR/RTTs,⁷ it becomes pertinent to assess the level of development of these same skills, as well as to identify possible factors influencing this level.

Although a recent study presents a list of digital skills which should be included in the educational curriculum and continuing professional development (CPD) programmes for TR/RTTs (see examples in Table 1),⁷ it has not yet been identified which skills are currently being developed and what their proficiency level is. It is therefore relevant to assess not

only the proficiency level of TR/RTTs in performance digital tasks, but also to identify possible factors influencing it.

Table 1 – Examples of TR/RTTs digital skills organized by themes and sub-themes.⁷

Dimensions (themes)	Skill
Transversal Digital Skills	
Electronic Patient Record (EPR)	<ul style="list-style-type: none"> - Create a new patient record - Access RT patient data - Add clinical data (e.g. treatment side effects, occurrences)
RT Planning Image	
Image Segmentation and Contouring	<ul style="list-style-type: none"> - Use contouring tools (e.g. geometric shapes, tracing) - Use processing tools (e.g. interpolation, threshold, translation) - Review and approve segmentation
RT Treatment Planning	
Plan Evaluation	<ul style="list-style-type: none"> - Use review tools (e.g. plan sum/subtract, dose comparison) - Compare treatment plans - Use biological optimisation tools
RT Treatment Administration	
Image Matching	<ul style="list-style-type: none"> - Use pre-analysis tools (e.g. scale and field alignment) - Use matching view tools (e.g. split window, spyglass, reverse) - Match 2D images (kV or MV) with reference image (DRR)
Quality, Safety and Risk Management	
Risk Management	<ul style="list-style-type: none"> - Report accidents and incidents on a platform (e.g. SAFRON, ROSEIS) - Audit the workflow and treatment courses (e.g. plan changes, schedules) - Create evaluation and prevention reports
Management and Research	
Department Administration and Management	<ul style="list-style-type: none"> - Use data collection tools of the activities performed (export data, productivity) - Create automatic reports (e.g. daily activities, billing) - Perform market research (e. g. supplies, technology)

Digital skills and related concepts such as "digital competence" have become key terms in the discussion about skills needed by all citizens to be able to participate and thrive in society, not only in terms of social and digital inclusion but also in terms of employability and economic growth.^{8,9} Despite global agreement on the importance of digital skills, no

common definition has been agreed upon, presenting different interpretations of the content of digital skill and the knowledge and abilities it encompasses.

Given the European context of this study, the European Qualifications Framework (EQF) for lifelong learning definition of 'skill' was used as a reference and is defined as "ability to apply knowledge and use know-how to complete tasks and solve problems".¹⁰ The definition for 'digital skills' used in this work more broadly describes the digital skills that professionals can develop as part of their training, as it refers to a 'range of different abilities, a combination of behaviours, expertise, know-how, work habits, character traits, and critical understandings'.¹¹ For the purpose of the present study, digital skills in the context of RT are defined as the digital-related knowledge, abilities and critical understanding in the professional context of TR/RTTs. Translating into the technological expertise required to effectively perform specific tasks or activities, such as "optimise image quality" (e.g. adjust kV, mA or ms) during the acquisition of a treatment verification image, or non-specific but relevant to the TR/RTT profession, such as "view application access logs" for data protection.(ref)"

Understanding the characteristics that influence digital skills, as well as the stage of training where they are developed, allows decision-makers to use this knowledge in the design of educational programmes and CPD. It is also fundamental to identify which digital skills are less developed in order to close these gaps, promoting standard education, which results in a better quality of practice, and consequently better patient care.

Aim

The aim of this study was to assess the level of development and training needs of TR/RTTs regarding digital skills across Europe. This study also aimed to identify the factors that influence the level of development of digital skills, the phase of professional development in which skills have been developed and highlight new emerging digital skills inherent to the rapid development of new technologies.

The aims of this study were: 1. Assess the proficiency level of TR/RTTs digital skills; 2. Identify the training needs of TR/RTTs; 3. Identify the factors influencing the level of proficiency; 4. Assess the stage of training and phase of professional development in which the skills have been developed; 5. Highlight new emerging digital skills inherent to the rapid development of innovative technologies.

Methods

Both qualitative and quantitative methodologies were used in this cross-sectional research.^{12,13} The aim was to assess, at one point in time, the level of self-perceived development proficiency of digital skills of TR/RTTs in their practice. An online survey was used as it is fast and inexpensive, especially in geographically dispersed populations.¹⁴

Survey design

A survey was designed, based on a previous literature review⁷, to identify the level of development of TR/RTTs' digital skills, but also to evaluate their association with the following factors: socio-demographic characteristics; educational background; professional status; and information and communication technology (ICT) skills.

