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CONCEPTUALISING DIGITAL COMPETENCY FOR ICT SPECIALISTS

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ABSTRACT

A competency-based approach to education has become central in discussing and assessing the quality of education. Competency is vital for any individual to cope successfully with challenging tasks in his/her professional, social and private life and achieve the goals set. In order to practically implement the approach in higher education institutions, it is necessary to understand what competencies are required by the labour market and what their structure is, as well as to select or develop models or frameworks for describing these competencies. One of the most relevant competencies in the modern world is digital competence which implies knowledge and skills to use information and communication technology (ICT) to achieve professional, social and personal goals. Although the need for developing digital competence is actual for specialists in any field, the definition of its structure for ICT professionals is mainly ignored. Therefore, it can hinder the development of quality educational programs and prevent graduates from being equipped with the necessary skills and knowledge. This study applies a systematic literature review to answer three research questions concerning the types and structure of digital competence of ICT professionals, the developed models and frameworks of digital and professional competence of ICT specialists, and the representation of digital competence in the existing competence frameworks and models. The research results offer the conceptualisation of digital competence for ICT specialists. It includes transversal digital competence, general professional digital competence, and specific professional digital competence, together with indicating an appropriate framework for each of the competence types mentioned.

Keywords: *competence framework, digital competence, higher education, ICT professionals, systematic literature review*

Introduction

Education at universities is no longer considered as the delivery of academic knowledge from a teacher to a student but as the acquisition of knowledge and skills that are dictated by the needs of the labour market and promote the employability of students and competitive growth, prosperity and innovation-driven development of world

economies. A New Skills Agenda for Europe (European Commission, 2016) has emphasised the need for higher education institutions (HEIs) "*to ensure that they equip graduates with relevant and up-to-date skills*". In this context, the concepts of competency and a competency-based approach to education have become central in discussing and assessing the quality of education. Competency is vital for anyone to cope successfully with challenging tasks in his/her professional, social and private life to achieve the goals set. Competency-based education ensures personalised and learner-centred teaching, learning and assessment that allow students to master and demonstrate observable skills to succeed in their future professional and adult life. In order to practically implement the approach in HEIs, it is necessary to understand what competencies are required by the labour market and what their structure is, as well as to select or develop models or frameworks for describing these competencies.

One of the most relevant competencies in the modern world is digital competence which implies knowledge and skills to use ICT to achieve professional, social and private goals. The European Union has set a goal that by 2030, at least 80% of citizens will have basic digital skills (European Commission, 2022). Currently, attempts are being made to define digital competence for citizens in general (Vuorikari et al., 2022), educators (Redecker, 2017), consumers (Brečko & Ferrari, 2016) and others. Although the need for developing digital competence is actual for specialists in any field, the definition of its structure for ICT professionals is mainly ignored. It is likely to be explained by the belief that ICT specialists should possess this competence by default, as various ICT solutions are intensively used in daily professional tasks. However, even without excessive analysis, it can be noted that digital competence of ICT specialists differs both in terms of content and depth from employees in other industries. Specialists in other fields mainly use ICT solutions to perform specific tasks and thus basically act as technology users. Their knowledge and skills remain at the level of the human-computer interface when it is necessary to know how to use a specific ICT tool for a specific task, i.e. run, configure according to the requirements of the task, enter correct data, receive and interpret an output, use the tool safely and ethically, and others. Those working in the field of ICT also use ICT solutions in their daily professional work but more intensively and need in-depth knowledge of the "internal content" of a specific ICT solution (structure, data processing steps, used technologies, and others).

The fact that the digital skills of ICT professionals stand apart from the similar skills of practitioners of other fields is demonstrated by several more general classifications of ICT digital skills. In 2016, the OECD proposed the classification of ICT skills necessary for the digital economy. It includes three levels (OECD, 2016a, 2016b): ICT generic skills, ICT specialists skills and ICT complementary skills. The classification of the International Telecommunication Union offers a categorisation of ICT skills into three levels (Hakizimana, 2021): basic digital skills, intermediate digital skills, and advanced digital skills. In this classification, it is the advanced digital skills that ICT professionals must possess. They include skills such as software development, programming, network and system administration, information systems and network security, database development

and use, artificial intelligence, mobile application development, and many others. The European e-Competence framework defines three levels of e-skills (CEN, 2014a): ICT practitioner skills, e-business skills, and ICT user skills. The skills of ICT practitioners, in this case, are related to "*the abilities required for the research, development, design, strategic planning, management, production, consulting, marketing, sales, integration, installation, administration, maintenance, support and service of ICT systems*" (CEN, 2014a). However, the European e-Competence Framework focuses on ICT practitioners' and e-business skills. According to the Economic and Social Council of the United Nations, ICT specialists need two types of digital skills (United Nations Economic and Social Council, 2018):

