European Software
Skills Alliance.

Europe's Most Needed Software Roles and Skills.

NEEDS ANALYSIS REPORT 2021

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essa. European Software Skills Alliance

About ESSA

The European Software Skills Alliance (ESSA) is a four-year transnational project funded under the EU's Erasmus+ programme. It ensures the skills needs of the rapidly evolving Software sector can be met — today and tomorrow.

ESSA provides current and future software professionals, learning providers and organisations with software needs with the educational and training instruments they need to meet the demand for software skills in Europe.

ESSA will develop a European Software Skills Strategy and Vocational Education and Training programmes for Europe. It will address skill mismatches and shortages by analysing the sector in depth and delivering future-proof curricula and mobility solutions; tailored to the European software sector's reality and needs.

Project partners

The ESSA consortium is composed of 26 partners from the academic and non-academic sectors involved in the education, training and software sectors.

Full partners
Adecco Formazione, AICA, AKMI, AMETIC, ASIIN Consult, BCS Training, Budapest University of Technology and Economics, Codecool, DIGITALEUROPE, Digital Technology Skills, Global Knowledge France, Global Knowledge Netherlands, Chamber of Commerce and Industry of Slovenia, Hellenic Open University, HU University of Applied Sciences Utrecht, Irish Computer Society, IVSZ, MODIS, UNINFO, University of Ljubljana, and Warsaw School of Computer Science.

Associated partners
Amazon Web Services, European Schoolnet, General Assembly, IT Professionalism Europe, and NVIDIA Deep Learning Institute

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Deliverable 4: "Software Services Profiles, Competences, and Skills Needs"
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List of abbreviations and acronyms

Abbreviations and acronyms	Description
ACM	Association for Computing Machinery
AI	Artificial intelligence
AIS	Automated Identification System
ALM	Application Lifecycle Management
API	Application Programming Interface
AR/VR/XR	Augmented Reality, Virtual Reality, eXtended Reality
BSc	Bachelor of Science
CAD	Computer Aided Design
CD	Continuous Deployment
CEN	Comité Européen de Normalisation
CEN/CWA 16458-1	European ICT Professional Role Profiles
CI	Continuous Integration
CI/CD	Continuous integration/ Continuous delivery
CSS	Cascading Style Sheets
CX	Customer Experience
D	Deliverable
DevOps	Development & Operations
e-CF	European e-Competence Framework
ECTS	European Credit Transfer and Accumulation System
EQF	European Qualifications Framework
ESCO	European Skills, Competences, Qualifications and Occupations
ESSA	European Software Skills Alliance
EU	European Union
EUIF	Estonian Unemployment Insurance Fund
FinOps	Financial Operations
Git	Global Information Tracker
GSE	Global Software Engineering
HMI	Human-Machine Interface
HR	Human resources
HTML	Hypertext Markup Language
ICT	Information and Communications Technology
IEEE	Institute of Electrical and Electronics Engineers
IoT	Internet of things

ISO	International Organization for Standardization
IT	Information technology
MLP	Multilayer perceptron
MSc	Master of Sciences
NACE	Nomenclature of Economic Activities
NACE J62	Computer programming, consultancy, and related activities
NACE J63	Data processing, hosting, and related activities; web portals
PHP	Hypertext Preprocessor
RPA	Robotic Process Automation
SE	Software Engineering
SEE	Software Engineering Environment
SME	Small and Medium-sized Enterprise
SQL	Structured Query Language
STEM	Science, Technology, Engineering and Math
SVN	Subversion
Sw	Computer software
UI	User Interface
UML	Universal Modeling Language
UWV	Dutch Employee Insurance Agency
UX	User experience
VET	Vocational Education and Training

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01. Executive Summary

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1. Executive Summary

1. Introduction

The European Software Skills Alliance (ESSA) is a four-year transnational project funded under the EU's Erasmus+ programme. Its aim is to ensure the skills needs of the rapidly evolving software sector can be met.
This report "Europe's most needed software roles and skills", in short: "Needs Analysis" is deliverable D.4., related to Work Package 2 in this project. It forms the foundation of the Software Skills Strategy, which is deliverable D.5. also related to Work Package 2.

1.1 Objective

With many organisations trying to keep up with the ongoing developments in ICT, the market has shown an increasing demand for software engineers. These developments have not only led to a shortage of software engineers to fulfil this increasing demand, but also to a shortage in the necessary skills to keep up with these changes. This growing skills gap is an area of great concern.
This Needs Analysis investigates this skills gap and identifies the current and the future needs for software skills in Europe. In this way, the Needs Analysis forms a basis for developing a Software Skills Strategy that can successfully match future supply with future demand.

1.2 Approach

The overall focus of this research is on software roles, competences, and skills, all related to the professional design, development, and maintenance of software. These activities all take place within organisations in the ICT sector and other organisations with an own need for these skills.
European frameworks are used as foundation to specify the software roles, competences, and skills. The relevant software roles are selected from the ICT professional roles as described in the "European ICT Professional Role Profiles" (CEN/CWA 16458-1) framework. The following software related role profiles are selected:

- Developer
- Test specialist
- Solution designer
- DevOps expert
- Digital media specialist

Each role has certain key competences linked to it. These are described in the "e-Competence Framework" (e-CF) (EN 16234-1). This framework identifies 41 competences related to the ICT professional field in general. In the research, a selection of 14 software related competences is made, such as Application Design, Application Development, Testing, and Component Integration.

Competences are made up of knowledge and skills. The research distinguishes the following skills:

- Hard software skills that are the focus of one or more role(s), e.g., programming, testing, working with data structures and algorithms,
- Profession-related skills relevant for people in software-related roles, e.g., project management, problem management, sustainability management, data science and analytics,
- Soft skills needed in these roles, e.g., problem solving, ethical behaviour, communication and teamwork.

The research investigates the current demand, the future demand, and the current supply. By mapping the existing education and training programmes, the gap between current supply and current and future demand can be determined.

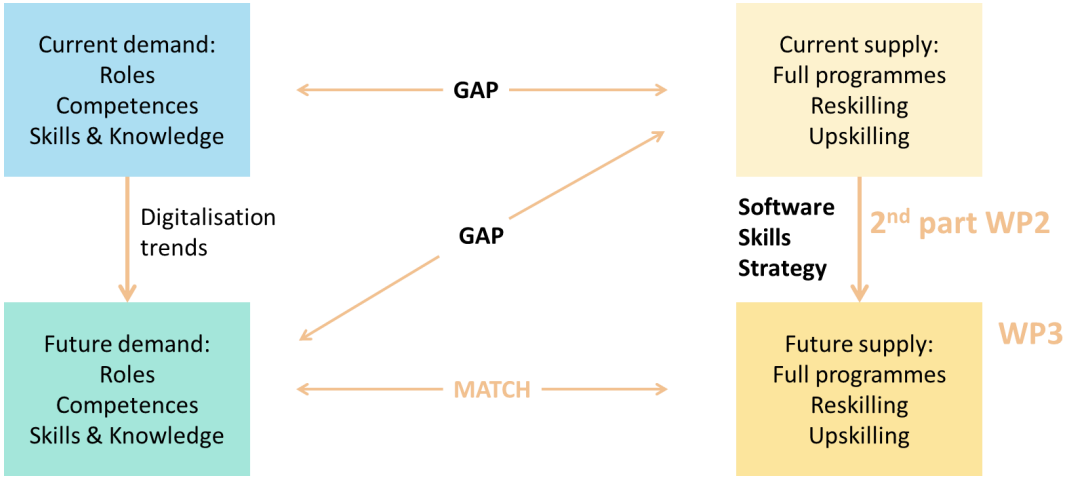

Figure 1: Overview of the Needs Analysis research

1. To establish the current demand, a desk research and a questionnaire are used. The desk research is composed of a literature study of scientific articles, an analysis of labour market reports and databases and an analysis of job vacancies. The questionnaire is distributed to organisations with own software skills needs to ask them about their demand.

2. The second element of the research is focused on the future demand, which is investigated by means of expert groups and interviews held at national and European level, the questionnaire, and labour market prediction reports, again at national and European level. Experts invited all have an expertise in the ICT labour market or in developments related to software needs.

3. The third element of the research relates to the current supply of a large range of programmes and training (VET and higher VET) offerings, delivered by VET providers, universities, and other. Desk research was used to map this supply.

Data collection in numbers	
Academic literature study	20 selected top papers for detailed analysis
Labour market desk research	63 national labour market reports
	14 national labour market databases
	905 job vacancies, 20 countries
Demand questionnaire	301 respondents, 21 countries
Expert groups	10 national expert groups, 118 experts, 9 countries
	1 European expert group, 14 experts
Supply desk research	>1000 VET and higher VET providers in 14 countries
	69 programmes studied in detail

1.3 Results

The needs analysis led to findings on current and future needs for software roles, skills, and education and training.

1.3.1 Roles

Among all software-related roles, the demand for developers is the highest. Not only now, but also in the future. Soft skills and knowledge of the business are increasingly important for developers to be able to function.

The role of the digital media specialist is — according to the study — not relevant in relation to software development, deployment, and maintenance. Preferably, job applicants need to have the right skills for the job when they start, as a lack of time for training is the main cause for a backlog in training.

Table Relative importance of software roles

Role	Now	In 5 years
Developer	*****	*****
DevOps expert	***	****
Solution designer	***	***
Test specialist	**	**
Technical specialist	***	**

1.3.2 Skills

Programming is the most in-demand hard skill with Java, Javascript, SQL, HTML, PHP, C++, C#, and Python being the most needed programming languages. Software professionals must have a solid understanding of programming principles as it is not clear which new programming languages will last in the long run and become more important.

There is also a need for certain profession-related skills like security management and project management. It is expected that, in the future, sustainability management and sustainable software development will become important.

Personal soft skills are becoming increasingly important for people in software roles. The most important soft skills are critical thinking and analysis, problem-solving, and self-management.

In addition, people in software roles also need interpersonal skills — mainly teamwork and communication skills — since almost all activities in these roles nowadays require collaborative working.

1.3.3 Education and training

As time for training is limited, upskilling people will be challenging. This requires short and modular training programmes that should be updated regularly and follow the newest technologies and trends. Micro-lessons and microcredentials will gain importance.

Software professionals should have more soft skills, but also need broader education. T-shaped professionals and Π-shaped professionals are considered to be the future. This means that initial education should provide comprehensive foundations in the field.

It is becoming increasingly important that software professionals know what and for whom they are programming. Every software professional should be equipped with basic business knowledge and skills, which must be part of curricula and training programmes. The ideal situation would be that every software professional has a second degree or at least some education and training in another field. To bridge the gap between education and practice, organisations and education providers should work together more closely.

Education of flexible lifelong learning software professionals is essential. Ideally, educating software professionals starts in primary school with teaching programming logic. The rest of the initial education should steer in the direction of flexible software professionals with fundamental understanding of hard and profession-related skills and good personal and interpersonal soft skills. This forms the foundation for lifelong learning to stay an up-to-date software professional and be able to adapt to new situations and technologies.

1.4 Main takeaways

The most in-demand software role is “developer”. The content of this role in terms of skills is changing, and organisations find it challenging to keep their developers up to date.

Certification plays an essential role in this. Especially the development of microcredentials related to smaller learning units is important as this helps to overcome time limitations.

The skills needed in software roles are certainly not restricted to hard software skills and other profession-related skills. There is a growing importance of soft skills that are needed to be successful as a software professional.

The cooperation between (large) organisations and educational institutions needs to be strengthened to close the gap between demand and supply.

The current and future demand for software professionals and corresponding skills require adjustments in the education and training offerings available to ensure a sufficient supply of professionals with the right skills, such as broader education, flexible programmes and learning paths, more attention to soft skills and broader professional skills, and knowledge of the business.

1.5 Use of this document

This document can be relevant to different stakeholders in a variety of ways. Some examples of possible uses are:

Policy makers may use the document to build policies or strategy upon or to assess the relevance of initiatives or proposals to enhance the software sector.

For **education and training providers** the document contains suggestions that are worth considering when designing learning programmes or training courses for (future) software specialists.

To know what trends and needs are relevant and will be relevant in the future is important to know for **businesses**, e.g., when attracting new personnel or in case of upskilling or reskilling of personnel.

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02.
Introduction

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2 Introduction

The work carried out in the ESSA's Work Package 2 focuses on updating the Occupational Profiles for software sector roles to match current market requirements, a market Needs Analysis to identify existing and emerging skills needs for each profile, and the design, development, and launch of an innovative Software Skills Strategy for Europe.
The Work Package is composed of three main outputs as follows:

- Profiles, competences, and skills Needs Analysis based on current EU initiatives/ sources, and primary research among industry stakeholders,
- An innovative new European Software Skills Strategy to bridge the current and emerging skills gap via VET programmes.
- Annual Skills Strategy Reviews, including feedback loops and refreshed Needs Analysis to improve VET programmes.

This report is about the first output: the ESSA Needs Analysis.

2.1 Goal and scope

The Needs Analysis investigates and identifies the current and the future needs for software skills in Europe and the nature of the skills gap that needs to be filled. Establishing the current demand for software roles, competences, skills, and knowledge is the first element of the analysis. Due to the rapid pace of digitalisation this demand will continue to evolve in the coming years, leading to potentially very different software skills requirements than those of today.

By mapping the existing education and training programmes, the gap between current supply and current and future demand can be determined. This analysis is mainly focused on why there is a gap and what roles and skills are important and/or will be important in the near future. It is not the intention of this study to estimate how big the gap is in absolute numbers. It is although the intention to show there is a shortage and the possible reasons behind this shortage. This gap analysis will form the final part of the Needs Analysis and will be a crucial element in determining how the Software Skills Strategy can successfully match future supply with future demand.

The overall focus of this research is on software roles, competences, knowledge, and skills within the Software Industry; which is primarily engaged in activities related to the design, development, and maintenance of software. The research was conducted among organisations in the ICT sector and other organisations with their own need for these skills. It is explicitly not about digital skills of the general workforce; the focus is on software skills. It is also recognised that, although the focus of this study is primarily on educators and employers, that the quality and relevance of software skills in the workforce affects wider society and can have important social, political, and economic implications for all citizens.

The Erasmus+ requirements and the project plan specify that the "EN 16234-1 e-Competence Framework (e-CF) - A common European Framework for ICT Professionals in all sectors - Part 1: Framework" and "CEN/CWA 16458-1 European ICT Professionals Role Profiles - Part 1: 30 ICT profiles" are inputs for this project. The e-CF standard and the

European ICT Professional Role Profiles report ensure a common language and point of reference when talking about these specific software roles, competences, and skills.

2.1.1 ICT Professional Role Profiles

The European ICT Professional Role Profiles (CEN/CWA 16458-1) incorporate the competences of the European e-Competence Framework (e-CF, EN 16234-1) as a main component of profile descriptions. The 30 ICT Professional Role Profiles provide a generic set of typical roles performed by ICT Professionals in any organisation, covering the full ICT business process. Figure 1 shows the 30 European ICT Professional Role Profiles (CEN/CWA 16458-1) overview and central focus of ESSA.