A survey was designed (Appendix), based on the list of TR/RTTs' digital skills from a previous literature review⁷, to identify which digital skills are being developed and what their level of proficiency is. Also to evaluate the association between this level and the following factors: socio-demographic characteristics; educational background; professional status; and information and communication technology (ICT) skills.

The survey included three parts: part 1 examined TR/RTTs' characteristics that may affect digital skills development,^{15,16,17} part 2 aimed at evaluating the level of digital skills proficiency in RT, and part 3 explored the context within which these skills were developed (Table 1).

Table 1 – Survey structure.

Parts	Sections
Part 1 – Socio-demographic, education, and professional characteristics	Section I – Socio-demographic, educational and professional characteristics Section II – ICT skills
Part 2 – RT digital skills' level of development proficiency for TR/RTTs' practice	Section III – Transversal digital skills Section IV – Specific (Planning Image, Treatment Planning and Treatment) Section V – Quality, Safety and Risk Management Section VI – Management and Research
Part 3 – Education of RT digital skills	Section VII – Education

Section II comprised the following generic ICT skills areas: Information processing (e.g. "save files and retrieve them"), communication (e.g. "share files and content using simple tools"), content creation (e.g. "produce multimedia content in different formats"), safety (e.g. "check the security configuration and systems of devices"), and problem solving (e.g. "solve technological problems by exploring the settings and options of programmes or tools"). This section consisted of the universal application of ICT products and technologies; and was adapted from the European Commission "Digital Competence Framework for Citizens".¹⁶ The participants were asked to rate themselves, as "basic" "independent" or "proficient" users of ICT in each area.^{2,11,16} Section IV explored the level of development proficiency of digital skills specific to the role of the TR/RTT, while sections III, V and VI explored digital skills applicable in the profession of TR/RTT, but also in other professions due to the rapidly evolving technology and ICT innovation. Section IV explored the proficiency level of digital skills in performing tasks in the areas of Image Planning, Treatment Planning and Treatment (referred to as specific to the TR/RTT profession). Sections III, V and VI explored the digital skills of TR/RTTs but not specific to the profession, i.e. applicable also in other professions, such as "Import and export data (e.g. DICOM images)" or "Collect and evaluate data for research". These non-RT specific digital skills result from the rapid evolution of technology and innovation in ICT, and are common to several professions.^{2,11,16,18-22}

Closed-ended questions were used to assess the skill level of TR/RTTs, as well as to explore the contribution (in %) of different educational settings on the development of these skills (section VII). These type of allowed a quick compilation of data and statistical analysis. Closed-ended questions allowed a quick compilation of data and statistical analysis. However, open-ended questions were also included throughout the survey so that respondents could add any digital skill not presented in the survey and expand their answers whenever appropriate. Where necessary, relevant supporting information was introduced throughout the survey to enable the respondent to give an informed and conscious response. Online surveys allow fast and effective access to a larger number of respondents and greater flexibility regarding the time or place of their participation.²³

Pilot study, validity and reliability

To check the consistency, clarity, and suitability of the developed tool, validity and reliability tests were performed on the questionnaire.

The validity test aimed to verify whether the objectives of the questionnaire were represented by the questions asked in the survey, i.e. whether the survey actually measures what is claimed in its aims.²⁴ To this end, seven experts from different fields of Radiotherapy and Medical Physics (Planning Image, Treatment Planning, Treatment, Quality Assurance, Management and Research) were invited to classify each question regarding their ability to measure what is proposed (content validity). A four-point Likert scale ranging from 1 to 4 (not relevant to relevant, respectively) was used to collect this data.^{25,26}

The Item-Content Validity Index (I-CVI) was calculated by dividing the number of questions rated 3 or 4 by the total number of questions, with the value 1 corresponding to the best content validity index.^{27,28} The survey had an I-CVI of 0.987, and it was considered valid.

Before any measurement instruments or assessment tools can be used for research, their reliability must be established. Reliability is defined as the extent to which measurements can be replicated, which reflects not only the degree of correlation but also an agreement between measurements. A test-retest was performed²⁹ where the same survey was administered twice to three RT professionals two weeks apart. The reliability was assessed by calculating the interclass correlation coefficient (ICC) using a two-way mixed and absolute agreement model. An ICC of 0.811 ($p < 0.001$), 0.836 ($p < 0.001$), and 0.884 ($p < 0.001$) were obtained for each RT professional respectively, showing a good reliability. The pilot survey was distributed to 66 TR/RTTs in a large oncology hospital, of which 52 responses were gathered, six were excluded for being incomplete, leaving 46 valid responses (response rate of 69.7%).