- skills to adapt and creatively use available technologies. They involve adapting software and/or technology to individualised needs and requirements and are required by individuals or businesses who have already acquired basic digital skills. Consequently, individuals or corporate ICT departments understand the basic algorithms and can use online resources to create new functions or develop more suitable applications when needed;
- skills to innovate based on adapted technologies. These include sophisticated programming skills and knowledge of complex algorithms. Creating new technologies is the highest level of digital skills.

Ignoring the digital competence of ICT specialists can hinder the development of quality educational programs. This study aims to conceptualise digital competence for ICT professionals in terms of its types and/or elements and to identify suitable descriptive frameworks and/or models.

The paper is structured as follows. The next section describes the research methodology. After that, the concepts relevant to the research topic are defined. At the end of the paper, research results and discussion points are presented. Finally, the paper ends with the conclusion section.

Methodology

The present study addresses the following research questions:

- What are the possible types and structures of digital competence of ICT professionals?
- What models and frameworks of digital and professional competence of ICT specialists have been developed?
- How is digital competence displayed in existing frameworks and models of digital and professional competence of ICT specialists?

A systematic literature review was used as the primary research method to answer the above questions. It was applied in two stages with the following steps:

- Stage I: Searching scientific databases
  1. Selecting scientific electronic databases. The search was performed in IEEE Xplorer, ACM Digital Library, Scopus, and Web of Science. Web of Science and Scopus are the leading electronic databases of bibliographic information and citation data

of publications across various disciplines. IEEE Xplore Digital Library and ACM Digital Library are electronic platforms for searching and studying publications published by the leading organisations – Institute of Electrical and Electronics Engineers (IEEE) and Association for Computing Machinery (ACM) – and their partners in computer science and electronic engineering.

2. Developing search strings. Based on the topic knowledge of the paper's authors and considering the research questions defined, it was decided to develop search strings consisting of two parts:
   - Part 1 included one of the following terms: "digital competenc*", "professional competenc*", where * replaces multiple characters in a search string and therefore allows for searching, for example, such terms as "digital competence", "digital competencies" or "digital competency".
   - Part 2 included one of the following terms: "ICT graduate", "IT graduate", "ICT specialist", "ICT professional", "ICT practitioner", "IT specialist", "IT professional", "IT practitioner", "computing", "computer science", "information technology", "computer engineering", "IT field", and "ICT field".
   - Some examples of the used search strings are the following:
   - "digital competenc*" AND "ICT specialist"
   - "professional competenc*" AND "IT field"
   - "digital competenc*" AND "computer science"
3. Conducting a search in the selected databases and screening paper bibliographic information, title, abstract and keywords by applying inclusion criteria. The following inclusion criteria were defined:
   - a paper is written in English;
   - a paper was published between 2010 and 2022. The year 2010 was chosen as a possible acceleration point for research on digital competence following the release of the first version of the European e-Competence framework and mentioning of this competence in several policy-related documents;
   - a paper addresses higher education in case of educational context considered in it;
   - a paper a) defines professional competence or digital competence of ICT specialists, or b) offers a model/framework for describing ICT specialists' competencies or curricula, or c) mentions existent models/frameworks for describing ICT specialists' competencies;
   - an electronic full-text of the paper is available;
4. Review and analysis of the found information sources.

- Stage II: Performing an additional search in the Google Search engine. Considering that the search in electronic databases provided only a few relevant publications, it was decided to perform an additional search in the Google Search Engine using search strings developed in Stage I. Each paper found was screened by applying the previously defined inclusion criteria. Finally, all of the documents found were reviewed and analysed.

The study was conducted in the autumn of 2022 and winter of 2023. In total, 17 information sources were selected and analysed, among them research papers, governmental documents, technical notes, and publications of professional associations.