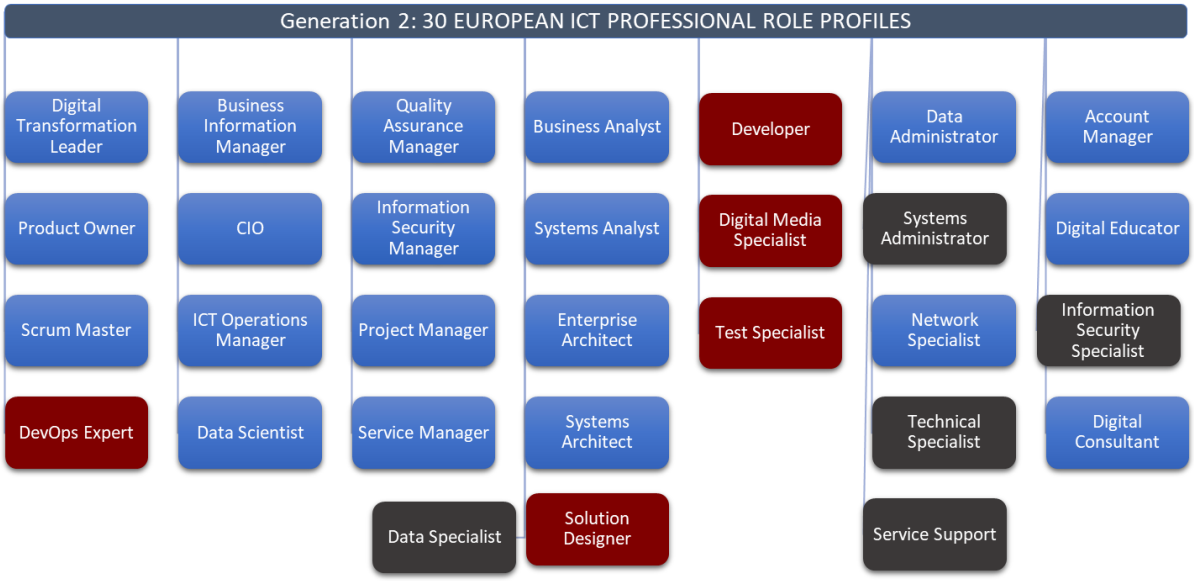

Figure 1 ESSA scope in ICT Professional Role Profiles (adjusted from CEN/CWA 16458-1)

As illustrated above, in dark red, the ICT Professional Role Profiles central in ESSA and the primary focus of the project are:

- Developer
- Test specialist
- Solution designer
- DevOps expert
- Digital media specialist

These roles require software skills as an essential part of their profile. It is not possible to do their job without "hard" software skills since they develop, deploy, and maintain software. The role of technical specialist is also studied for the specialists in that role that focus on maintaining software in that role and therefore need software skills as an essential element to do their job.

In the occupational field there are specific versions of each of these roles, as well as an array of job titles and descriptions. A more detailed description of these roles, including alternative names can be found in annex A.

Other ICT professional role profiles that are related to software skills are indicated in the figure in dark grey: Data Specialist, Systems Administrator, Technical Specialist, Service Support, and Information Security Specialist. People in these roles will need software skills to a certain extent to perform their jobs, but other skills are more essential, and even with limited software skills it is possible to perform the role. The question is addressed whether these roles will need more software skills in the future.

In other European ICT Professional Role Profiles it also can be helpful to have some software skills, but it is not critical for the execution of the role to have specific software skills. These professionals will need basic, general software knowledge and skills, but are out of the scope of this project.

2.1.1.1 e-Competences

EN 16234-1 “e-CF” as a European norm, is a neutral standard, developed and maintained through an EU-wide balanced multi-stakeholder agreement process, under the umbrella of the European Committee for Standardization. The standard is also a key component of the European Digital Agenda for ICT Professionalism. The e-Competence Framework (e-CF) (EN 16234-1) identifies 41 competences related to the ICT professional field.

Dimension 1 5 e-CF areas	Dimension 2 41 e-Competences identified	Dimension 3 5 e-Competence proficiency levels				
		e-1	e-2	e-3	e-4	e-5
A. PLAN	A.1. Information Systems and Business Strategy Alignment					
	A.2. Service Level Management			■	■	
	A.3. Business Plan Development			■	■	■
	A.4. Product/Service Planning		■	■	■	
	A.5. Architecture Design			■	■	■
	A.6. Application Design	■	■	■		
	A.7. Technology Trend Monitoring			■	■	■
	A.8. Sustainability Management			■	■	
	A.9. Innovating				■	■
	A.10. User Experience		■	■	■	
B. BUILD	B.1. Application Development	■	■	■		
	B.2. Component Integration		■	■	■	
	B.3. Testing	■	■	■	■	
	B.4. Solution Deployment	■	■	■		
	B.5. Documentation Production	■	■	■		
	B.6. ICT Systems Engineering			■	■	
C. RUN	C.1. User Support	■	■	■		
	C.2. Change Support		■	■		
	C.3. Service Delivery	■	■	■		
	C.4. Problem Management		■	■	■	
	C.5. Systems Management	■	■	■		
D. ENABLE	D.1. Information Security Strategy Development				■	■
	D.2. ICT Quality Strategy Development				■	■
	D.3. Education and Training Provision		■	■		
	D.4. Purchasing		■	■	■	
	D.5. Sales Development		■	■	■	
	D.6. Digital Marketing		■	■	■	
	D.7. Data Science and Analytics		■	■	■	■
	D.8. Contract Management		■	■	■	
	D.9. Personnel Development		■	■	■	
	D.10. Information and Knowledge Management			■	■	■
	D.11. Needs Identification			■	■	■
E. MANAGE	E.1. Forecast Development			■	■	
	E.2. Project and Portfolio Management		■	■	■	■
	E.3. Risk Management		■	■	■	
	E.4. Relationship Management			■	■	
	E.5. Process Improvement			■	■	
	E.6. ICT Quality Management		■	■	■	
	E.7. Business Change Management			■	■	■
	E.8. Information Security Management		■	■	■	
	E.9. Information Systems Governance				■	■

Figure 2 EN 16234-1 (e-CF) overview competences by CEN

In relation to software roles and skills, 14 competences can be identified as potentially relevant. Further research will determine which of these competences are central for

people in software roles and which are of limited relevance. The 14 competences to be studied further are:

A.6. Application Design	C.3. Service Delivery
A.8. Sustainability Management	C.4. Problem Management
B.1. Application Development	C.5. Systems Management
B.2. Component Integration	D.7. Data Science and Analytics
B.3. Testing	D.11.Needs Identification
B.4. Solution Deployment	E.2. Project and Portfolio Management
B.5. Documentation Production	E.8. Information Security Management

Although EN 16234-1 e-CF and ESSA in-depth methodologies adopt clear and market-proofed conceptual definitions of competences, knowledge, skills, and roles (see section 1.2.); in many other cases the distinction between competences and skills is not explicitly made. For example, the European Skills, Competences, qualifications, and Occupations (ESCO) makes no distinction between skills and competences.

The distinction between the two is also not always clear in organisations. For that reason, competences are not mentioned in the data collection, and it refers to these competences in terms of the related skills. So, for example, the competence "Documentation production" is represented in the study by the profession-related skill, or rather a group of skills, called "documentation production".

2.1.1.2 Skills

Skills cannot be seen separately from roles. An employer needs a person with certain competences and skills to perform a role and does not need just stand-alone skills. Articles about the developments in the software industry also indicate that skills other than merely the hard software skills are becoming increasingly important.

Changing methods of software development (e.g., Agile) and industry contexts (e.g., Industry 4.0) do not necessarily require a big change in hard skills but do require the ability to apply those skills in different ways (e.g., teamwork).

Therefore, this study will also focus on soft skills, which are in most cases transversal skills that apply across all or most roles in ICT, but also in other fields.
The skills that are relevant for the roles that are the focus of this project are the subject of this Needs Analysis. A basic division is made between:

- The hard software skills that are the focus of one or more role(s),
- Other profession-related skills relevant for people in software-related roles, and,
- The soft skills needed in these roles.

An overview of the skills used in this study can be found in annex B.

2.1.1.3 Level of analysis

The results from the Needs Analysis will inform the development of the European Software Skills Strategy. This will be one strategy for the whole of Europe with room for localisation.

The need for software roles, competences and skills is not bound by borders. The need is international, and people can find work in the sector all over Europe. There are different regional needs, but these are always part of a larger picture. Trends in software also know no boundaries.

The focus in this Needs Analysis is therefore on the EU level. This means that all data will be analysed centrally, and the final report will focus on the EU level, but the national level will also be addressed as the influence of countries in the analysis is measured. For example, analysis will include whether a particular skill is only found to be of significance in two or three countries. Partners are also invited to draft their own (inter)national report based on the analysis of data found in their country or area, when they think it will be of value to them. This will provide insights into the current situation in their own region but will not be part of the final Needs Analysis report.

2.2 Overview of the study

The three elements that need to be researched in the Needs Analysis are the current demand, the future demand, and the current supply. All three of these elements need different input to provide an overview of the situation in such a way that a gap analysis can be performed. Therefore, a methodology is developed which contains different data collection techniques and different target groups.

The digitalisation trends themselves are not an object of study in this research. They are only of interest insofar as they function as drivers for future demand. The focus is on the future roles, competences, skills, and knowledge that are a result of these trends.

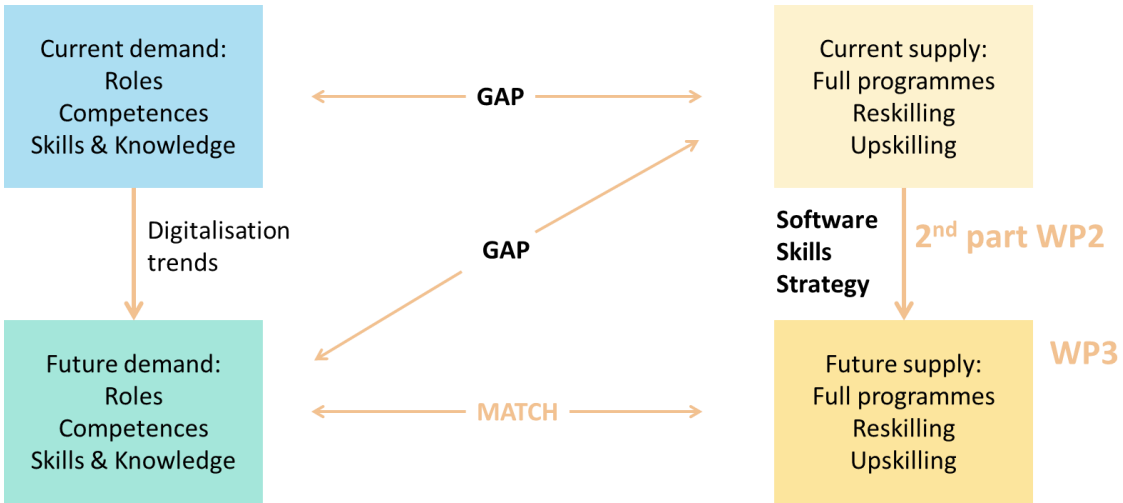

Figure 3 Overview of the Needs Analysis

2.2.1 Data collection techniques

Starting from a standard methodology and considering triangulation and the right level of data collecting, the most suitable data collection techniques for the different elements of the Needs Analysis could be identified.

A great amount of data on the current and future market has been and is already being collected, and the project benefits from this research by investigating these sources.

The current demand was studied further by a questionnaire, while the future demand was studied with a method suited for investigating predictions involving expert opinions. The current supply was studied completely via desk research supplemented with questions to specific suppliers, when necessary.

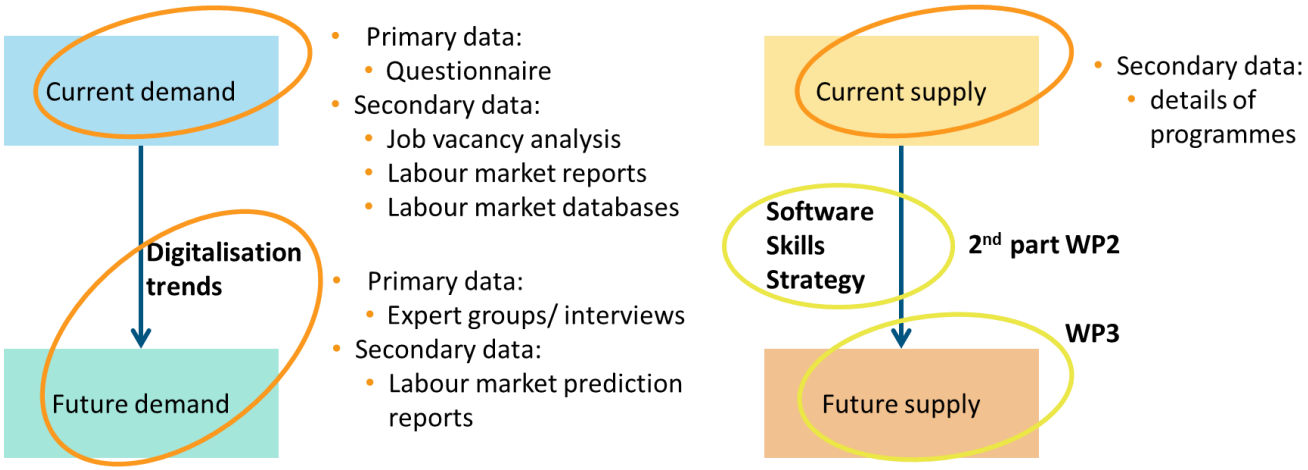

Figure 4 ESSA Needs Analysis elements and data collection techniques

2.2.1.1 Current and future demand desk research

The desk research studying the current and future demand contained the following aspects:

- Study (peer reviewed research) articles on software roles, skills, and competences
- Collect and analyse market and trends reports
- Analyse job vacancies for software roles

These aspects were studied on both a European and national level. Both levels are addressed in this project because they complement each other. Most of the time the European level provided an overview, while on a national level more detailed data was collected.

2.2.1.2 Current demand questionnaire

A questionnaire was distributed to organisations with software skills needs to ask them about their current demand for software roles, competences, and skills.

2.2.1.3 Future demand expert groups

There are research methods to provide predictions. Due to the international nature of the project and the current limitations due to COVID-19, a method requiring physical presence was not feasible. In addition, a method that requires a great amount of direct interaction is not ideal in an online environment. As a result, focus groups were deemed the most appropriate method, and in this case more specific expert groups, since we are asking experts for their views. Expert groups will also be used for the WP2 deliverable "an Annual Skills Strategy Review including feedback loops and refreshed Needs Analysis". Using the same techniques within this initial Needs Analysis is useful because it can function as an example and test for the Annual Skills Strategy Review.

2.2.1.4 Current supply desk research

The current supply consists of a large range of programmes and training (VET and higher VET) offerings. Desk research was used to map this supply. The details of the programmes with the most students were studied to establish which skills are taught in these programmes.

2.2.2 Population and samples

The population of a study consists of every entity that the study aims to make a statement about. A sample of this population consists of the entities that provide input to the study. For every technique, another sample can be used. In general, one could say that the demand and supply of software skills is the population of this study, but it is less abstract and more practical to divide the population in a demand and a supply side.

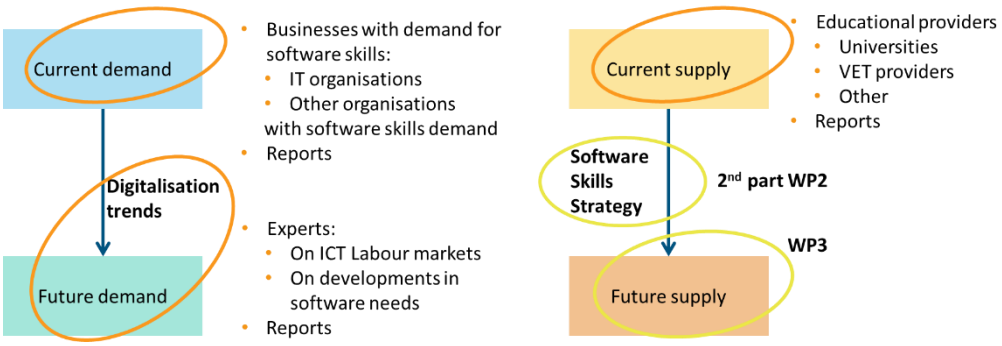

Figure 5 ESSA Needs Analysis elements and study target groups

The population on the demand side consisted of organisations with a demand for software skills. These are predominantly IT organisations, but also other — mostly large — companies with demand in software skills. These are companies that for example develop or maintain their own applications. The desk research, and in particular the job vacancy analysis, provided a more exact demarcation of which organisations are relevant and belong to this population. A sample for a questionnaire consisted of a random sample of organisations from all EU member states. Experts assessed the future demand of organisations with

demand for software skills. These experts came from the organisations studied, as well as highly valued ICT thought leaders and academics.