Some amendments were made to the questionnaire following feedback from the participants. The internal consistency (reliability) was measured through the evaluation of the responses to repeated questions within the questionnaire using the Cronbach's alpha reliability coefficient. The value obtained was 0.983, i.e. there was high internal consistency.³⁰

Survey distribution

This study is part of the SAFE EUROPE project funded by the European Commission (under an Erasmus+ Sector Skills Alliance grant)³¹. Therefore, the survey was distributed by the professional organisations within the consortium: Associação Portuguesa de

Radioterapeutas - ART (Portugal), Society of Medical Radiographers - SRM (Malta), Polskie Towarzystwo Ekonomiczne - PTE (Poland) and the European Federation of Radiographer Societies – EFRS (across Europe).

The target population included all TR/RTTs working in Europe. The accessible population included all European TR/RTTs who were members of the professional organisations mentioned above or linked with the SAFE EUROPE project.

Invitations were sent via email by the professional organisations (ART, PTE, SRM and EFRS) to professionals who agreed to receive this type of information (email lists). The EFRS distributed the survey to the national associations members. To increase the number of participants, invites were posted on the SAFE EUROPE social media platforms (Twitter, Facebook and LinkedIn) and shared by the consortium members. The survey was electronically distributed using Google Forms software and was available from March to November 2021.

RT digital skills score

The assessment of the RTT/TRs' skills level was performed by analysing the results obtained in sections III to VI of the survey. In these sections, participants were asked to rate their level of proficiency development for an extensive list of digital skills in a Likert scale ranging between 1 (underdeveloped) and 5 (highly developed).³² It was considered that all questions contribute equally to the outcome of each segment, just as each segment contributes equally to the final score of the RT digital skills. Thus, a score was assigned to each participant on a scale from 0 to 100, in which the higher their level of digital skills proficiency development, the higher their score; 100 corresponds to a participant who rated every skill as “highly developed”.

Data analysis

Statistical analysis was performed using R software v4.0.5. Categorical variables were summarized as frequencies and percentages. Continuous variables were presented as median, minimum, and maximum.

Comparisons between independent groups were performed using Mann–Whitney or Kruskal-Wallis tests for continuous variables. The Spearman's rank correlation coefficient (r) was used to measure the strength of the relationship between two continuous variables.

The Friedman test was used to determine if there was a statistically significant difference between the different digital skills presented to the participants. The Nemenyi test was conducted as a post hoc test, to determine which digital skills were the most and least developed. All tests of statistical significance were two-sided; a p value <0.05 was considered significant.

For the collection of additional information from the survey, a thematic analysis using a free and open source qualitative data management software (Taguette Version 1.3.0, European Organization for Nuclear Research, Switzerland) was carried out, which allowed the analysis of data from the open-ended questions.^{33,34} A theoretical analysis (Percy, W. H., Kostere, K., & Kostere, S. (2015). *Generic Qualitative Research in Psychology*. *The Qualitative Report*, 20(2), 76-85. <https://doi.org/10.46743/2160-3715/2015.2097>) was used with the aim of identifying digital skills used in the professionals' practice and not listed in the survey. The data collected were analysed individually and organised under the appropriate pre-existing themes(ref), keeping in mind that new themes may also emerge during the data analysis process. Investigator triangulation were used to provide multiple observations and conclusions. This type of triangulation allows both the confirmation of results and the presentation of different perspectives, adding breadth to the phenomenon of interest (Denzin, N.K. (1978). *Sociological methods: A sourcebook*. New York, NY: McGraw-Hill) (Carter N, Bryant-Lukosius D, DiCenso A, Blythe J, Neville AJ. The Use of Triangulation in Qualitative Research. *Oncology Nursing Forum*. 2014;41(5):545-547. doi:10.1188/14.ONF.545-547).

The pilot survey was not included in the data analysis.

Ethical considerations

Ethical permission was granted by the Institute of Nursing and Health Research Ethics Committee at Ulster University, Belfast (FCNUR-20-032-A). Participant Information was provided at the beginning of the survey, and all data was kept safe, either by locks or passwords, for physical and electronic data respectively. ~~There was no coercion of participants, as it was necessary to click voluntarily on the link to participate.~~

Results

From a total of 123 responses, 101 valid responses were analysed, and 22 were removed according to the exclusion criteria (Figure 1).