Concepts and Definitions

In order to conceptualise the digital competence of ICT specialists, it is first necessary to define the related terms and their use in a digital context. The meaning, possible typology and even the correct spelling of the concept of competencies have been intensively discussed issues for many years (see, for example, (Frezza et al., 2018)) and are beyond the scope of this paper. However, most definitions still define competence in terms of knowledge, skills and attitudes, as the European e-Competence framework does: "*Competence is a demonstrated ability to apply knowledge, skills and attitudes for achieving observable results*" (CEN, 2014a). In the context of computer science, the previously mentioned constituents are made more explicit (Clear et al., 2020):

$$\text{Competency} = [\text{Knowledge} + \text{Skills} + \text{Dispositions} + \text{Task}],$$

where

- knowledge is a factual or "know-what" dimension of the competency,
- skills are a "know-how" dimension of competency referring to the capability and strategy for applying "know-what" to perform a task in context,
- dispositions are a "know-why" (the socio-emotional tendencies, predilections and attitudes) dimension of competency that prescribes a requisite character or quality in task performance,
- task is the construct that frames the skilled application of knowledge and makes dispositions concrete.

The application and manifestation of knowledge, skills and dispositions in the professional activity of an individual call for the concept of professional competence. García et al. (2019) define professional competence as "*The degree of utilisation of knowledge, skills, and the good judgment related to the people's profession, and in correspondence with all the situations that can be lived in the exercise of professional practice*". In the context of ICT specialists, it should be noted that one of the world's largest educational and scientific societies in computer science, ACM, emphasises that professional competence of ICT specialists "*begins with technical knowledge and an awareness of the social context in which they work can be used. Professional competence also requires skills in communication, reflective analysis and recognising and overcoming ethical challenges*" (ACM, 2018). Thus, the proposed definitions allow one to conclude that the concept of professional competence is quite broad. It encompasses all knowledge, skills and attitudes that can be demanded by an occupation and has a multi-component structure.

In general, competencies are classified into two main types. First, technical competencies, also called hard or specific competencies, are directly related to a job or activity made by an individual (Hernandez-Linares et al., 2015). Second, transversal competencies, such as communicative competence, problem solving, creativity, and others,

are necessary for any work, and their essential feature is transferability between fields (Sá & Serpa, 2018). They are also called generic or soft competencies (Hernandez-Linares et al., 2015) and are contrasted with specific competencies (Sicilia, 2009). Therefore, one can conclude that technical and transversal competencies are part of the professional competence of a specialist in any field.

Ferrari (2012) has provided a well-known definition of digital competence: "*Digital competence is the set of knowledge, skills, attitudes (thus including abilities, strategies, values and awareness) that are required when using ICT and digital media to perform tasks; solve problems; communicate; manage information; collaborate; create and share content; and build knowledge effectively, efficiently, appropriately, critically, creatively, autonomously, flexibly, ethically, reflectively for work, leisure, participation, learning, socialising, consuming, and empowerment.*" Thus, digital competence is specifically related to using ICT solutions in contexts like learning, work and social participation (European Commission, Directorate-General for Education, Youth, Sport and Culture, 2019). Furthermore, Calvani et al. (2008) have indicated that digital competence is a multidimensional phenomenon characterised by technological (flexibly exploring new technological contexts), cognitive (access, selection and critical evaluation of information), and ethical (responsibly interacting through ICTs) dimensions and their integration. A systematic review of research about definitions, synonyms and background domains of digital competence is given by (Ilomäki et al., 2016; Spante et al., 2018).

Thus, the professional competence of ICT specialists consists of a set of competencies, and digital competence is only one of them (see Figure 1).

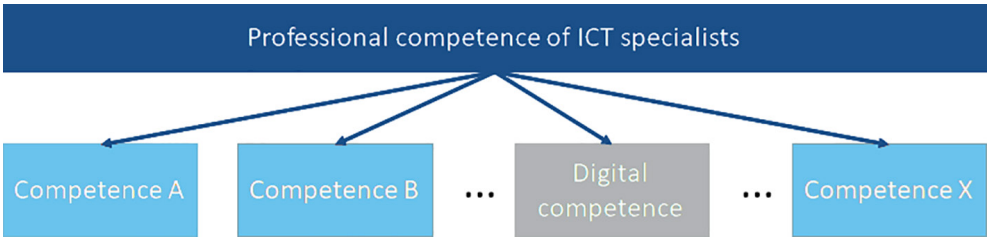

Figure 1 Digital competence as a component of professional competence of ICT professionals

Results

Research question 1: What are the possible types and structures of digital competence of ICT professionals?