The population on the supply side consisted of suppliers of training in software skills on VET and higher VET levels. This supply is offered by both public and private sector educational providers like universities, VET providers, vendors, and suppliers of internal staff training. To ensure quality, the sample consisted of as many responses as possible representing the "supply" from all EU member states.

2.2.2.1 Needs Analysis zones

The validity of this Needs Analysis will be the highest when input from as many EU member states as possible is collected. Because the project partnership does not include representatives from all 27 EU countries, partners were invited to attempt to collect data from adjacent countries to increase the quality of the research. The partners country of origin was of course central, but if a partner is interested in another country or has limited access to data or respondents in their own country, the partner was invited to also look at other countries. The assignment of zones was to avoid overlaps in that situation. This will also lead to a better software skills strategy and in line with that, better opportunities to close the skills gap.

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03.
Literature Study

Co-funded by the
Erasmus+ Programme
of the European Union

3 Literature study

Research literature on the ICT labour market and specifically on the software labour market was studied to identify insights that are important for this study. Given the current nature of the topic, only studies from 2018 or later were taken into consideration (with exceptions). Relevant articles that were studied were those that informed the project i.e., on software development skills, competences, and knowledge, with some focus on education (ideally VET) and future orientation. The most important selection criterion was a strict focus on the topic of software development and creation and not on general user skills for software or expert user skills (e.g., CAD, animation). Partners with access to academic library databases were asked to contribute to this part.

3.1 Introduction

Software development is part of the wider discipline of software engineering, although in this literature review it was found that there is often not a clear or consistent distinction between how the terms are used. The IEEE (1990) defines software engineering as "The application of a systematic, disciplined, quantifiable approach to the development, operation, and maintenance of software; that is, the application of engineering to software". Software development can be understood as more focused on developing the actual software, whilst the term software engineering suggests — but does not necessarily imply — a broader remit in terms of analysing the problem or context in which the software will be used. In terms of skills and roles they are often used to describe similar skill areas and job roles.

In recent years, the advancements in software have led to changes in its use and scope as well as changes in how it is developed from both a technical and social perspective. The current policy and research focus is both technical and social. An important goal of the new Horizon Europe Research and Innovation programme is the achievement of Human-Centred software.

Various new software engineering skills will be necessary to achieve this vision. There is increased automation of aspects such as testing, deployment, and management of new releases; and at the same time there are new approaches to working in teams to create software and services (e.g., DevOps). The increased maturity of software engineering goes along with an increasing variety of societal and business needs, which, in turn, determines an increasing complexity and scale of services and applications. Emerging fields like IoT, Big Data, Cyber-Physical Systems, and the introduction of new complex technologies (e.g., Spark, Storm) lead to even newer software-defined paradigms for infrastructural resources. All these addresses several problems but require specific expertise and skills.

The rationale of the present study is to conduct a comprehensive literature review to find useful evidence on the demand for software skills which is important for the design and relevance of software skills education at VET level. This also includes, not only factual listing, but also evidence in the form of critiques, analysis, and discussion about software education and how it relates to the needs of employers and wider society. This can provide useful

evidence on how the challenge of software education is framed and how views of its core concepts and assumptions may have changed.

To maintain the focus of the study, an applicable taxonomy was used — broadly based on the e-CF — which helps us provide useful insights into the needed skills at VET level. The taxonomy broadly categorises skills into hard skills (also known as "technical skills") and soft skills (also known as "behavioural skills"). Relevant to our proper understanding of needs, and consequently, design of curricula for VET training, is clarity on the knowledge required by software engineers, as well their changing roles.

All these aspects have been analysed systematically by studying the literature, and we have identified interesting outcomes of research that are relevant and can be used to prepare new educational courses at VET level. The focus of this study is on the required skills that serve as building components to be able to combine them into specific courses, so that they can help transform various existing roles into new ones.

3.2 Methods

The focus of the present study is the understanding of the literature in terms of existing skills, any desired improvements of such skills as well as the approaches used to achieve such intended improvements. The value of including academic research, as opposed to just labour and skills reports, is also to gain insights into current debate, thought leadership, academic practices, and critical voices around software skill development.

Performing a survey in this context, however, is challenging due to the complex relationships that exist among the key concepts and contexts. The high-level e-Competence Framework (EN 16234-1:2019) concepts such as competence, knowledge, skills, attitudes, roles/function; are sometimes understood in varied ways in the literature. It was impossible, nor desirable, to only cover *needs* because the majority of articles also discussed methods, strategies, and educational approaches to meet those needs — such as delivery methods, definition of courses, and similar.

The focus was on recent (since 2018) peer reviewed literature, although formally published papers may have had publication delay through peer review process. The use of Arxiv mitigates this to an extent as it includes pre-prints.

This survey covers a broad list of peer-reviewed papers archives, particularly, Scopus, ACM, IEEE, Arxiv, and the AIS library. An iterative approach using expertise from four research-engaged partners in the ESSA project was used. A draft list of search terms and sources was produced, and suggestions were added to create the final list of sources and search terms as shown below.

Data base	Search terms	Date Range
Scopus	“Software engineering“ “software skills” “skills” “competence” “knowledge”	Priority to sources published since 2018 though, on review of papers, a selection of older papers was also reviewed.
ACM		
IEEE		
Arxiv		

AIS library	“software education” “programming” “DevOps” “computational thinking” “logic”

Figure 6 Sources and search terms

Application domains included aerospace, medicine, automated transport, bioinformatics, construction, and others.

The papers were sorted by abstracts and titles and a small selection was chosen. This was further refined based on the reading of the full paper, and further discussions on what may count as the most useful evidence for the project. A result summary is provided below in figure 7.

3.3 Presentation of the results

Team members searched the databases independently and then met to discuss findings and suggest further improvements to searches. As one example, it was found useful to investigate a small number of older papers to provide historical perspective on skills that were core and stable elements of software competence. It was also found that many papers included interesting case studies or examples of software skills teaching so that was also deemed relevant to include to meet the wider purpose of the project to improve curriculum and design of software VET. These papers, although not strictly focused on skills needs, will be useful for the skills strategy work in Q3 and Q4 of 2021.

Sources	Initially selected papers	Selected top papers for analysis
Scopus	7	3
ACM	10	2
IEEE	6	3
Arxiv	11	4
AIS library	10	6
Totals	43	20

Figure 7 Results overview

The content of the selected top papers was then analysed by using a template to assist in identifying the core relevant content. The design was partly inspired by the structure of the EN 16234-1:2019 "e-Competence Framework (e-CF) - A common European Framework for ICT Professionals in all sectors - Part 1: Framework". The template design is provided in figure 8. Within the academic literature the discussion of hard skills (technical skills) is nearly always at a more general level, so this is similar to the profession-related skills discussed in the rest of the report.

Paper reference	name(s), title, outlet, etc.
Knowledge	List any knowledge elements that are mentioned in the paper (as keywords or in short sentences to provide context)
Hard/ profession-related skills	List any skills that are mentioned in the paper (as keywords or in short sentences to provide context)
Soft skills (incl. behavioural skills	List behavioural aspects that are mentioned in the paper (as keywords or in short sentences to provide context)
Roles/function	List roles, function/job titles related to software development that are mentioned in the paper.
Educational Delivery method(s)	If the paper discusses specific training / teaching methods or tools list them here.
Paper type	What type of research is used in the paper, e.g., literature review of skills needs, case study of one course/ engagement with industry
Other remarks	e.g., adding context such as domain, research approach

Figure 8 Paper analysis template

The following sections outline the key themes and findings from the selected papers, based on the analysis. This is done mainly on a concept based approach (Webster & Watson, 2002) drawing on the analysis done using the paper analysis template. A more detailed spreadsheet (in annex D) shows the full analysis. As the focus of the search was to provide useful evidence for policy, a slightly different approach was taken to the review papers in this report that provided an overview of software skills demand either through a literature review or other methods. These are analysed in table 9 (presented below), with detailed listing of their contribution given their value in providing a quick "snapshot" for policymakers.

3.4 Literature survey papers

The analysis of the selected literature review/survey papers is provided in figure 9 using the columns that were relevant to these papers. These papers are especially useful in providing an overall summary of skills, perceived trends in skills, factors driving those trends, and some proposals to design software education in a better way so that it can meet these needs. The overview table provided shows that the focus is still primarily on technical software and programming skills, whilst some new skills are required to manage both new ways of developing software (e.g., Agile) and new work contexts.

As software becomes more integrated into work practices (e.g., Industry 4.0) and artefacts (e.g., automated vehicles) people working in software development must be able to see the broader impact of their work and liaise with a wider range of people. It is also important to note that three out of five of these papers specifically recommend the use of externally validated competence/skills or similar type of framework to address the problem of designing curricula for software skills.

	Knowledge	Hard/ profession-related Skills	Soft Skills (e.g., Behavioural)	Roles	Key recommendations
(Garousi et al., 2019)	SE economics, Mathematical foundations, Engineering foundations, SE process, SE Models and methods, SE Professional Practice, Computation foundations	Maintenance, Requirements, Testing, Development, Design, quality management		Configuration manager, Project manager	In looking at skills they **must be prioritised** into ones that are **very important and where there is the largest gap** between industry and education (in terms of difference between importance for industry and attention for it in education).
(Cico et al., 2021)		**Agile, development, prototype, project management**, Software Implementation, Usability and Value **Global Software Engineering (GSE), and Lean Software Start-up** Skills in trends not taught yet: biology and computing, system of systems	Kanban XP Scrum, human-centred, Test driven development, Prototype Lean **Customer focus** **Innovation** **Entrepreneurship** **International focus (GSE) and ability to work in diverse teams**		Software **technologies**, **processes**, and **practices** that are popular in industries should be included in the teaching approach. Few considered the impact of the practical element of the course settings in delivering useful final products. The proposed models should take care that simulations provide **realistic, stakeholder participation**. Use of models (e.g., FOSS) and real-life case studies were useful.

(Zabavnik et al., 2019)	UML (Universal Modelling Language), quality management ISO standards	Hardware in the loop Application Lifecycle Management (ALM) tools version-control systems (Git, SVN	Lean		Context is UML skills needed for the automotive industry and skills for the new development and testing processes in industry. Focus on avoiding mistakes is key.
(Föll et al., 2018)	Software dev. for car drive system knowledge; Software dev. for aerospace industry; Banking & Insurance industry knowledge	Process Optimisation; Project Management Embedded Systems; Java Development; Infrastructure Web Development; Object Oriented Development; User Interface; Quality Assurance; Supply Chains; Business Intelligence;	Social behaviour; personal skills; personal responsibility; project leadership; collaboration; consulting skills; problem-solving Customer Relations; Strategic Management; E-Commerce; Innovation Management;	developer, IT security specialist, business and systems analyst, service desk agent, and project manager	Job vacancies as well as literature used to identify skills demand. e-CF and SFIA used in curriculum provided.
(Beckett & Daberkow, 2019)	Knowledge context is Industry 4.0 and digital transformation	Internet of Things, data driven decision making & support, data-analytics, data integrity, machine learning, big data, artificial intelligence, smart transactions & system integrity, data security (secure links), human - computer interface,	Communication, Collaboration skills. organisational agility, Scrum, human-centred,		Focus on mapping individual competence sets. The challenge is the identification of current and future competency requirements.

Figure 9 Literature survey papers

3.5 Skills

The selected papers are discussed by focusing on the knowledge, ICT professional technical skills (hard skills), and soft skills (behavioural skills/attitudes). In the review of the literature the question of core mathematical skill was also sometimes discussed, so this has been allocated a separate section. In some cases, additional papers are cited when they illuminate a particular specialist area. From a high-level perspective, software education is acknowledged to be both important and challenging, requiring both fundamental skills and a strong future focus:

> *"Education for software engineers should prepare students to stay current in the face of rapid change. Existing studies report educational challenges that exceed fundamental skillsets."*
> ***Cico, 2021, p. 1***

3.5.1 ICT Profession-related Skills

Based on our findings (see figure 9) there are many emerging new or changing skill requirements related to the design, development, and potential uses of software. It should be noted that many of these are not completely new, rather extensions or developments of existing software development skills or new skills that are still seen as dependent on core software development skills. Data skills are becoming increasingly important in terms of accurate modelling and quality criteria for data quality (Beckett & Daberkow, 2019). Much of what is termed "AI" is often advanced data analysis software and both the technical and social aspects of this are needed in software developers.

In terms of more advanced AI (Hoover et al., 2019), machine learning, neural networks, and the use of AI to support creativity are seen as a growing area; although still underpinned by traditional programming skills. Simulation and modelling skills (Leathrum et al., 2019) are found to be important and also require more traditional programming skills as a foundation. It includes the ability of software to act in a trustworthy, dependable, secure, privacy-and-human-rights preserving, democratic and non-discriminatory way, among others. The increasingly embedded nature of software, for example IoT or Industry 4.0 (Zabavnik et al., 2019), is also blurring traditional distinctions between hardware and software and wider skillsets are needed.

Augmented and virtual reality skills are also increasing in importance (Shaba et al., 2019) as well as more personalised and creative software for the designers and the creative industries (Hoover et al., 2019); The detailed technical skills (hard skills) required and identified in this report are best reviewed by consulting the relevant tables in the annexes.

3.5.2 Soft skills

Soft skills are often discussed, most papers at least mention them, but rarely in any great depth in terms of what exactly these skills may mean for software developers. In summary, these skills are increasingly needed in terms of being able to operate in complex teams that are developing the software and in terms of understanding the wider organisational context in which the software will be used (insofar as this informs its design). Examples

include the necessity to understand quality and safety as it applies to software (Zabavnik et al., 2019). It is noted that, in line with most workplaces, software development is becoming increasingly global and staff will need the skills to work across different cultures in diverse teams (Cico et al., 2021). This should be born in mind to avoid an overly European focus in the ESSA Software Skills Strategy.

Professional practice is normally discussed in terms of communication and behavioural skills. The role of professional ethics is very rarely mentioned and this is discussed at length in a recent paper critiquing assumptions regarding industry relevant education for software developers (Ryan, 2020). This low emphasis on ethics is surprising as the recent ACM curricula guidelines (Clear et al., 2019) provide extensive material on integrating professional ethics into computing education including software development, but it appears to not be directly translated into teaching practice. It may be covered in related topics such as AI and Big Data which have clear and publicly acknowledged ethical aspects, but this should be investigated when looking at supply. In summary, a review of "demand" for software skills should consider some wider issues than solely the needs of employers.

3.5.3 Mathematical/logical/critical skills

25% of the top 20 papers discussed, at least to an extent, the importance of critical thinking. The review papers, in particular (Engelbrecht et al., 2018; Günay et al., 2018) , that discussed the importance of reflection and critical thinking in software skills, emphasised that experience and evidence showed that this must be taught in specific contexts which the students are likely to encounter. There was limited discussion of mathematical skills, with some exceptions such as a mention by (Garousi et al., 2019), although computational thinking (itself a rather ill-defined term) was included in some cases (Thorat & Kshirsagar, 2021).

One of the papers discusses the importance of teaching the software development process in a structured computational thinking process. This is to prevent the perceived problem that students often learn the maladaptive practice, also known as "bad habits" when learning how to develop software, then tend to retain these throughout their career (Higgins et al., 2017). There is also some discussion on the statistical skills and data skills and how they are increasingly intrinsically linked to software development (Reinhart & Genovese, 2020). From a business perspective (Stanton & Stanton, 2020) discusses how business students now need data analytic skills and provides suggestions on how to teach this effectively. It is reasonable to conclude that data, software development, business skills, and statistical skills are increasingly perceived to be more integrated in the workplace and that this should be reflected in educational provision.