Statistical analysis

Socio-demographic characteristics and ICT Skills

The socio-demographic characteristics of the respondents are presented in Table 2, and the level of their ICT Skills is in Table 3. The median age of the participants was 34 years, ranging between 23 and 66 years old. The median years of experience in RT were 12 years, ranging between less than a year and 36 years.

Table 2 – Respondents' socio-demographic characteristics.

		n (%)
Gender	Female	73 (72.3%)
	Male	27 (26.7%)
	Prefer not to say	1 (1.0%)
Initial academic level (EQF)	EQF4	1 (1.0%)
	EQF5	5 (5.0%)
	EQF6	72 (71.3%)
	EQF7	11 (10.9%)
	EQF8	12 (11.9%)
Highest academic level (EQF)	EQF4	1 (1.0%)
	EQF5	3 (3.0%)
	EQF6	54 (53.5%)
	EQF7	29 (28.7%)
	EQF8	14 (13.9%)
Country where respondents currently work	Austria	3 (3.0%)
	Belgium	2 (2.0%)
	Croatia	1 (1.0%)
	Denmark	1 (1.0%)
	Finland	1 (1.0%)
	France	6 (5.9%)
	Italy	1 (1.0%)
	Malta	2 (2.0%)
	Netherlands	4 (4.0%)
	Norway	5 (5.0%)
	Poland	17 (16.8%)
	Portugal	36 (35.6%)
	United Kingdom	22 (21.8%)
Radiotherapy areas of practice where participants have experience (participants were allowed more than one selection, with the "other" option corresponding to an open question)	Planning Image, Treatment Planning, Treatment	22 (21.8%)
	Planning Image, Treatment Planning; Treatment, Other	8 (7.9%)
	Planning Image, Treatment	31 (30.7%)
	Planning Image, Treatment; Other	8 (7.9%)
	Treatment Planning, Treatment	7 (6.9%)
	Treatment Planning, Treatment, Other	2 (2.0%)
	Treatment, Other	3 (3.0%)
	Treatment	17 (16.8%)
	Treatment Planning	3 (3.0%)
Number of radiotherapy areas with experience	1	20 (19.8%)
	2	41 (40.6%)
	3	32 (31.7%)
	4	8 (7.9%)
Training in digital skills in the last 12 months	No	63 (62.4%)

	Yes	28 (27.7%)
EQF - European Qualifications Framework, EQF4 - Secondary level course, EQF5 - Short higher education programme, EQF6 - Bachelor's degree, EQF7 - Master's degree, EQF8 - Doctoral Degree		

Table 3 – Respondents' ICT skill level.

		n (%)
Information processing	Basic user	10 (9.9%)
	Independent user	39 (38.6%)
	Proficient user	52 (51.5%)
Communication	Basic user	14 (13.9%)
	Independent user	62 (61.4%)
	Proficient user	25 (24.8%)
Content creation	Basic user	52 (51.5%)
	Independent user	15 (14.9%)
	Proficient user	34 (33.7%)
Safety	Basic user	29 (28.7%)
	Independent user	22 (21.8%)
	Proficient user	50 (49.5%)
Problem-solving	Basic user	29 (28.7%)
	Independent user	19 (18.8%)
	Proficient user	53 (52.5%)

The sample was distributed by 13 European countries, according to Table 2. However, there was a predominance of answers from Portugal, the United Kingdom (UK) and Poland.

Although the UK is no longer a member state of the European Union/European Economic Area (EU/EEA), it was decided to include the responses in the data analysis, since the survey was designed, and its pilot study applied, in 2019, in the period before the UK left the EU/EEA. The survey was distributed across Europe from March 2021, just after the transition period, and therefore it was considered that the responses of UK participants still reflected their membership status.

Most respondents replied that the educational level that gave them access to the profession was the bachelor's degree (EQF6). However, more than 40% of the respondents have additional postgraduate education at Master's and Doctorate levels. Regarding the number of Radiotherapy areas where respondents indicate having experience, 40.6% refer to two areas of Radiotherapy practice, with the majority selecting the areas of pre-treatment imaging and treatment administration.

When asked about training in digital skills in the last 12 months, 62.4% of respondents reported not having received any training.