During the research, only one information source was found that considered different types of digital competence in the context of ICT specialists. Álvarez-Rodríguez and Vera (2022) have specified both specific and transversal digital competencies adopting their definitions from the Mexican National Accreditation Council in Informatics and Computer Science:

- specific digital competencies are the necessary competencies defined for the specific profile of a specialist in the field of ICT, such as a computing specialist, software engineer, computer science specialist, computer engineer, data engineer, cyber security engineer and Internet of Things engineer;
- transversal digital competencies are the necessary competencies for using ICT as an intermediary between different work participants or as a work management tool, and they include the following competencies, which can be realised with the help of ICT solutions: oral and written communication, information analysis and synthesis, problem approach and solving, solution modelling, autonomous learning, teamwork, decision making, and effective use of ICT tools (including new technologies).

This viewpoint is well aligned with the specificity of the everyday work of ICT specialists. Those who are working in the ICT field use technology both:

- for their direct job duties, such as testing tools for executing software system tests, programming environments for coding, version control systems for tracking changes in software code, and others, and
- for performing supporting tasks such as communication with members of a specific project team, organisation of one's work, and others.
- Thus, specialists in the field of ICT need both specific digital competence, which requires the use of ICT solutions for the work to be performed in the field of ICT, and transversal digital competence, which is related to the use of ICT solutions for supporting tasks.

Research question 2: What models and frameworks of digital and professional competence of ICT specialists have been developed?

In the European Union, transversal digital competence is described by the DigComp framework, version 2.2 of which appeared in 2022. It can be attributed to any field, also the ICT field. The framework is structured in several dimensions (Vuorikari et al., 2022):

- the first dimension consists of five basic components of digital competence: Information literacy and computer literacy; Communication and cooperation; Creation of digital content; Safety; Problem solving;
- in the second dimension, a total of 21 specific competencies are defined, dividing them by the components mentioned above;
- the third dimension specifies skill levels;

- the fourth dimension provides examples of knowledge, skills and attitudes according to each previously defined competence;
- the fifth dimension describes the use cases of competencies.

The analysis of information sources allowed identifying a number of models and frameworks used to describe specific competencies in the ICT field. Certain models are more general and are intended for a broader range of ICT specialists without distinguishing a specific position or role (see Table 1). Other models, on the contrary, focus on competencies specific to a specific ICT position or role (see Table 2). Finally, there are also models that, on the one hand, provide a more general view that applies to ICT professionals in general, but on the other hand, are adaptable to a specific position, role or sub-sector of the ICT field, for example, in the SFIA 8 model, together with a general view, there are available also digital transformation skills view, software engineering competencies, DevOps skills view, big data/data science skills view, information and cyber security skills view, enterprise IT view (The SFIA Foundation, 2021).

Table 1 General competence frameworks for the ICT field

Model or Framework	Published; Current version year	Developer	Country	Structure
European e-Competence Framework (e-CF) (CEN, 2014a)	2008; 2020	European Committee for Standardization (CEN) and the European Committee for Electrotechnical Standardization (CENELEC).	European Union	Four dimensions: 5 e-Competence areas encompassing 40 e-Competences, 5 e-CF proficiency levels, and examples of knowledge and skills.
Information Technology Competency Model (U.S. Department of Labor, 2021a)	2012; 2021	U.S. Department of Labor, Employment and Training Administration	USA	9 tiers; 1.–3. foundational competencies, 4.–5. industry competencies; 6.–9. specialisation competencies
SFIA 8 model (The SFIA Foundation, 2021)	2000; 2021	SFIA Foundation	United Kingdom	Six knowledge and skill categories, 121 skills, and 495 unique skill-level descriptions.
ESCO (European Skills, Competences, Qualifications and Occupations) (European Commission, n.d.)	2010; 2020	European Commission	European Union	Descriptions of 3008 occupations and 13890 skills.
Skills Framework (SFw) for Infocomm Technology (Government of Singapore, 2022)	2017; 2022	SkillsFuture Singapore (SSG), Workforce Singapore (WSG), Infocomm Media Development Authority (IMDA)	Singapore	Two main components – technical competencies and generic competencies, including competency proficiency levels.