3.5.4 Knowledge

It should be noted that knowledge in terms of software development is rarely explicitly discussed in any of the academic literature, but it does exist normally as a background assumption. "Skills" is the commonly used term; "competence" is used occasionally, and one can deduce that certain knowledge areas will be needed to support skills and competences. In terms of the knowledge that will be needed by employers, the emergence of new trends

suggests that it is probably helpful educationally to identify as "useful knowledge" the knowledge "about" new contexts, for example Industry 4.0, in the workplace. Students need to know something about these contexts in advance of starting work, this is generally factual, contextual knowledge as opposed to practical knowledge or hard skills. It is also not clear if more generic issues such as mathematics, logic, and critical thinking are perceived as knowledge or skills, although there is preference for skill-based terminology.

3.6 Roles

The key areas that are influencing software skills are AI, Big Data, Industry 4.0, and modelling (particularly in research). One predicted trend (Cico et al., 2021) is biology and computing, as well as system of systems.

Trends give rise to new types of roles and types of employment for software development. None of the papers reviewed had a big focus on new roles (either in e-CF terminology of others) in terms of actual job titles, but rather in terms of changes in existing roles, or in particular, the need for software developers to undertake multiple roles (Licorish & MacDonell, 2021). Trends can (potentially) be usefully classified as trends that strongly influence the actual content of software development (e.g., big data, modelling, AI) and those that provide a new or substantially changed context in which software developers need to work (e.g., Industry 4.0, research, smart agriculture, creative industries). Further thought could be given to the usefulness of this distinction in developing a skills strategy. There are also trends that are further from the traditionally perceived comfort zone of software developers, particularly the increased use of software in the creative industries (Jacobs et al., 2018) and this may require some different education approaches. This is also the case with the impact of the increased scale and reach of software, in that students can no longer be allowed to see the social or environmental impact of software as not within their responsibility (Ryan, 2020).

3.7 Training/Education

Many of the papers are critical of the current educational offering in software. Some of the criticisms are possibly contradictory and difficult to address simultaneously. They identify both weaknesses in general core fundamental understanding (Higgins et al., 2017) as well as a requirement that any general skill is taught in a particular context (Engelbrecht et al., 2018; Günay et al., 2018). The lack of industry focus is criticised by many (Cico et al., 2021) as well as one critical paper arguing there is too much industry focus (Ryan, 2020). This section covers some of the suggestions from most recent literature review papers on the different approaches to education they recommend based on their analysis. The literature reviews are a good source for this, as are a few case studies (Quezada-Sarmiento et al., 2018) of particular initiatives. It should also be noted that many papers recommended the use of an external skills or competence framework in curriculum planning, so this would appear to have fairly widespread acceptance as a practice.

One recent literature review (Cico et al., 2021) was particularly detailed in its recommendations which are detailed below.

> *"One key finding is that course material and structures tended to skew away from real-world conditions. To address this issue, we recommend the following adjustments. First, course designers should consider integrating SE courses with summer jobs in the industry. This approach would help students get a taste of the Agile practices while tackling challenges in a professional setting. Secondly, SE courses should span two semesters and incorporate the active participation of industry stakeholders. The roles taken by these stakeholder participants can encompass anything from mentors to clients, as already noted by many sources"*
> ***Cico, 2021, p.17.***

The summary recommendations from Cico paper (p.17) are provided below.

SE Trend	Difficulties	Solutions
Agile Software Development	• Designing manageable courses • Introducing adequate external pressure • Recreating Agile industry practices • Prepare students with real-challenges	• Integrate course modules (e.g., SE classes and summer jobs) • Longer course duration (e.g., SE courses spanning over two semesters) • Active involvement of industry stakeholders (mentors, clients, and customers)
Software Implementation, Usability and Value	• Emulating industry software development environment in SEE	• Integrating practical knowledge with theory through open lab spaces (cf. studio-based learning) • Active involvement of industry stakeholders (mentors, clients, and customers)
Lean Software Startup	• Fostering innovation mindset within SEE • Adopting innovative technologies and tools	• Include external activities into courses (e.g., Hackathon, Bootcamp, and Software Workshops) • Active involvement of industry stakeholders (mentors, clients, and customers)
Global Software Engineering	• Adopting collaborative development • Tackling cultural differences, tool choice, technical difficulties, and time zone differences	• Frameworks of collaboration among Universities • Active involvement of industry stakeholders (mentors, clients, and customers)
System of Systems	• Coordination and technical set up of the course	• Partnership with enterprises from the software industry

Figure 10 Table 1 Summary recommendations from Cico "Difficulties and solutions in the adoption of SE Trends within SEE."

Further recommendations from (Cico et al., 2021) include:

- Explore emerging SE Trends, such as Lean Software Start-ups, GSE, and potential industry trends for the coming decade. We encourage educators to put challenges specific to the classroom setting in perspective with software industry challenges.
- Provide courses that have more realistic SE settings. Problem Based Learning has a role.
- Foster the collaboration of industry-education joint activities within the SE courses.

It is observed that "Agile" is taught a lot, perhaps because it seems easy to teach, but there is evidence it is not taught with enough rigour or connection to real-life product development. This should also be noted when reviewing the gap between supply of education and demand as it appears that a large number of Agile modules in curricula are not necessarily an evidence that it is meeting demand.

There is limited critical discussion around the relative role of industry and education/the state in educating software developers. An exception is an interesting discussion by a very experienced software educator (Ryan, 2020) who notes that industry needs, employee needs and society's needs maybe in conflict in some cases, and students should be aware of this. Whistle blowing, for example, is not what most employers want, but students should be made aware of its potential role to halt unethical behaviour.

> *"It Is concluded that software engineering education must go beyond industry needs and include topics and values that industry may not even want us to teach"*
> ***Ryan, 2020, p.1.***

This should be born in mind for the strategy document as software education should also respond to the needs of wider society not just the needs of specific employers. There are many resources available on teaching computing ethics (Bullock et al., 2021; Clear et al., 2019) and some focused work on ones particularly relevant to VET software education could be included.

3.8 Main findings literature study

There is broad and fairly well-established understanding in the literature of the key software trends and how they may shape industry and society. In terms of improving our understanding of the current and future skills needs in the software industry, the academic literature is most informative in terms of proposing models to ensure processes and frameworks are in place to facilitate meaningful communication and cooperation between the various stakeholders (including, not exhaustively, industry, the public sector, citizens, students. The most important findings are:

- Use external frameworks to guide curriculum
- Do not lose sight of fundamental skills
- Check that industry and practical engagement are "true to life"

Recommendation	Cico et al, 2021	Zabavnik et al., 2019	Garousi et al., 2019	Beckett & Daberkow, 2019	Föll et al., 2018
Use frameworks	·	·	·	·	·
Global approach	·				
Verify use of practical projects	·	·			
Fundamental skills			·	·	·
Soft / team skills	·	·	·	·	·

Figure 11 The key findings of the key papers

essa.

04.
Demand Study

Co-funded by the
Erasmus+ Programme
of the European Union

4 Demand study

The first goal of this Needs Analysis is to gain insight on the current demand for software roles and skills in the member states of the European Union.

4.1 Labour market reports and databases

General and more specific labour market reports were studied to gain insight in the current ICT labour market. This was done on a European (and world) level, as well as on a local (national) level.

Besides this, databases on labour markets were also analysed, both on European and national levels.

4.1.1 Methods

Reports and databases were selected that provide information on the ICT labour market and more specific software roles on a national level and published since 2018. Also, European reports and databases were selected to collect the same information at this level.

Information sources could include relevant government departments, national bodies specialising in skill development, or established ICT or software professional associations, larger IT consultancy firms, Trade Unions, national statistical institutes, chambers of commerce and specialised labour market intelligence organisations.

Types of reports sought were government policy documents or professional bodies reports (commissioned research “state of the art” reviews regarding software trends and skills).

“Reports” could be viewed broadly: every written formal document on the (national ICT) labour market could be classified as a report. This included also documents like white papers etc. but excluded news items or blogs. Also, every source with numbers that could be queried could be classified as a database, but the data collection of these numbers had to be done in a professional way.

Also, databases were studied as labour market reports are often reporting on a more general level, while databases contain more detailed information on more specific roles and even skills. Relevant databases are provided and maintained by a national statistics office or another government agency, or a private institute depending on national context.

The data gathered focused on ICT professional role profiles, skills, and competences. But also, the number of jobs needed for a certain role, as well as the preferred entry levels for a job. National and European databases were studied. National databases provide in general more details, while on European level the differences between countries and regions become clear.

4.1.2 European labour market reports and databases

Most labour market reports, and the information extracted from databases, provide information on the level of the overall ICT sector. Although software professionals are only a subset of this sector, this more general information is also relevant for software professionals since there is no indication that the trends will be different. It could even be argued that trends like shortages in professionals are more prominent in the case of software professionals. For example, Michael Page (2021) concludes that software engineer and developer is the profession wanted in most countries in Europe, based on a list that has been compiled sourced from official occupation shortage lists published by national governments. It is leading the list of all possible occupations and is way ahead of other ICT related jobs.

4.1.2.1 ICT specialists in Europe

The broader context of this project is a fast-growing ICT-sector in general. Eurostat (2020) reports that in the last decade the proportion of ICT specialists in the total employment in the EU has risen from 3.0% in 2011 to 4.3% in 2020. The number of ICT specialists in the EU rose by 50% in this last decade from around 5.5 million in 2011 to almost 8.5 million in 2020. There are of course differences between the member states.

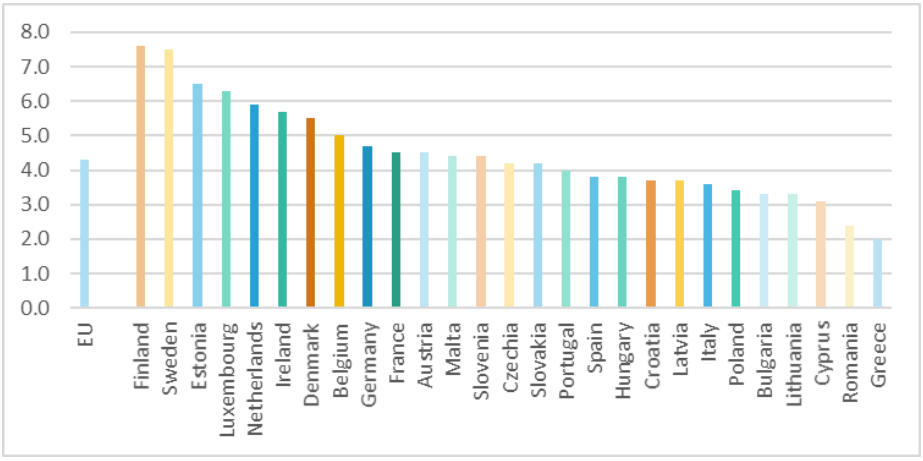


Figure 12 Proportion of ICT specialists in total employment (percentage), 2019

The lead group of countries have at least 5% of their labour force working as ICT specialist. These are Finland, Sweden, Estonia, Luxembourg, the Netherlands, Ireland, Denmark, and Belgium. The EU countries lagging behind the most are Romania (2.4%) and Greece (2.0%). This is not specific to these countries, but to this area in Europe, because also non-member states like Turkey, North Macedonia, Montenegro, and Serbia have percentages below 3%, and the member states Bulgaria and Cyprus are only just above 3%.

In absolute numbers, Germany has by far the most ICT specialists: around 1.9 million which is 23.1% of the total amount of ICT specialists in the EU. Other large countries follow with France having 1.2 million ICT specialists (14.5% of total EU) and Italy having 0.8 million (9.8%).

The countries at the lower end in terms of the percentage of their labour force in ICT are on the other hand at the higher end when looking at the percentage of women working as ICT specialist. The only member states that have a share of more than 25% women in ICT specialist roles are Bulgaria (28.2%), Greece (26.5%) and Romania (26.2%). In this Eurostat statistic the countries lagging behind are Hungary, Malta and Czechia, with little more than 10% of women. The overall EU share of women hardly changed in the last decade from 17% in 2011 to 18.5% in 2020. A growth of only 1.5 percentage points. During this period three countries showed more than a seven-percentage point growth in women: Greece, Luxembourg, and Austria.

4.1.2.2 Shortage in ICT professionals

Despite the strong growth of the sector, Eurostat (2020) still also reports a shortage of ICT professionals, or at least that some organisations have difficulty filling vacancies. They report that in 2019, 9% of all organisations were looking for ICT specialists and that 5% of all organisations stated that it was hard if not possible to fill those vacancies. So more than half of the organisations that tried to recruit had hard-to-fill vacancies.

It becomes even more problematic when looking at the size of the organisations that require ICT professionals. It shows that especially large organisations encounter problems filling vacancies. 46% of all large organisations in the EU were looking for ICT specialists and 30% of all large companies reported problems with filling vacancies. That means that 70% of large companies when searching for ICT professionals had trouble finding them. Small (6%) and medium (18%) companies are scouting a lot less for new ICT professionals, but they also encounter problems filling vacancies. In more than half of the cases they have hard-to-fill vacancies if they are looking for ICT professionals.

This trend is even more visible focusing only on organisations in the ICT sector and an even further focus on the sub sector “Computer programming, consultancy and related activities, information services”. Looking at all organisations of more than ten people recruiting ICT specialists in 2015, 38% reported hard to fill vacancies, which rose to 55% in 2020. Looking at the ICT-sector it rose from 56% to 73%, and the programming and consultancy sub sector rose from 59% to also 73%.

In 2020 Eurostat asked organisations about the reasons vacancies were hard to fill. The lack of enough people applying was the main reason with over 80% of the cases in the programming and consultancy sub sector, almost 80% in the ICT-sector and 75% in all organisations looking for ICT specialists. The lack of relevant ICT qualifications from education and/or training is mentioned as the second most important reason with almost 70% of all organisations. Lack of relevant working experience and too high salary expectations of the applicants are also given as a reason in about two thirds of the cases.

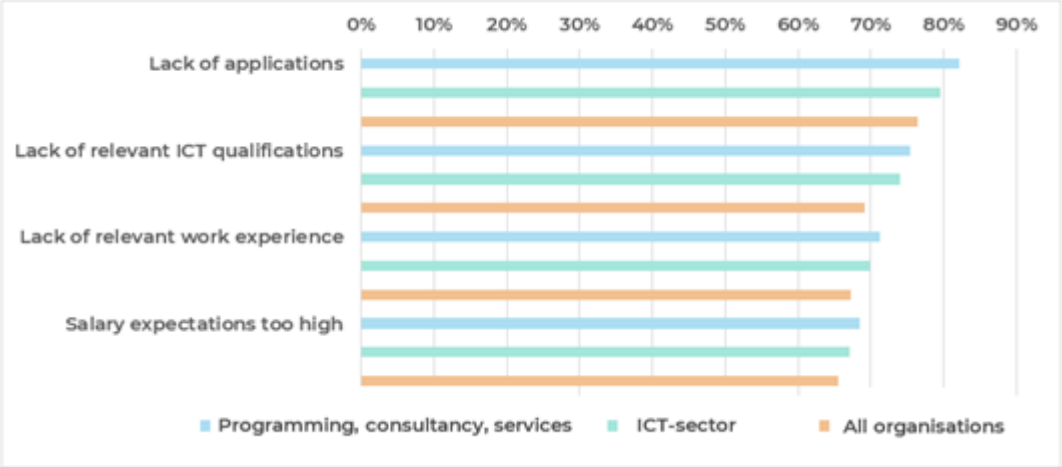


Figure 13 Reason hard to fill vacancies, 2020

The World Economic Forum (2020) listed 20 job roles that will increase in demand in the next five years. Almost all jobs on that list are ICT related, with a top ten position for developers, so it does not look like the demand will decrease in the coming years.

4.1.2.3 Education and training

Most labour market reports and databases don't focus on details of education and training, but there is information about the educational attainment level people should have acquired as a prerequisite for a position as an ICT specialist.

The levels are divided into two categories: levels 0-4 and levels 5-8. The non-tertiary category in this case will mostly be level 4 with some level 3 given the nature of the professional field. The trend is clear that more and more ICT jobs require tertiary education increasing from 55% in 2011 to almost 64% in 2020.