In Table 3, where ICT skills levels are presented, most respondents consider themselves basic users regarding content creation, while for information processing, only 10% consider themselves as a basic user and the majority as a proficient user. In the skills related to problem solving and security, 53% and 50% of respondents reported themselves as proficient, respectively, while in communication, only 25% identify themselves as proficient.

Level of RT digital skills

The RT digital skills score in Table 4 shows that Transversal Digital Skills was the section with the highest score, followed by the Treatment section. On the other hand, Treatment Planning and Management and Research sections showed the lowest score. With the Friedman test showing a statistically significant difference between all sections, followed by the post hoc test (Table 5), these scores translate into the sections with the most and least developed digital skills.

Table 4 – RT digital skills score by section.

Sections	Number of questions	Score	p-value
Transversal	27	85.2 (35.2-100.0)	<0.001
Treatment	59	75.5 (0.4-100.0)	
Planning Image	29	69.8 (3.4-100.0)	
Quality, Safety, and Risk	25	57.0 (4.8-100.0)	
Management and Research	14	50.0 (0.0-100.0)	
Treatment Planning	41	31.0 (0.0-100.0)	
Total	195	62.4 (20.6-98.4)	

Table 5 – Nemenyi Post-Hoc test results.

Sections	Planning Image	Treatment Planning	Treatment	Quality, Safety and Risk	Management and Research
Transversal	<0.001	<0.001	0.388	<0.001	<0.001
Planning Image		<0.001	0.430	0.131	0.003
Treatment Planning			<0.001	<0.001	0.015
Treatment				<0.001	<0.001
Quality, Safety and Risk					1.000

Socio-demographic characteristics relationship with RT digital skills score

The relationship between the socio-demographic characteristics and the digital skills score

was also studied (Table 6).

Table 6 – Relationship between socio-demographic characteristics and survey score.

		Total Score (Min-Max)	p-value
Age/years	34 (23-66)	62.4 (20.6-98.4)	0.047 (r = 0.20)*
Initial academic level (EQF)	EQF4	74.7 (74.7-74.7)	0.211
	EQF5	73.4 (61.5-82.6)	
	EQF6	63.7 (31.3-98.4)	
	EQF7	60.6 (50.7-93.2)	
	EQF8	55.8 (20.6-84.5)	
Highest academic level (EQF)	EQF4	74.7 (74.7-74.7)	0.364
	EQF5	75.5 (61.5-82.6)	
	EQF6	62.9 (39.7-98.4)	
	EQF7	63.7 (31.3-93.2)	
	EQF8	59.7 (20.6-84.5)	
Years practising Radiotherapy	12 (0-36)	62.4 (20.6-98.4)	0.005 (r = 0.28)*
Number of Radiotherapy areas with experience	1	49.9 (20.6-76.3)	<0.001
	2	60.4 (33.8-98.4)	
	3	69.8 (31.3-97.7)	
	4	78.1 (63.3-97.0)	
Training in Digital Skills in the last 12 months	No	60.2 (20.6-92.5)	0.289
	Yes	70.0 (41.2-98.4)	

EQF - European Qualifications Framework *Spearman's rank correlation coefficient

The Spearman's rank correlation test showed a weak positive relationship between age (r=0.20) and time of experience (r=0.28) with the digital skills level score obtained, in which the higher the age and time of service, the higher the score. The number of areas of practice in which TR/RTTs have experience also demonstrates a significant difference, where the greater the number of areas of practice, the higher the score obtained. No relationship was found between the other demographic characteristics and the score.

ICT skills level relationship with RT digital skills score

A statistically significant difference was found between the generic ICT skills of communication, content creation, and problem-solving, with the RT digital skills scores

obtained by the participants (Table 7).

Table 7 – Relationship between ICT Skills level and RT digital skills score.

		n (%)	Total Score Median (Min-Max)	p-value
Information processing	Basic user	10 (9.9%)	54.4 (39.7-80.3)	0.130
	Independent user	39 (38.6%)	66.9 (27.6-98.4)	
	Proficient user	52 (51.5%)	63.0 (20.6-97.7)	
Communication	Basic user	14 (13.9%)	54.5 (20.6-75.2)	0.008
	Independent user	62 (61.4%)	68.7 (27.6-98.4)	
	Proficient user	25 (24.8%)	58.3 (31.9-96.6)	
Content creation	Basic user	52 (51.5%)	58.8 (20.6-96.6)	0.005
	Independent user	15 (14.9%)	76.3 (43.6-98.4)	
	Proficient user	34 (33.7%)	67.5 (31.3-97.7)	
Safety	Basic user	29 (28.7%)	60.7 (41.1-97.7)	0.190
	Independent user	22 (21.8%)	73.7 (40.3-98.4)	
	Proficient user	50 (49.5%)	62.1 (20.6-97.0)	
Problem-solving	Basic user	29 (28.7%)	59.3 (27.6-92.5)	0.048
	Independent user	19 (18.8%)	72.6 (40.3-98.4)	
	Proficient user	53 (52.5%)	63.7 (20.6-97.7)	