Table 2 Specific competence frameworks for the ICT field

Model or Framework	Published; current version year	Developer	Country	Structure
Enterprise Security Competency Model (U.S. Department of Labor, 2020)	2015; 2020	U.S. Department of Labor, Employment and Training Administration	USA	9 tiers; 1.–3. foundational competencies, 4.–5. industry competencies; 6.–9. specialisation competencies.
Cybersecurity Competency Model (U.S. Department of Labor, 2021b)	2017; 2021	U.S. Department of Labor, Employment and Training Administration	USA	9 tiers; 1.–3. foundational competencies, 4.–5. industry competencies; 6.–9. specialisation competencies.
Unified Competence Gate for Software Professionals (UComGSP) (Assyne et al., 2022)	2022	Assyne, N. Ghanbari, H. & Pulkkinen, M.	Finland, Estonia, Ghana	62 hard competencies, 63 soft competencies, and 25 essential software engineering competencies.
Competency Framework for Software Engineers (Rivera-Ibarra et al., 2010)	2010	Rivera-Ibarra, J.G., Rodríguez-Jacobo, J., Fernández-Zepeda, J. A., & Serrano-Vargas, M. A.	Mexico, USA	Technical competencies– knowledge and use of technology; Social – interpersonal relationships, cooperation and teamwork, handling and solving conflicts; Personal – development in the job environment, personal development, rights and limits.
Software Engineering Competency Model (SWECOM) (IEEE Computer Society, 2014)	2014	IEEE Computer Society	USA	Technical skills (divided into life cycle skill areas and cross-cutting skill areas), cognitive skills, behavioral attributes and skills, requisite knowledge, and related disciplines.
Software engineering body of skills (SWEBOS) (Sedelmaier & Landes, 2015)	2015	Sedelmaier, Y., & Landes, D.	Germany	Content: collaboration, communication, structuring one's way of working, personal competencies, problem awareness, problem-solving, and additional competencies.
Software Assurance (SwA) Competency Model (Hilburn et al., 2013)	2013	Hilburn, T., Ardis, M., Johnson, G., Kornecki, A. & Mead, N.R.	USA	Knowledge areas and units related to SwA competency, competency levels from 1 to 5, along with a breakdown of individual competencies based on knowledge and skills.

Research question 3: How is digital competence displayed in existing frameworks and models of digital and professional competence of ICT specialists?

The digital competence of ICT specialists is typically not separately distinguished and described in the competence models and frameworks considered in Tables 1 and 2. References to specific technology or activities with specific technologies may appear in the description of particular competencies; for example, in the European e-Competence Framework, they are included in the descriptions of examples of knowledge and skills (CEN, 2014b). In (Rivera-Ibarra et al., 2010), the use of technology is distinguished as a separate group of competencies in competencies related to job functions and includes assessment and selection of ICT tools, as well as their adaptation and use. Such ignoring of digital competence is most likely because the work of ICT specialists mainly involves the intensive use of various technologies for the performance of daily professional tasks and, as a result, the digital competence of ICT specialists, in this case, is closely intertwined with other competences and is therefore considered to be possessed by ICT specialists by default.

Similarly, the Information Technology Competency Model (U.S. Department of Labor, 2021a) defines the competencies required for individuals to excel in information technology, including their knowledge, skills, and abilities. The model is presented as a pyramid with multiple tiers, organised based on the increasing specialisation and specificity of skills required. The pyramid structure does not suggest any hierarchical arrangement of competencies, nor does it imply that the skills at the top are of higher importance than those at the bottom. Each pyramid tier is further divided into blocks that represent specific competency areas. This framework highlights fundamental IT user skills, such as using a computer, communication devices, and related applications to input, retrieve, and communicate information (U.S. Department of Labor, 2021a). This model includes working with tools and technology in the workplace competencies section.

The SFIA 8 model (Hayashiguchi et al., 2022; Raj et al., 2021; The SFIA Foundation, 2021; UNESCO-UNEVOC, n.d.) includes six knowledge and skill categories: strategy and architecture, change and transformation, development and implementation, delivery and operation, people and skills, and relationships and engagement. It includes the development of digital skills and abilities such as data analysis, software engineering, cybersecurity, network management, project management, communication, and collaboration skills. SFIA version 8 has expanded digital competencies, such as digital management and digital transformation, which are essential to promote the development of digital skills and adaptation to the rapidly changing IT industry.