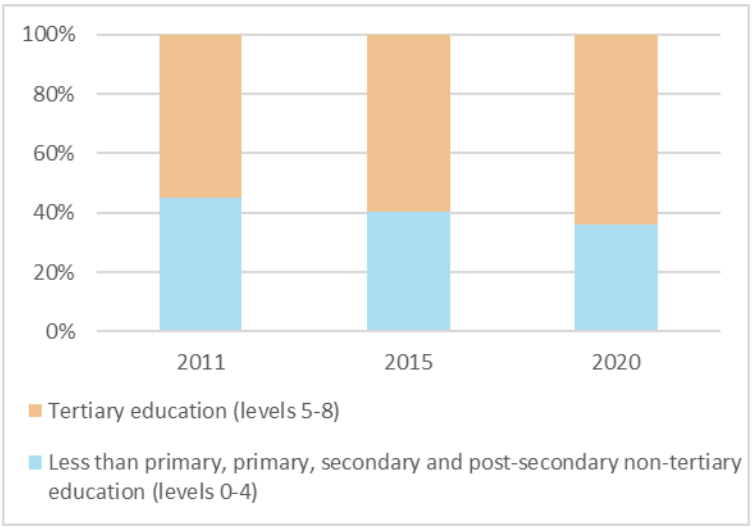


Figure 14 Trend in EU of ICT specialists' educational attainment level, 2020

This EU average is lowered by the fact that two of the three countries with the most ICT specialists, Germany and especially Italy, have a lot of non-tertiary educated people working as an ICT specialist. In Italy less than 40% of ICT specialists have a tertiary education and in Germany this percentage is only 50%. This is a significant contrast to countries like Lithuania, Ireland, Spain, Cyprus, and France, which all have over 80% tertiary educated ICT specialists.

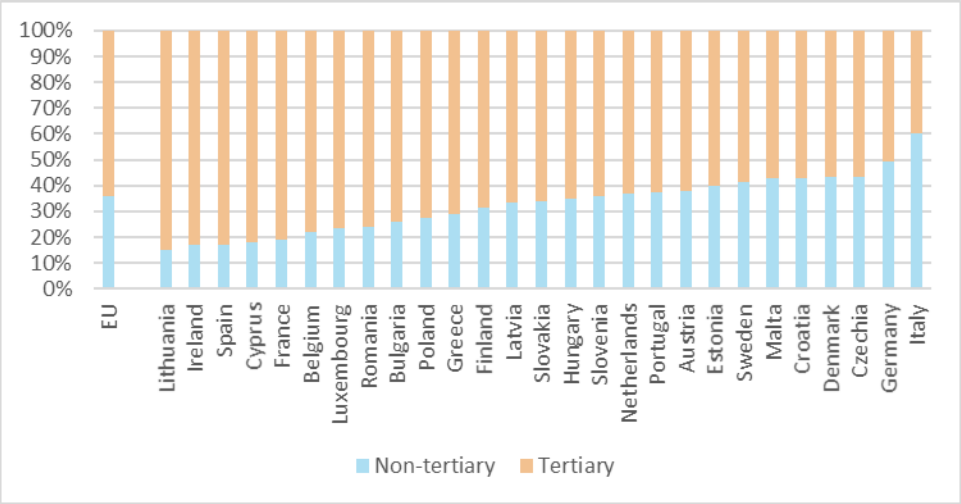


Figure 15 ICT specialists by education attainment level (percentage), 2020

This could be explained by the fact that in Italy there are upper secondary schools that lead to an Informatics degree: Technical Institutes with a specialisation, and Informatics and Economic Institutes with a specialisation on Business Information Systems. For Germany, the explanation could be the dual education system, that combines apprenticeships in a company with vocational education. Having said this, the fact remains that the educational level of ICT professionals in Germany and Italy are on average lower than in other countries.

The Future of Jobs report of the World Economic Forum (2020) stated that due to the COVID-19 pandemic 42% of organisations are planning to accelerate the digitalisation of upskilling/reskilling (e.g., by using education technology providers) and 35% of organisations are planning to accelerate the implementation of upskilling/reskilling programmes. These are the fourth and fifth largest impacts of COVID-19 according to organisations only to be topped by other impacts that also involve ICT (accelerate the digitalisation of work processes, provide opportunities to work remotely and accelerate the automation of tasks).

4.1.3 National labour market reports and databases

The national labour market reports were mostly in local languages. The key results and relevant data from those reports were translated and collected in excel. Collected and analysed are 63 national labour market reports and 14 national labour market databases from 14 countries. See annexes G and H for an overview of the reports and the databases.

Estonia

Senior software developers' positions are in most demand. It is expected that 24,400 software development and high-level IT administration and analytical positions are needed by 2027. Currently, the number of open positions in Estonia remains over 10,000. The rate of job vacancies was highest in information and communication (3.7%). According to a labour needs survey conducted by the Estonian Unemployment Insurance Fund (EUIF) the Estonian labour market will be most in need of programmers among some jobs in other sectors in the coming years.
Furthermore, a large labour shortage is indicated when it comes to software developers. The current workforce lacks sufficient qualifications. In addition to software developers there is also a need for systems admins and web designers. To tackle this the Estonian Government has started a project called "Choose IT" in 2020. The training is free, and by the end of it most students were offered a job at the company they did an internship with.

Ireland

In their report "Future jobs Ireland 2019", the Irish government acknowledges that for businesses and economy to succeed managers and workers must have up-to-date skills and continue to train and develop throughout their careers. This can be achieved by accessible upskilling options and relevant and up-to-date courses offered by education and training providers.
In the ICT Skills Action Plan, a joint initiative in which the Irish government, the higher and further education and training sector and industry are working together to meet Ireland's high-level ICT skill needs for the future; new reskilling pathways are developed, ICT apprenticeships are stimulated, and the expansion of the Skillnet Ireland networks. Besides this there will be a continuing requirement to ensure the attraction of international talent.

The Netherlands

The Dutch Employee Insurance Agency (UWV) mentions in their "factsheet labour market" a still growing shortage of labour, especially at the higher and scientific professional levels. This is especially true for software developers in specific programming languages or applications, database administrators and analysis and security specialists. Suggested solutions to solve this personnel shortage include: intensified recruitment of personnel (head-hunters, social media etc.), retraining of job seekers, deployment of students, traineeships, parttime work, deployment of post-secondary, non-tertiary professionals in jobs at bachelor level, deployment of senior ICTers (> 10 years' experience) and recruitment of personnel outside the Netherlands (Eastern Europe, Spain, Portugal; but also, outside Europe).

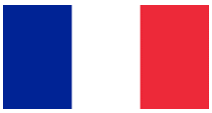
Demand for ICT personnel that masters several disciplines in the process increases, as well as the popularity of the full-stack developer. The largest portion of all ICT personnel is active in software and application development. Forecasting needs until 2024: Software and application developers: 20.300; Database and network specialists: 5.100; ICT Support: 3.800. The same trend is seen in Germany.

Germany

A growing personnel shortage for IT specialists is recognised, reported by over 850 directors and (personnel) managers in companies across all sectors. 70% of them report a shortage. 60% expect this to grow. The most wanted roles are programmers and IT administrators.

Italy

From a large research study of job vacancies "Osservatorio delle competenze digitali" done by AICA, Anitec-Assinform, Assintel, Assinter Italia, and AgID, it appears that again developers are the most sought-after. However, the second and third most sought positions after developers (almost 49,000 vacancies) are those of digital consultant (more than 12,000 vacancies) and digital media specialist (almost 7,000 vacancies). 4,500 vacancies are related to new types of professionals, related to AI, big data, blockchain, cloud, IoT, mobile and robotics.



France

The developer is currently the most popular role in the ICT sector. LesJeudis, an IT and digital marketing labour market research company reports that in the coming years the following roles will be most in demand: full stack developer, video games developer, front end developer, data scientist, AI specialist, security specialist, DevOps specialist, IT architect, IT project manager, and mobile developer.

Slovenia

The number of companies that employ ICT professionals is 2,686. In 2020, 1084 companies tried to hire ICT professionals, of which 752 faced difficulties in recruiting ICT professionals. While employers expect an average growth of overall employment of 1,3%, for the ICT sector this is 3,3 %.

Hungary

In an extensive Hungarian research and analysis of labour market needs for IT qualifications and competences (GINOP; "Program your future!" project) it was found that 12,000 people would be employed by IT and non-IT companies in the role of developer/software engineer in Hungary in the next 2 years.

Based on an analysis of 6989 unique job offers in the first half of 2020 in Poland, the vast majority of job offers were targeted towards mid (46%) and senior (also 46%) levels of experience. Job offers for juniors

Poland

comprised only 8% of offers overall. Decreases were noticeable for backend and other top categories: frontend, mobile, DevOps. There was, however, an increase in job offers targeted to full-stack programmers and testers. Interestingly, the decrease in the number of job offers in the backend category was correlated with the increase in the full-stack category - specialists in this area have more skills and knowledge, as they know both backend and frontend technologies. 38% of hiring managers in Poland state that full-stack specialists are top priority and it is the first role to fill in IT. Knowing JavaScript remains the most important requirement (33% of job vacancies) it appeared in every third offer), just before Java and Git (every fourth offer).

Malta

In Malta, most job opportunities, around 26%, will be for professionals (high level occupations in science, engineering healthcare, business, and teaching), followed by service and sales workers with 20%. From 2021-2030, the expected employment growth in computer programming and information services is 2.6%. This is much higher than the EU average of 1,5% expected employment growth. It is also number 1 in the top ten occupations of employment.

Greece

Greece still has the lowest proportion of ICT specialists (1.4 %) in the EU, but the share of ICT specialists has been relatively steady over the last few years. With Greece continuing to suffer from a brain drain, addressing the shortage of ICT specialists. According to estimations, the use of ICT is needed in more than 90 % of workplaces. It is recognized there is a need to reconfigure the educational and vocational training system closer to the needs of the economy, to expand on the job training programmes and provide incentives to firms to increase training of their employees.

Cyprus

According to the findings of the Digital Economy and Society Index report, only half of the Cypriot population possesses at least basic digital skills. At the same time Cyprus has the lowest share of Science, Technology, Engineering and Math (STEM) graduates among all EU countries. The country also has a low share of ICT specialists in the workforce compared to the EU average. From 2021-2030, the expected employment growth in computer programming and information services is 3.7%.

4.1.4 Main findings labour market reports and databases

It was often specified in different reports that the importance of soft skills is increasing. Furthermore, the number of difficulties faced in recruiting ICT professionals is increasing: a gap between supply and demand was mentioned several times.

In some countries, the IT industry is one of the top three attractive industries (in terms of salary levels, stability, security) (e.g., Romania). Other countries are dealing with "brain drain"; potential candidates go abroad to find a job in IT, because of better conditions. Some countries are strategically investing in methods to attract ICT professionals from abroad (e.g., Ireland, Estonia).
In many reports, a lot of data can be found about the importance of cyber security; there is an increasing need for competences and role profiles in this field. Most data is focused on developers and the ICT sector in general.

Figure 16 Actions to fill the gap between supply and demand according to national labour reports

4.2 Job vacancy study

A study of job vacancies was performed to get insight into what software skills are asked for in the current market. This was done by analysing what skills are mentioned in job vacancies for software roles. The objective of the job vacancy study was not to get a complete overview of all software-related job vacancies. The objective was to find evidence of the skills that are asked for by employers when looking to hire employees in software-related roles.

4.2.1 Methods

Partners were asked to keep track of their searches by filling in a record with search terms and filters they used and the amount of total hits using a filter or key term in the search of job vacancies. This provided a general picture of the amount of job vacancies that pop up when somebody is looking for a vacancy in a certain role. A separate record was used to fill in the details of relevant job vacancies.

Filters on websites for job vacancies were used to focus as much as possible on software-related vacancies. Search terms that were used are for example “software” and the five selected ICT professional roles names were used (DevOps expert, developer, digital media specialist, test specialist, solution designer or related (ESCO) names. A list with possible names was used to select job vacancies — see annex A for an overview of roles, descriptions and alternative ESCO names.

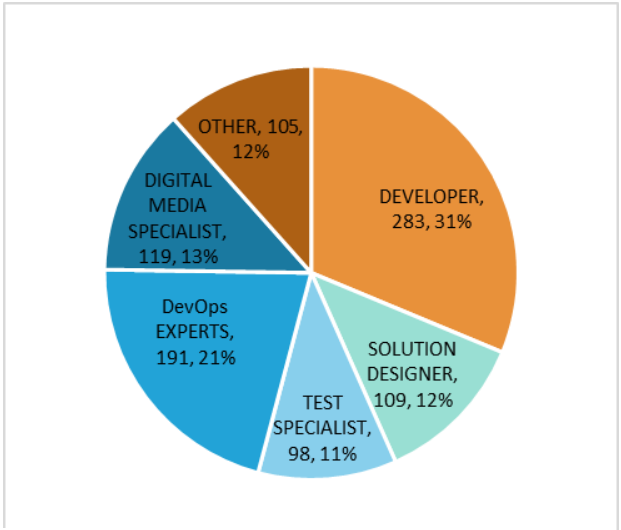


*Figure 17 SEQ Figure * ARABIC 17 Overview job vacancies by role profile in the sample*

The job vacancies found fitted in one of these five roles, but there was also the possibility to label a job vacancy as “other” as long as the job vacancy was still about a software role.

There were 905 job vacancies analysed in detail of which the developer role was the most found and analysed role, but also the other roles were present enough in the sample to analyse the requirements for these roles adequately. Please note that this does not say anything about which role has more or less vacancies in total. It is just a description of the sample that is used in this study.

Data was collected on the type of skills requested (hard, profession-related and soft skills), on job titles, levels, years of experience and educational level, and on company size and company sector.

4.2.2 Details of the sample

The job vacancies study is not focused on providing an overview of all the available job vacancies at the moment. Therefore, the details of the sample are only relevant to get an impression of what kind of characteristics the selected vacancies in the sample have. Collected and analysed were 905 job vacancies from 20 countries.

4.2.2.1 Job vacancies by company size

The most job vacancies available came from large companies (>250 employees). Vacancies from medium (<250 employees) and small companies (<50 employees) each are approximately 50% of the number of vacancies from large companies. The number of job vacancies between medium and small companies are similar. Taken together they have approximately the same number of vacancies as large companies. Micro (< 10 employees) have the least vacancies.

An important finding is that whereas large companies and SMEs have the least vacancies related to digital media specialists, these types of vacancies form the largest portion (19,3%) from all the vacancies of micro companies.

The test specialist is the most sought-after role by large companies (50%). Directly followed by the DevOps expert, the solution designer, and the developer, with each role equating to approximately 40%.

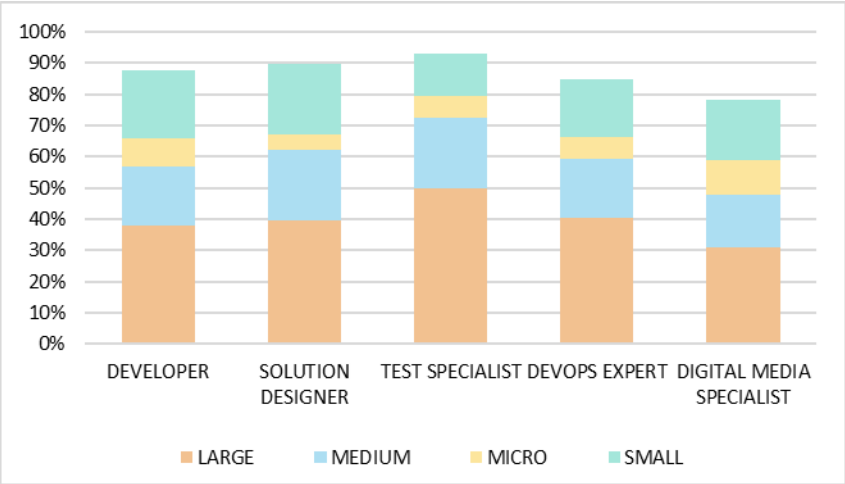


Figure 18 Job vacancies by company size (percentage)

4.2.2.2 Job vacancies by sector

Companies in the programming sector had the highest number of job vacancies for developers (30,3%), solution designers (24,8%) and DevOps experts (27,2%). Most job vacancies for test specialists are from other ICT companies (companies that cannot be classified in one of the other categories) (28,6%). Approximately 50% of all job vacancies comes from companies in programming and other ICT related activities, except for digital media specialist. Non-ICT SMEs had the highest number of job vacancies for digital media specialists (22,7%).