Educational context in which the digital skills are developed

With regard to the stage at which digital skills were developed, the Friedman test (Table 8), showed a significant difference between the different contexts studied ($p < 0.001$). The Nemenyi's post-hoc test (Table 9) identified that respondents develop the RT digital skills mostly in informal CPD contexts, followed by basic education and voluntary CPD. ~~Less-relevance was given to mandatory CPD and postgraduate education.~~ **The respondents gave less importance to “mandatory CPD” and “postgraduate education” for the development of digital skills.**

Table 8 – TR/RTTs' educational context where digital skills were developed.

Digital Skills Education	Percentage	p-value
Informal CPD	33 (0-100)	<0.001
Basic radiographer education	20 (0-100)	
Voluntary CPD	20 (0-40)	
Mandatory CPD	16 (0-40)	
Postgraduate education	0 (0-60)	

CPD - Continuous Professional Development

Table 9 – Nemenyi Post-Hoc Test results.

Digital Skills Education	Postgraduate education	Mandatory CPD	Voluntary CPD	Informal CPD

Basic education	<0.001	<0.001	0.020	<0.001
Postgraduate education		0.376	0.009	<0.001
Mandatory CPD			1.000	<0.001
Voluntary CPD				<0.001

CPD - Continuous Professional Development

Thematic analysis

At the end of each section from III to VI, the participant was given the opportunity to identify any other digital skills that are used in their practice and not identified in the list of digital skills included in the survey.

The suggestions made were scanned for similarity and examples, marking similar intended meanings (e.g., "planning system database management" and "active directory management"), and organised under the pre-existing themes⁷ or matched to form a new theme. The input from the participants resulted in digital skills coded into two themes and three sub-themes (see table 10).

Table 10 – Thematic analysis of the open-ended questions.

Themes	Sub-themes	Digital skills
Transversal	Technologies/ IS	- Set up the IS
	Patient agenda	- Use of a checklist for activities
Management, Research	Departmental IS administration and management	- Manage the TPS database - Manage IS - Manage hardware - Access all the functions of IS - Manage directories

IS- Information Systems, TPS- Treatment Planning System

The new codified sub-theme was "Departmental Information Systems (IS) administration and management", all the others corresponding to the previously identified themes and sub-themes. However, all digital skills in Table 10 correspond to potential tasks to be added to the list of digital skills published previously⁷, as they were identified by the participants as tasks of TR/RTTs practice and not present in the survey list.

These presented digital skills correspond to new tasks performed by TR/RTTs in practice, as they do not correspond to any skills from the survey list. References were also made to RT technologies/techniques that were not included in the survey, such as "perform MRI imaging", "use MRI images for treatment planning", "use of adaptive radiotherapy", "perform adaptive radiotherapy (Cone-beam Computed Tomography based)" and "perform

proton therapy".

~~However, beyond these, skills with the same or similar meanings to those included in the survey were also suggested by respondents, e.g: "Import patient position images through the IS" and "Import and edit patient positioning data parameters."~~

Discussion

This is the first study exploring the development **proficiency** of RT digital skills of TR/RTTs in Europe. As such, this paper constitutes a relevant contribution to knowledge. The main conclusion of this study was that TR/RTTs develop different digital skills at different levels. Friedman's test and the corresponding post-hoc tests suggest that digital skills related to "treatment planning" and "management and research" were the least developed themes. This agrees with previous literature that showed that "management and leadership" and "research and education" were underdeveloped by TR/RTTs working in the linear accelerator.⁶ Furthermore, another study showed that training programmes do not always include RT treatment planning.³⁵ **This may be due to the fact that many educational programmes have a low percentage of RT in the curriculum and treatment planning may not be covered in every course. Additionally, after graduation only a few TR/RTTs work in treatment planning, and they may be losing skills in this area.** However, this study shows that digital skills corresponding to treatment planning are also underdeveloped.