In the field of ICT, ESCO defines ICT-related occupations and skills required for these roles, such as computer use, database and network design and administration, software and applications development and analysis, and more (Sanz et al., 2018; Varbanov & Georgiev, 2018).

The Skills Framework for Infocomm Technology (Government of Singapore, 2022) describes various skills and competencies for working in different ICT sectors, such as software engineering, data analytics, network management, and project management.

The framework consists of several modules, including modules of technical skills and modules of soft skills and behavioural competencies. The job roles' skills and competencies are categorised into two main types: technical skills and competencies, and critical core skills, formerly referred to as generic skills and competencies. The technical skills modules cover various areas relevant to digital competence, such as software development, database management, cloud computing, artificial intelligence, and the Internet of Things. Overall, the Skills Framework for Infocomm Technology supports the development of a highly skilled and adaptable workforce in the digital economy, which is essential for the growth and competitiveness of the ICT industry in Singapore and beyond.

Discussion

According to the analysis made, the digital competence of ICT specialists is divided into:

- professional digital competence, which is related to knowledge, skills and attitudes related to the use of ICT solutions for the work to be carried out in the field of ICT;
- transversal digital competence, which is knowledge, skills and attitudes related to the use of ICT solutions for supporting tasks, such as communication with other employees, work organisation, network etiquette, and others.

Taking into account the fact that there are both general descriptions of professional competence of ICT specialists and specific descriptions of positions and roles, it is possible to claim that professional digital competence is also divided into two types:

- general professional digital competence, which is attributed to any specialist in the field of ICT and provides a set of general knowledge, skills and attitudes regarding the use of technology for professional duties in the field of ICT, for example, knowledge of the internal structure and principles of operation of computers, organisation of computer networks, types of data storage, programming environments, and others;
- specific professional digital competence, which covers skills, knowledge and attitudes required for the specific position/roles in the field of ICT.

The conceptualisation of digital competence for an ICT specialist is reflected in Figure 2. It also specifies an appropriate competence framework for each of the competence groups. The DigComp framework developed in Europe is suitable for describing transversal digital competence. The European e-Competence Framework specifies general professional digital competence. Specific professional digital competence is different for different roles. Figure 2 gives an example of this type of competencies for a cybersecurity specialist.

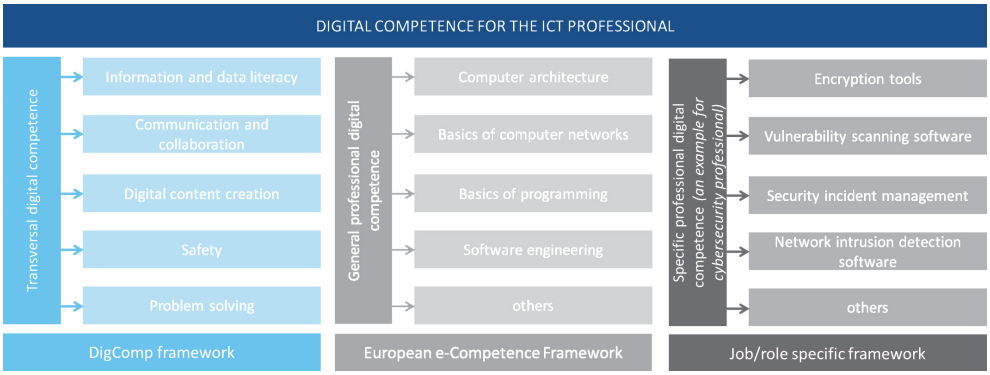

Figure 2 Conceptualisation of digital competence for ICT professionals

Conclusion

Professional competence frameworks and models are essential tools for employers and professionals in the ICT field to ensure they have the skills and knowledge required to succeed in their roles and help guide professional development and educational programs. Nowadays, many frameworks exist. They differ in scope, coverage, structure, and level of detail. Digital competence is a part of the professional competence of ICT professionals. The paper has demonstrated that it is multifaced phenomenon as it comprises transversal digital competence, general professional digital competence and specific professional digital competence. All three types of digital competence must be addressed and developed in the study process of ICT professionals in HEIs.

Further research could be directed to validating the proposed conceptualisation of digital competence for ICT professionals by engaging ICT practitioners and enterprises in its evaluation and refinement. Additionally, it would be rational to do an inventory of existent and identify missing frameworks that can be used to describe specific professional digital competence.

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