In consultancy, the largest number of vacancies is for solution designers (18,3%), and to a somewhat lesser extent for test specialists (17,3%) and DevOps experts (16,2%).

Large multinational non-ICT companies have an approximately equal number of vacancies for all roles (between 13 - 17%). There are almost zero vacancies from non-ICT governmental organisations and hardly any from web portals (between 1 - 3 %), except for digital media specialists (9,2%).

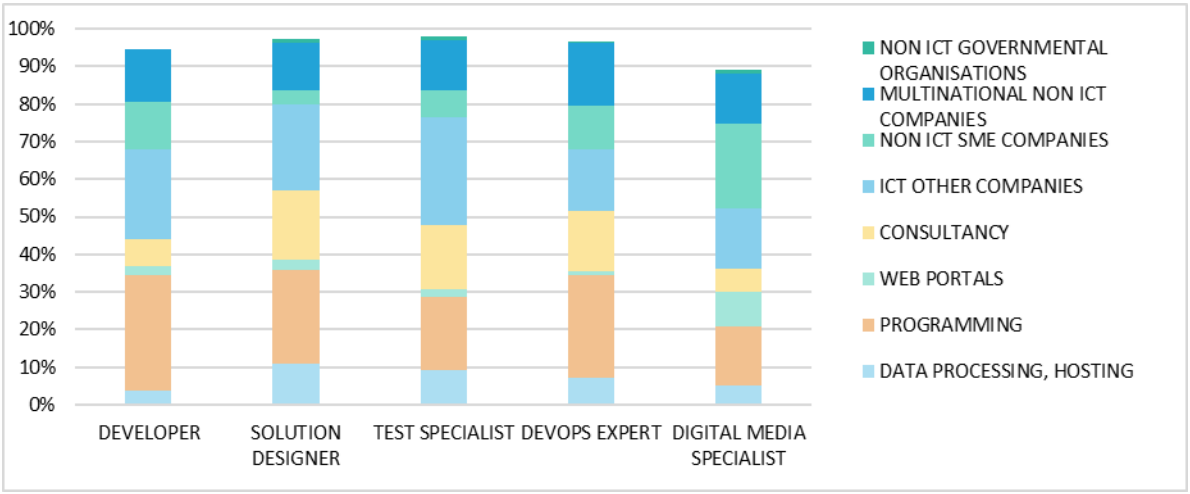


Figure 19 Job vacancies by sector (percentage)

4.2.2.3 Job vacancies by entry level

The most frequent expected entry level for each profile is the intermediate level. This is especially true for a digital media specialist, where 50,4% of vacancies indicate this level. Only 8,4% of digital media specialist vacancies are at the junior level, which is also the lowest number compared to job vacancies for other roles at this level.

Entry at a junior level is most frequent for test specialists (25,5%), directly followed by developers (21,2%). Entry at senior level is most frequent for solution designers (26,6%), directly followed by DevOps experts (24,6%).

The percentage of the job vacancies without a clearly specified entry level is quite high for all vacancies (between 18,5 – 28,3%), which is maybe a bit surprising. Uncertainty about the entry level is the highest for developers (28,3%).

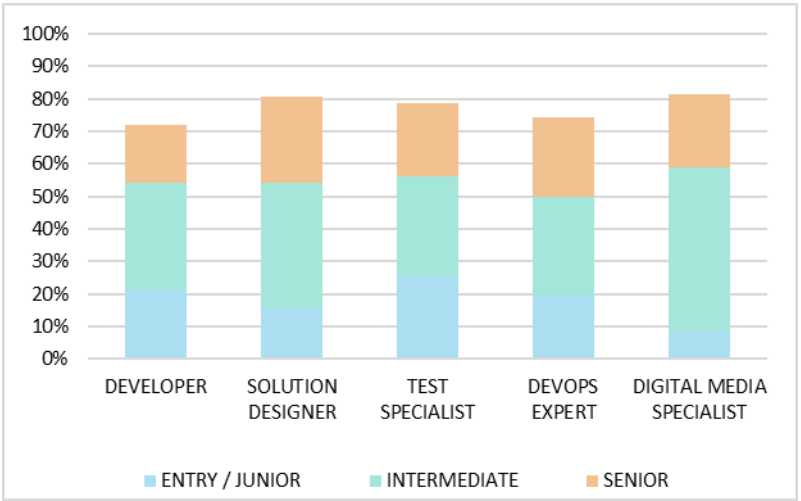


Figure 20 Job vacancies by entry level (percentage)

4.2.2.4 Job vacancies by required years of experience

The required years of experience are not specified in 40% to 55% of vacancies, except for solution designer vacancies (only 25,7 % are not specified). The highest percentage not specified relates to DevOps expert vacancies (55%).

In job vacancies that specify required years of experience, the number of years is in most cases either less than 3 years or between 3 – 5 years. This holds for approximatively 50% of vacancies expressing this number. Only in approx. 10% of all vacancies is a higher number of years' experience is required.

Candidates with more than 10 years of experience were the least sought after in all job vacancies. The highest percentage (2,8%), was found in solution designer vacancies.

Experience between 6 – 10 years was required in 17,4% of solution designer vacancies, again the highest number of all job vacancies. These years of experience are asked for in only approx. 10% of other job vacancies.

For developers 3 – 5 years of experience was the most sought after (26,5%), followed by solution designers (23,9%). For the other vacancies, these years of experience were required in 20% of those vacancies.

The highest number of vacancies with less than 3 years of experience, was for solution designers (30,3%), followed by vacancies for digital media specialists (25,2%) and test specialists and developers, (both approx. 20%).

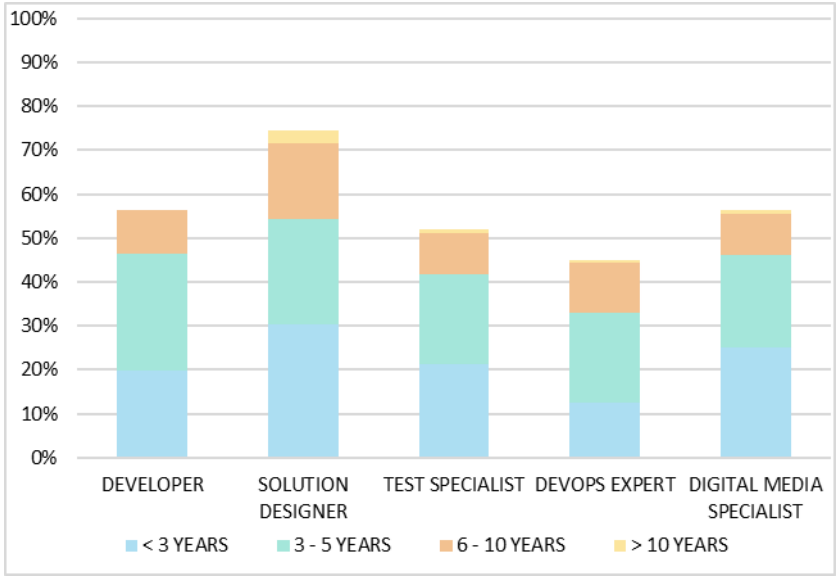


Figure 21 Job vacancies by required years of experience (percentage)

4.2.2.5 Job vacancies by required educational level

The required educational level is, depending on the role, in 38% to 52% of vacancies not specified, except for solution designer vacancies (only 22% not specified). Digital media

specialist vacancies (52,1%) have the highest percentage of not specified required educational level. In general, just under half of all ICT vacancies advertised do not specify a required educational level for applicants.

For job vacancies that specify a required level, EQF 6 is the most required level for all vacancies. This holds true for most solution designer job vacancies, of which 72% requires EQF 6. For the other job vacancies appr. 66% requires EQF 6, except for digital media specialist, 56%.

Candidates with EQF 8 were the least sought after in vacancies. The highest percentage (3,5%), was found in digital media specialist vacancies that specify educational level.

EQF 7 was required in 21% of solution designer vacancies that specify a required level, which is the highest number of job vacancies requiring EQF 7, followed by vacancies for test specialists (19,6%).

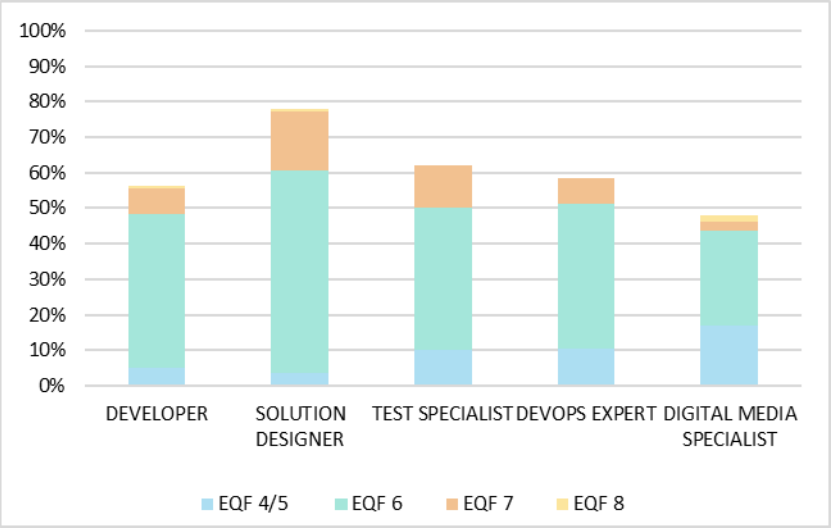


Figure 22 Job vacancies by required educational level (percentage)

4.2.3 Hard and profession-related skills

The descriptions in job vacancies are analysed on the keywords that are used. These are on the one hand programming languages and on the other hand other words that are dominantly present in the descriptions of the required software-related skills. The analysis is made for each role separately to establish whether there are differences between roles.

4.2.3.1 Developer

In job vacancies related to the role of developer, often programming languages are mentioned. Most mentioned are SQL and Javascript (30% of vacancies), HTML, GIT, CSS (25%), Java, C#, React (20%), and Python, PHP (10%).

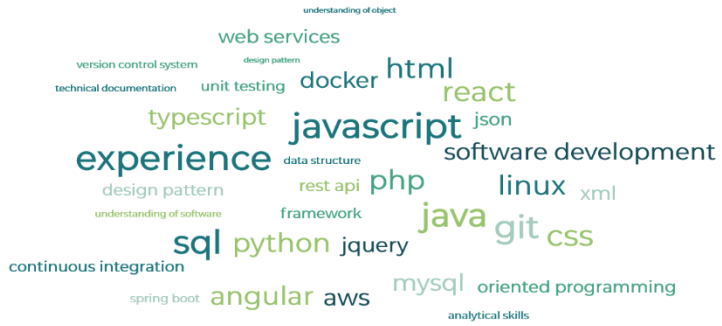


Figure 23 Hard and profession-related skills for developers

Words such as "development", "experience" and "design" are often used in longer phrases, which defined the desired competence more precisely.

4.2.3.2 Solution designer

Job vacancies related to solution designer mention mostly SQL (25%), Microsoft and cloud (20%), and Javascript, HTML (15%). Also the ability to work with specific platforms (e.g., Azure (10%), .NET (7%)) was mentioned.

Figure 24 Hard and profession-related skills for solution designers

4.2.3.3 Test specialist

Hard skills mentioned most in test specialist vacancies are Selenium (18%), Jira (16%) and SQL (15%). Also mentioned are Python, Java, REST (11%) and .NET (7%).

The word "testing" and "test" appears most often, which makes sense given the profile. But also the words "tools" (41%), "automation" (30%), and "security" (15%) are mentioned.

Figure 25 Hard and profession-related skills for test specialists

4.2.3.4 DevOps expert

In vacancies related to DevOps experts the ability to work with platforms is required, such as Linux and Docker (30%), Kubernetes and Jenkins (25%) and Ansible (19%). Python is the language that appears most often here (27%).

Other words that appear frequently in these vacancies are “experience” (54%), “development” (25%), “CI/CD” and “continuous” (19%) and “management”, “infrastructure”, and “programming” (16%).

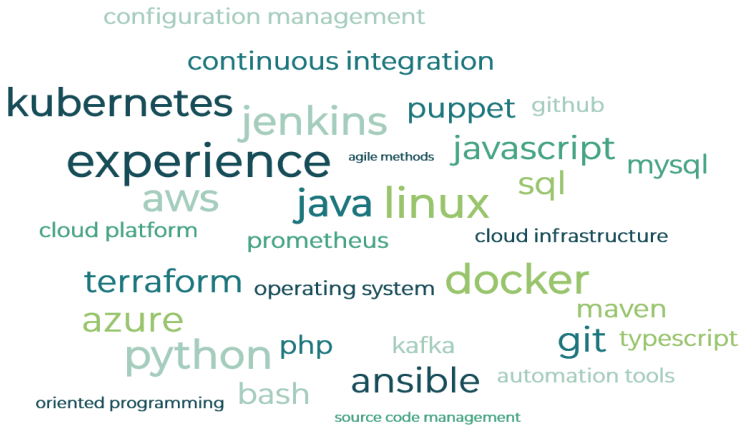


Figure 26 Hard and profession-related skills for DevOps experts

4.2.3.5 Digital media specialist

For the digital media specialist, the most frequently mentioned hard skills in vacancies are HTML, JavaScript, CSS and Adobe (30% each). Compared to the other profiles, HTML, CSS and Javascript appear here more often. Of these four, CSS and Adobe are typically related only to this specific domain. This holds for many of the other skills mentioned here as well, like Photoshop, PHP (16%), Illustrator, and Sketch (13%).

Figure 27 Hard and profession-related skills for digital media specialists

Logically, the most common word used is "design" (47%). Most job titles for the role of Digital media specialist include the word “Designer” (39%), which corresponds to the frequency of the word "design". Also, terms like "marketing" (13%), "media" and "optimisation" (10%) appear.

4.2.4 Soft and other required skills

As with hard skills, an analysis has been performed on the text used in job vacancies to indicate what soft skills are required for the job and what other skills are explicitly mentioned. Again, a division between role profiles is made to establish there are differences in required skills depending on the specific software-related role.

4.2.4.1 Developer

Being able to work in a team; “teamwork” is mentioned in 40% of developer related job vacancies, followed by communication skills (27%). Problem solving, analytical skills, self-management and agile (12%) are other words mentioned in these vacancies. Independency is also valued in some vacancies (7%). Mastery of the English language is frequently required (33%).

Figure 28 Soft and other skills for developers

4.2.4.2 Solution designer

Teamwork and communication are both frequently required soft skills (40%). Besides these also analytical skills and being able to operate independently are mentioned often (20%). Customer orientation is also valued (13%).
English is the most demanded language (45%).

Figure 29 Soft and other skills for solution designers

4.2.4.3 Test specialist

Again, communication (35%) and teamwork (29%) are both the most frequently required soft skills. Besides these also analytical skills (26%) and problem-solving skills (15%) are mentioned often. An agile (14%) and proactive (10%) attitude are also valued (13%). English is the most demanded language (41%).

Figure 30 Soft and other skills for test specialists

4.2.4.4 DevOps expert

Also, in DevOps vacancies communication (28%) and teamwork (33%) are both the most frequently required soft skills. Besides these also problem-solving skills (14%) analytical skills (11%) are mentioned often. A responsible (14%), agile (11%) and independent (8%) attitude are also valued. English is the most demanded language (31%).

Figure 31 Soft and other skills for DevOps experts

4.2.4.5 Digital media specialist

Again, teamwork (36%) and communication (27%) are both the most frequently required soft skills in digital media specialist vacancies. Besides these also analytical skills and creativity (15%) are mentioned often. Being able to work independently and problem-solving skills (12%) are also considered important.
Again, English is the most demanded language (32%).