Even though the RT digital skills median score was 62.4 (out of 100), the score ranged from 20 to 98.4. As such, it is essential to understand the heterogeneity of the TR/RTT workforce. This range also suggests that some TR/RTTs have very underdeveloped digital skills, with TR/RTTs with a score of 0 in some RT digital skills sections ("Treatment Planning" and "Management and Research").

Additionally, the larger the number of areas of expertise of the TR/RTT (Planning Image, Treatment Planning; Treatment, Other), the higher the score. This shows that digital skills may be developed as TR/RTTs gain experience in different areas of practice. These results are supported by the fact that age and years of experience correlated with an increased RT digital skills score, giving them time to learn new digital skills in practice. However, this must be confirmed by additional research.

A digital skill is underpinned by skills in ICT to retrieve, assess, store, produce, present and exchange information, to communicate and participate in networks.^{8,ref} In the context of RT, ICT skills are included not only in the performance of more general tasks, but also in specific ones. For example, in one of the ICT skills assessed, "communication", in order for the TR/RTTs to be able to share images and content using simple tools, they need to have at least the basic level of this previous ICT skill. In this study, there was a relationship between higher ICT skills and RT digital skills scores. "Basic users" in "communication", "content creation" and "problem-solving" ICT skills had statistically lower RT digital skills scores. This relationship was expected since higher ICT skills are essential to developing professional-specific digital skills.^{1,8,17}

Regarding the educational context in which digital skills are developed, it was pointed out that TR/RTTs develop most digital skills through CPD (69%). Of these, 33% developed digital skills through informal CPD, which may include on-the-job training, once again, supporting the prior hypothesis that digital skills are mostly gained through practice. Nevertheless, only 20% of the digital skills were developed in their training to become TR/RTTs and 36% through voluntary and mandatory CPD. ~~therefore, this must be considered when designing RT education programmes and CPD activities.~~ Although less relevance was given to mandatory CPD (16%) and postgraduate education (0%) by the respondents, some of the skills are developed through these training and this should be considered when designing RT educational programmes and CPD activities.

~~In the thematic analysis of the open-ended questions, there was an opportunity to add new skills to the previously published list of digital skills for TR/RTTs.⁷ Some digital skills suggested in the open-ended questions were already on that list, validating their importance.~~ In the thematic analysis of the open-ended questions, a single sub-theme was identified that differed from the pre-existing themes⁷. However, all the digital skills coded and presented in Table 10 differ from the skills already published in the previous review, and an opportunity arose for their inclusion in the published list of digital skills for TR/RTTs.⁷

The reference, by the participants, to RT technologies and techniques that were not mentioned in the survey demonstrate the heterogeneity of knowledge and skills of TR/RTTs, conditioned by the variability of technology available³⁶ but also by the divergence in the training of these professionals.³⁷ This is reflected in the role development of the TR/RTTs' practice, where in some countries there is another level of practice - advanced

practice (AP). Professionals working in AP roles extend or expand areas of practice using different skill sets. These practitioners work with more autonomy and accountability in the RT setting.³⁸ For this, their radiotherapy-specific skills should always be updated, which also includes digital skills to work with the radiotherapy IS.

In order to address the digital skills proficiency it becomes necessary to adapt undergraduate and further education in the TR/RTT profession. A focus can go through the curricular implementation of digital literacy (Hautz S, Exadaktylos AK, Hautz WE, Sauter TC. Digitale Kompetenzen in der medizinischen Ausbildung der Schweiz: eine Standortbestimmung. *GMS J Med Educ.* 2020;37(6):Doc62. DOI: 10.3205/zma001355), ICT skills (Kijisanayotin et al. (2009), but also RT-specific digital skills, using the published list of digital skills as educational guidance.⁷

Some universities have already successfully implemented and evaluated an elective curriculum for the promotion of digital skills in healthcare, as is the case of the University Medical School of the Johannes Gutenberg University of Mainz (Kuhn S, Müller N, Kirchgässer E, Ulzheimer L, Deutsch KL. Digitale Kompetenzen für Medizinstudierende – Qualitative Evaluation des Curriculum 4.0 "Medizin im digitalen Zeitalter. *GMS J Med Educ.* 2020;37(6):Doc60. DOI: 10.3205/zma001353) or the University of Hamburg (Werner R, Henningsen M, Schmitz R, Guse AH, Augustin M, Gauer T. Digital Health meets Hamburger Modellstudiengang iMED: Konzept und Einführung des neuen interdisziplinären Hamburger Wahlpflichtbereichs Digital Health. *GMS J Med Educ.* 2020;37(6):Doc61. DOI: 10.3205/zma001354) with the introduction of a longitudinal interdisciplinary elective course "Digital Health" for medical students in year 3 or above. These examples can serve as a basis for training TR/RTTs, and can be a starting point for developing a joint digitization strategy. The aim is to provide a structured teaching of digital skills. In the future, it would be interesting to research the training strategies implemented with regard to their effectiveness in later working life.

Limitations

Convenience sampling was used since only members of the professional organisations or those with access to the SAFE EUROPE consortium media could participate in the survey. Therefore, the respondents may not be a true reflection of the European TR/RTTs population. To compensate, a strong emphasis was placed on disseminating the survey across European professional organisations. Although there is no formal estimate available globally for the number of TR/RTTs (doi:10.1200/GO.21.00358), based on the most recent HCPC data (<https://www.hcpc-uk.org/resources/freedom-of-information-requests/2018/number-of-therapeutic-radiographers-on-the-hcpc-register---may-2018/>),

the number of TR/RTTs females/males in this study (72.3% and 26.7%, respectively) was considered representative of the general RT population. The survey was sent via email by the professional organisations (ART, PTE, SRM and EFRS) to professionals who agreed to receive this type of information and picked up by social media. Therefore, the exact response rate is difficult to determine.

Since the level of digital skills development **proficiency** is directly related to the respondent's perception of them, the answers may have some bias. The researchers tried to minimise this possibility by clarifying the questions as much as possible. In addition, the questionnaire was kept anonymous to minimise social desirability bias.

Further research is recommended to understand the digital gaps identified in the survey. This additional research should allow a deeper understanding of the factors influencing these digital skill development **proficiency** levels and at what stage these skills should be integrated into the education of TR/RTTs.

Recommendations

It is recommended that training for TR/RTTs should also develop the digital skills required to perform tasks in this profession **at a high level of proficiency**. This training can be offered as part of their RT education. However, since CPD (voluntary, mandatory and informal) seems to have a role in developing digital skills, this may be an adequate option to upskill TR/RTTs.

The development of ICT skills is an essential base for developing RT-specific digital skills. As such, it is recommended that TR/RTTs develop these skills prior to or during their RT training programmes. Since the number of RT areas of practice where the professional has experience seems to be related to the RT digital skills score, it is recommended that all TR/RTTs have the opportunity to gain experience across all areas of RT.

This study addressed the digital skill needs for the whole RT profession. However, it would be pertinent to study what are the specific needs for different roles of TR/RTTs. This is, therefore, suggested as a future study.

~~It is also recommended that further investigation of the digital skills associated with the RT technologies/techniques highlighted by participants is required in order to update and include new sub-themes in the list of digital skills available in the literature, allowing an adaptation to the emerging and future practice of TR/RTTs.~~

It is also recommended to further investigate the digital skills and RT technologies/ techniques highlighted by the participants. The aim would be to update the list of digital skills available in the literature with new sub-themes, seeking an adaptation to the emerging and future practice of TRs/RTTs.

Conclusion

Digital skills ~~have never been more essential to the workforce as they are no longer 'optional' but crucial~~ **are essential in radiotherapy workforce.** The digitalisation of the economy is one of the most important drivers behind the transformation of healthcare and the way healthcare professionals work, and this digitalisation is likely to become even more significant in the years to come. This new paradigm poses a challenge for TR/RTTs, as current RT practice depends entirely on the support of digital equipment. As such, they must develop the necessary digital skills to provide appropriate care to cancer patients.

The education and training sector **for TR/RTTs** must be intelligence-driven to develop and adapt its provision to meet the changing needs of this digitisation. ~~Education programmes must be updated, and digital skills must be part of the skills required at every level.~~

Education programmes should ensure that digital skills are part of the required skills at all levels.

These skills can be developed in many ways: during TR/RTTs' initial education, through formal CPD (mandatory or voluntary) and informal CPD, such as on-job training. Treatment planning, management and research-related digital skills were the least developed. As such, training in these areas is recommended.

Finally, work experience across the different areas of RT (such as pre-treatment imaging, planning and treatment) is one factor that seems to impact digital skills score. This conclusion is supported by the increase in digital skills with age and years of experience. It is imperative to continue the research on the digital skills of TR/RTTs, to include new themes and sub-themes that can cover new technologies and the corresponding skills, which are considered essential in the current TR/RTT curriculum.

Word count:

Manuscript – 3743

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