Figure 32 Soft and other skills for digital media specialists

4.2.5 Main findings job vacancies

SQL, Javascript, and HTML are in general the hard skills that are the most in-demand. 15 - 30% of vacancies for all the roles mention one or more of these hard skills. Python is the most in-demand in relation to DevOps experts (27%).
For solution designers and DevOps experts the ability to work with specific platforms is considered important. Test specialists have to work with tools for testing, while digital media specialists have to work with design tools and applications.

Security is an issue that appears only in vacancies for test specialists (15%), while continuous integration/ continuous delivery ("CI/CD") and "management" (16%) are terms only used in relation to DevOps experts and the terms "marketing" (13%), "media" and "optimisation" (10%) are related uniquely to digital media experts.

In all job vacancies, teamwork and communication are the most frequently required soft skills (between 30 – 40%). Although to a somewhat lesser extent, other required skills are analytical and problem-solving skills.

Analytical skills are most required for test specialists (26%), followed by solution designers (20%), and to a lesser extent for digital media specialists (15%), developers (12%) and DevOps experts (11%).

Problem-solving skills are equally required (12 – 15%) for developers, test specialists, DevOps experts, and digital media specialists.

The ability to work independently is also mentioned to a certain extent, most frequently in solution designer vacancies (20%), and in just below 10% of the vacancies for developers, DevOps experts, and digital media specialists. An independent attitude is not required for

test specialists. Besides independence (7%), self-management is mentioned in job vacancies of developers (12%).
The ability to work flexibly in agile environments is important for test specialists (14%), DevOps experts (11%), developers (12%), and solution designers (9%).
Creative skills appear mostly in digital media specialist vacancies (15%), while customer orientation is a specific skill related to solution designers (13%).

In 30 - 40% of all vacancies English is the required language, besides mastery of the national language.

4.3 Questionnaire

4.3.1 Methods

A questionnaire was distributed to organisations with software skills needs to ask them about their current demand for software roles, competences, and skills.

4.3.1.1 Questionnaire development

The questionnaire was developed based on the project requirements and input from partners. The first phase was to invite partners to provide questions they considered relevant in the questionnaire. The first version of the questionnaire was drafted based on the requirements of the project and this input. This version was improved based on feedback from the partners. The next version was implemented in EU Survey and tested by 17 people. The adjustments made based on this test resulted in the final version. The questionnaire was available for respondents from May 24 until June 20.

The questionnaire consisted of the following sections: “about your organisation”, “software roles”, “software skills”, and “training”.

About your organisation
This section contained general questions about the organisation. It provided information to analyse whether country, size or sector has influence on the software roles, software skills and training needs of the organisations.

Software roles
In this section, the five selected ICT professional role profiles were presented with questions about the demand for these roles. Also, the organisations were given the possibility to add roles that are directly in need of software skills.

Software skills
The software skills were divided into hard, profession-related and soft skills. The hard skills are skills related to the production and maintenance of software. The profession-related skills are broader skills that software roles need, but are also broader skills for the ICT profession, such as security management and ICT project management. Soft skills are skills that are relevant for software roles but are relevant as well for all kinds of working environments, such as communication and teamwork.

Training
In the end, the main focus of the project is about the training that is needed to close the skills gap. The last section of the questionnaire was therefore about the training needs of the organisation. Respondents were asked for reasons to have their personnel trained in software roles, if they have a backlog in that and the reasons for that backlog, about their training strategies and methods, and the importance of qualifications.

4.3.1.2 Population and sample

The population of the questionnaire were organisations that have their own demand for software skills. These organisations are divided into two main categories: ICT organisations and other organisations with their own software skills needs.

The ICT sector division is based on the NACE codes. With relation to organisations that have thier own need for software skills, NACE J62 (Computer programming, consultancy, and related activities) and NACE J63 (Data processing, hosting, and related activities; web portals) organisations were included. It was important that the main focus of the organisations was in the described area. The non-ICT organisations with their own software roles and skills needs are divided into SME, large, and governmental organisations. Annex F shows the list of the type of organisations.

The companies in the sample could be of all sizes. They were categorised using the standard EU format:

- Micro: less than 10 people working in the organisation
- Small: less than 50 people
- Medium: less than 250 people
- Large: over 250 people

Respondents were approached through several channels. Partners used their own mailing database and sent out a general invitation. Partners also approached potential respondents

in a more personal way, by email and phone. In ICT organisations the HR department was approached to source the information. In other companies outside ICT, the HR department was approached, but also the head of ICT. Additionally, also open invitations were used, using social media like LinkedIn and Facebook. Finally, some partners used organisations like their national association for ICT to distribute the questionnaire among their members.

The questionnaire has a total of 301 respondents from 21 countries. This comes down to less than a 6% margin of error on a 95% confidence level, which allows drawing conclusions with enough certainty given the (in comparison) limited importance of a questionnaire in a multi-method approach.

4.3.2 General information on respondents

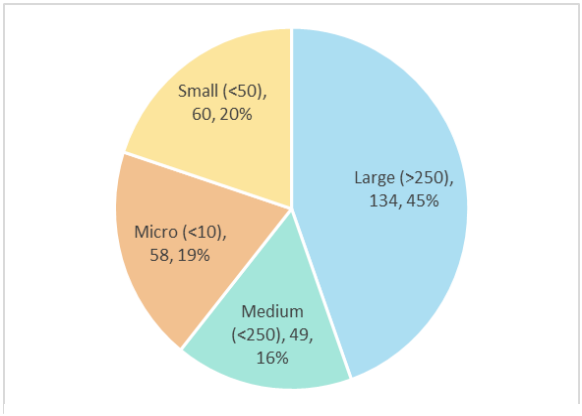


Figure 33 Respondents questionnaire by company siz/e

Almost 50% of the responses came from large organisations (> 250 employees). Small (< 50) and micro-organisations (< 10) each had 20% of responses, and medium organisations (< 250) had a response of 15%. This seems a little bit strange since only 99% of the businesses in the EU are SMEs, but it is explainable by the fact that it is already established that especially large organisations are searching for software specialists.
The topic is more important to them than to most SMEs.

Respondents were mainly organisations in the ICT sector (64%). 10% of the responses came from educational organisations, followed by finance, insurance and real estate companies (5%) and manufacturing (4%). 9% of responses came from organisations in the category “other”.

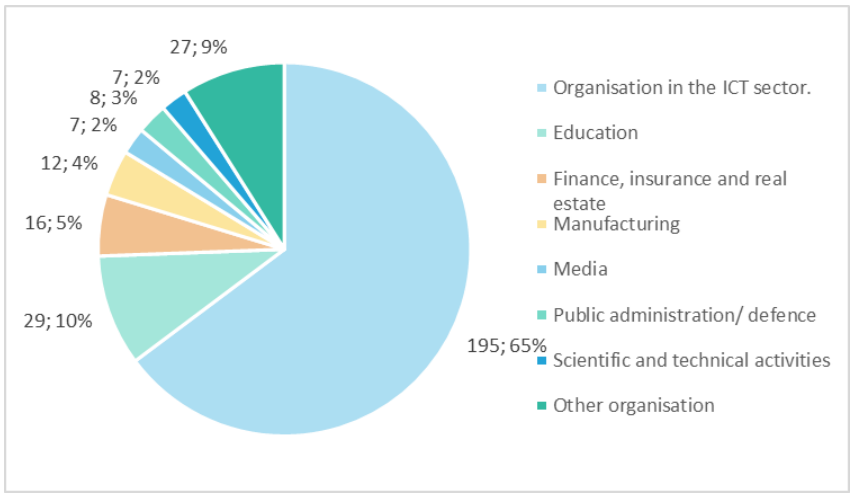


Figure 34 Respondents questionnaire by organization type

Of the organisations in the ICT sector, almost 40% are involved in programming activities, and 26% are related to consultancy. Web portals/ platforms and data processing/ hosting each are 10% of responses. 22% of responses came from organisations in the category involved in "other ICT activities".

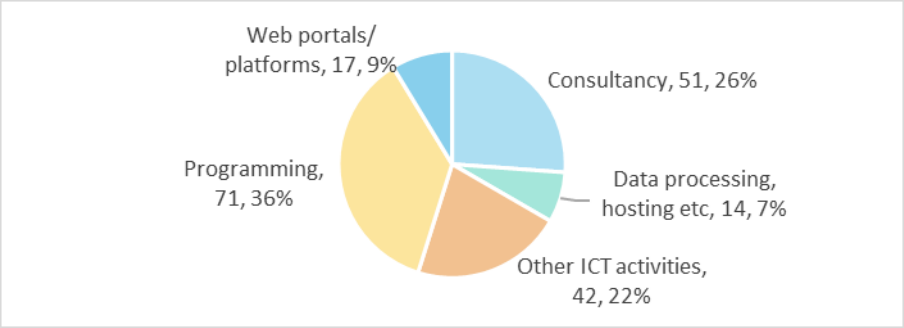


Figure 35 Respondents questionnaire by type of ICT organisation

4.3.3 Professional roles

The main question about the professional roles is what organisations expect that the need for extra people in certain roles will be. The options are that organisations don't have need for extra people in the role or that they have need at the moment and/or expect to have a need in the next five years. This is regardless of whether they already have people working in that role. Respondents could select multiple options, so they could indicate they have a need now and also expect to have a need in the future.

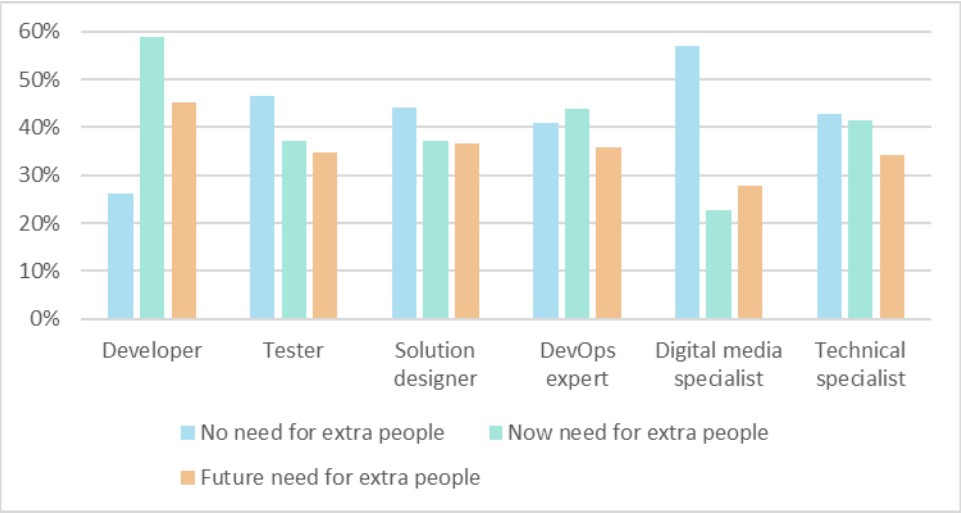


Figure 36 Need for extra people in role profiles

Almost 60% of all respondents are looking for extra developers at the moment. This is the highest percentage, in comparison to the demand for other roles. Somewhat more than a third (between 30-40%) of the organisations is looking for people in other roles like tester,

DevOps specialist, and Technical specialist. Only the role of digital media specialist is lagging behind with only around 20% of the organisations looking to hire people.

The same trend is visible when looking at the prediction for the need in the next five years. 45% of the organisations will need extra developers and around a third of organisations will need extra people in the other roles. Again, digital media specialists are lagging behind with less than 30% expected need.

It is also very relevant from an education and training perspective whether organisations are planning to hire people that already possess the right skills for the role or that they will train their own personnel. Respondents could select multiple options. The overall picture is that for all roles both hiring with the right skills and training their own personnel are more or less equally important. Only for the developer role is hiring substantial more important than training their own personnel.

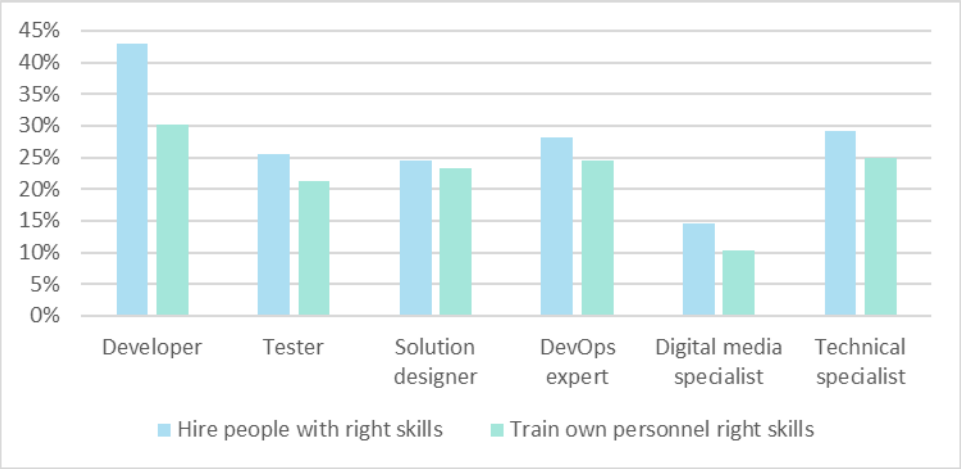


Figure 37 How do organisations fill roles (hire and/or train)?

4.3.4 Competences and skills

The next focus is on the specific skills that people in software-related roles need to perform their role. This is divided into hard skills, other profession-related skills and more general soft skills.

4.3.4.1 Hard skills

The most needed kind of hard skill are programming skills which can be explained by the fact that developers are most needed and also in other roles programming skills can be relevant. It is striking that the relatively new group of skills, algorithm skills, emerges second. There is little need on the other hand for design skills which is in line with little need for the design role.

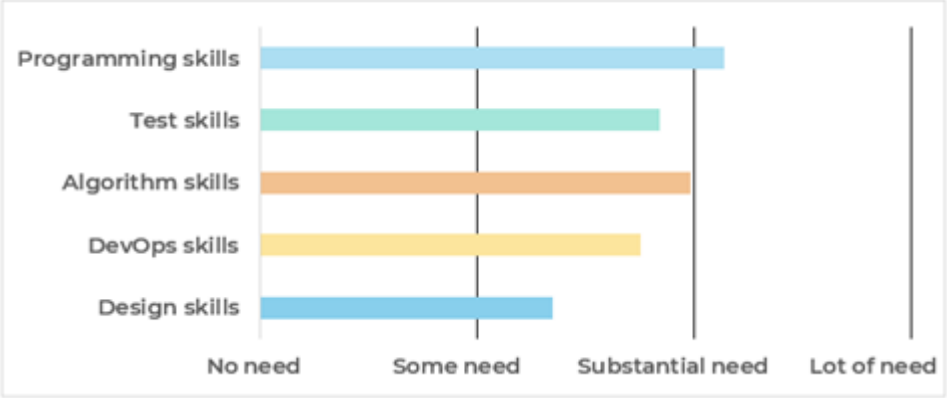


Figure 38 Need for hard skills

A more detailed look at the programming languages needed by the respondents reveals that the most well-known languages are also needed the most. Java, Javascript and HTML are most needed followed by Python and languages from the C-family. The respondents didn't indicate much need for the other programming languages. Also, in the open field "other" respondents did not indicate a language that stands out with only a few languages with more than one mention like for example Delphi (4 times) and Dart/Flutter (3).

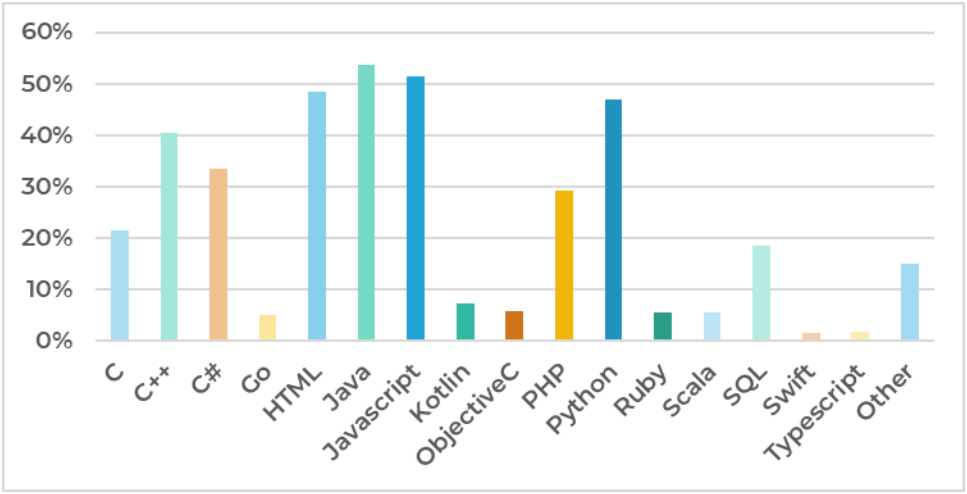


Figure 39 Need for programming languages

4.3.4.2 Profession-related skills

The responses on the profession-related skills indicate that there is a need for these kinds of skills for people in software-related roles, but only to a certain extent and with no clearly more important skill(s). The most important skills are security management, project management, software development lifecycle skills and data science and analytics skills. Sustainability management on the other hand is considered to be the least needed skill for people in software-related roles.

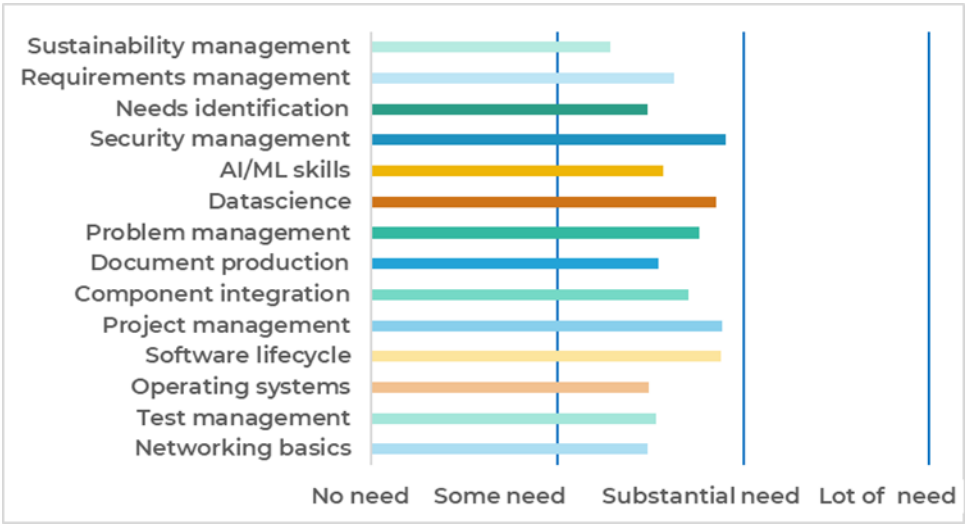


Figure 40 Need for profession-related skills

4.3.4.3 Soft skills

The need for the more transversal soft skills is higher than for the profession-related skills. Important skills relating to the person themselves are problem solving and critical thinking. Self-management is also considered to be an important skill. Skills relating to working with others, teamwork, and communication, are also very important according to the respondents. Leadership skills are the least important soft skill for people in software-related roles.

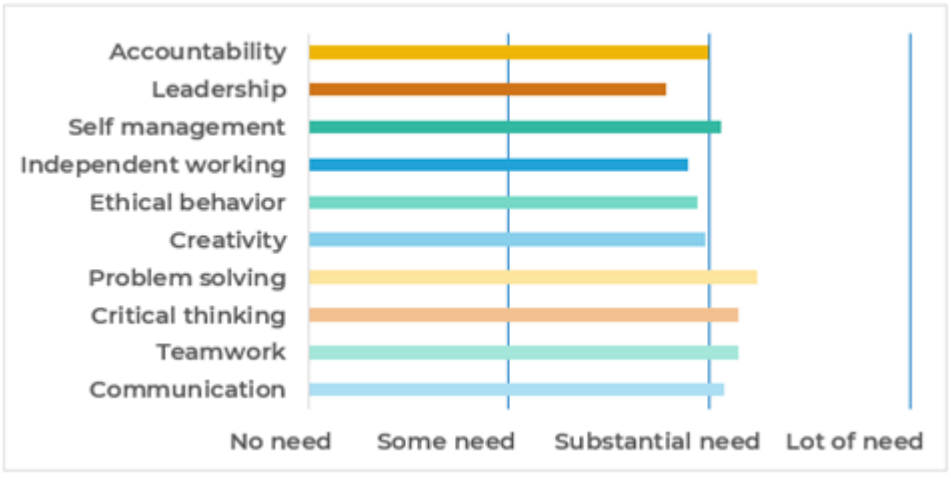


Figure 41 Need for soft skills

4.3.5 Training

Over 75% of the organisations indicated that there is a need for training personnel in software roles. When asked about the reasons for this need, nearly four-fifths of these organizations indicated that new technological developments ask for new skills. This is almost twice as much as the second reason being that new business processes require new skills. This means that the biggest drivers for training of existing personnel are new developments in technology and business.

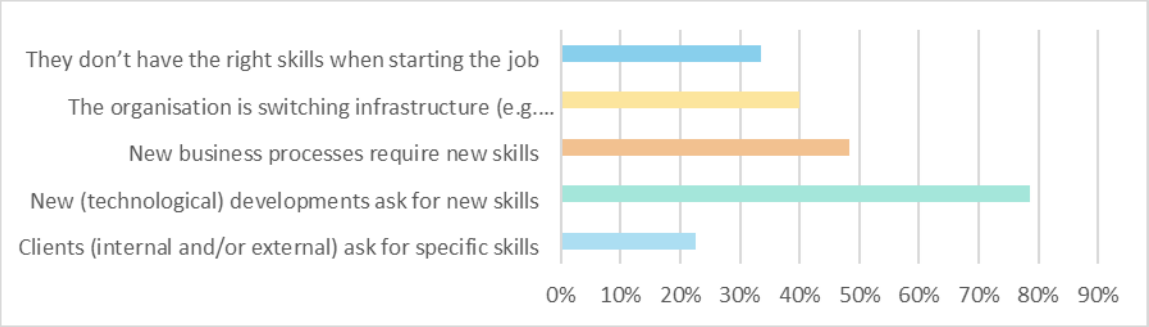


Figure 42 Reasons for having to train people

40% of the organisations with training needs state that they have a backlog in that training. The reasons for that are in most cases time related. 71% of the respondents indicate that the people in software roles don't have time for training and 45% of the organisations don't have time to organise it. According to a third of the organisations the costs of training are too high and the same number of organisations don't have people available to train personnel. The availability of external training is only considered an issue by 9% of the respondents.

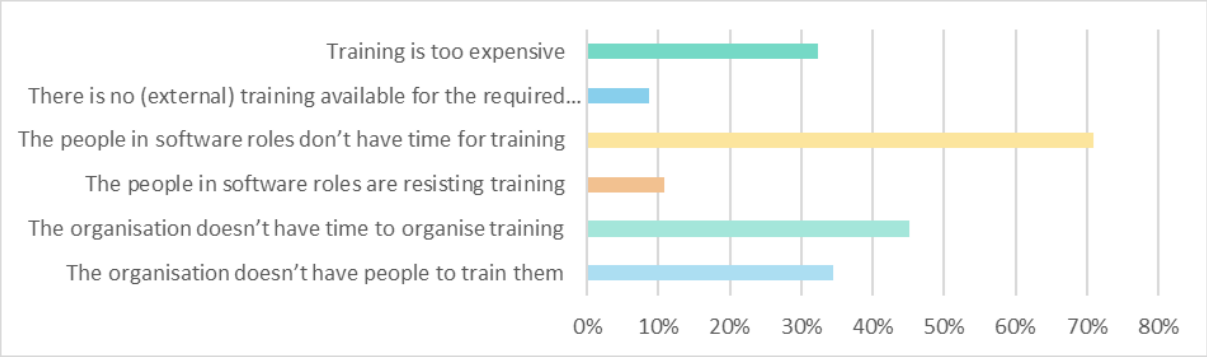


Figure 43 Reasons for backlog in training

4.3.6 Main findings questionnaire

Most respondents are looking for extra developers now (60%), and in the next five years (45%). Almost a third of the respondents is also looking for Testers, DevOps specialists and Technical specialists, now and in the coming years. Digital media specialists is the least sought for, almost 60% indicated they have no need for them.

Hiring developers that already possess the right skills from the beginning is to be preferred above training own personnel. For the other roles, both hiring with the right skills and training own personnel are more or less equally important.

The most needed kind of hard skill are programming skills (more than substantial need), directly followed by algorithm skills (substantial need).
The most important profession-related skills are considered security management, project management, software development lifecycle skills and data science and analytics skills.
The need for the more transversal soft skills is higher than for the profession-related skills, esp. problem solving, critical thinking, self-management, teamwork and communication.
The biggest drivers for training of existing personnel are new developments in technology and business. Reasons for a backlog in training are mostly time-related.

4.4 Expert groups

Expert groups were used to gain insights into the future situation of the demand for software roles, skills and the provision of those. Experts discussed possible future scenarios on these topics. This was done in a synchronous way during online meetings. The intention was to come to a consensus, but it is also possible that the outcome would consist of two or more scenarios. The principle that the Needs Analysis provides input for a European Skills Strategy leads to the fact that the expert groups should also be situated on a European level. The expert groups were therefore conducted on two levels: zone level and European level.

4.4.1 Methods

Partners from the consortium were asked to organise and coordinate an expert group meeting. These groups are composed of experts from partners' own country and preferably also from other countries in their zone. Contributors from the same country were asked to cooperate to organise an expert meeting. The meetings were online meetings of around 2 to 3 hours with 6 to 12 experts. Meetings were split in two meetings if there were more than 12 experts.

If not all views could be exchanged in one meeting of an expert group, a second meeting could be organised in which the results of the first meeting were discussed.

The expert groups were a relatively open questioning of experts. In this way, the experts got the opportunity to communicate their expectations regarding future demand and discuss this amongst each other. The moderator(s) steered it in the right direction by posing open questions related to the future of software needs.

The agenda of each expert meeting contained at least the following items:

1. Opening and introduction of the participants
2. Short introduction of the project
3. Discussion on future demand of software roles, skills and training
4. Follow up and close

Each expert group session was reported, in a uniform way by using the same format. The format contained the following entry fields:

- Information on the session/organiser (country, date, location)
- Information on participants (role, organisation)
- Outcomes on the demand for software roles in the next five years
- Outcomes on the skills needs (hard, profession-related and soft) in the next five years
- Outcomes on the training needs in the next five years
- Other outcomes

The sessions held were open discussions with some guidance so that at least the elements roles, skills and training were covered. The discussion was divided in three questions:

- **Discussion question 1:**
  - What will the demand for software roles (like for example developers) be in the next five years?
  - This is about whether experts expect there will be a growth or shrinkage in demand for those roles and what for example they think will be the number of vacancies that will need to be filled. It is also about whether some roles will become less or more dependent on software skills.
- **Discussion question 2:**
  - What skills will be important in those roles in the next five years?
  - This is about hard skills like specific programming languages, but also about soft skills and general ICT skills that experts think will be important to fulfil software roles in the coming years.
- **Discussion question 3:**
  - What is the need for training in the next five years?
  - This is about what experts think about training needs. Can current software people be upskilled for the new roles/ skills or is there a big need for reskilling people from other professions or will training young people for their first job be sufficient? It is also about whether they think that companies will arrange more or less training themselves than now or will the demand for external training increase in the coming years.

4.4.1.1 Selection criteria for experts

Experts invited to the expert groups should have a good insight into future developments. Experts can come from the occupational field as well as from the research field.

Experts coming from the occupational field should have insights in labour market developments in software roles and skills. Their focus and expertise can be on Human Resources with specific knowledge on the future developments in software roles and skills. Their focus and expertise can also be on future developments in the ICT sector with specific knowledge on how this translates into the need for software roles and skills.

Typical candidates are:

- Heads of HR departments of ICT companies (responsible for the staffing strategy)
- Managers of employment agencies or recruitment agencies specialising in ICT
- CIOs of large companies (responsible for ICT strategy and sourcing)

Experts can also have a more research-oriented background. An expert can for example be an academic in labour market intelligence in the field of ICT or an academic in new technologies and their effect on the labour market. Also, trendwatchers on labour market developments can become an expert. In any case experts need to have expertise in labour market developments and not (only) on technological developments, trends, and hypes.

4.4.1.2 Expert groups in the long run

One of the deliverables of WP2 is an Annual Skills Strategy Review. The ESSA European expert group will play a role in this structural review process and partners were invited to establish a national expert group with the same goal. Also, it is very well possible that the European expert group and national expert groups are invited to provide their views on deliverables in this project, like for example the curricula that will be an output of WP3. The intention is to keep this structure also after the formal ending of the project.

4.4.2 National expert groups

In total, 10 national expert groups were conducted, in which 118 experts discussed the relevant research questions of this study. The expert group sessions took place in 9 countries: Estonia, France, Germany, Hungary, Ireland, Italy, the Netherlands, Slovenia and Poland.

In addition to this, in the Netherlands a series of interviews was also conducted with selected experts besides two sessions with expert groups.

Also 2 in-depth interviews were conducted, one with a senior professor in software engineering at a large university in Canada and another one with the Irish governmental task force on Future Skills.

4.4.2.1 Roles

Growth in demand for software roles was recognised. Experts agree that there will be increased demand for software developers that also understand the business and the customer (DevOps approach), therefore they need knowledge of the industries for which they are developing.

In all partner countries similar software roles were indicated, most of them already covered by the role profiles relevant in this research. However, experts suggested some additional or new roles, for example roles in the field of human-computer interaction, roles in the field of cybersecurity, VR/AR/XR roles and behavioural scientist roles. In some expert groups a growing demand for developers specialised in certain sectors was stressed, such as fintech, biotech, pharmtech, and medtech. In every role one will have to understand the basics of programming and the logic behind it.

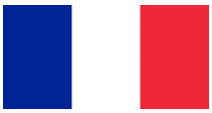
Hungary

Experts identified that the most in-demand roles will be the full stack developer role, DevOps/cloud engineer role, IoT expert, Coder and Business Analyst, and roles in the field of industry automation

and IT security. They expect the demand for data/information research experts will be low, and for data engineers to be medium.

Estonia

Experts expect no roles are likely to disappear in terms of software development. They expect a greater need for UI and UX designers, IoT and AI professionals, Big data analysts, and software licensing specialists.



France

Experts indicated a growth in demand for all the 6 principal software roles identified — Solution Designer (100%), Developer (100%), Technical Specialist (50%), Test Specialist (33%), Digital Media Specialist (33%) and DevOps Expert (16%). The demand for DevOps being stationary, they expect an increasing demand for DevSecOps, FinOps and Tech Leads. There is already a critical shortage for Solution Designers and Solution Architects. They stress the need for different types of developers (AI interface, AR/VR/XR, IoT, UI, UX, and HMI developers, Full Stack developers, back end and front-end developers). Besides, there is an increasing need of developers that know business fields like biotech/lifescience, e-mobility software developers, etc.

Germany

An increasing demand is expected for various software-related roles. Apart from a continuous demand for specialists with concrete software skills, more and more staff with more general skillsets is expected, with hard skills as well as transferable skills required in collaborative work.

Ireland

The largest perceived demand is for skillsets in the Data Analytics/Data Science arena. Most experts indicated that Software Development is critical and that individuals need a hybrid of software development skills rather than just an expertise in a specific language. There will be a fusion of technologies so the ability to move comfortably between AI and Blockchain but be cognisant of cybersecurity and cloud infrastructure to deliver the technologies will be the key. A minority of experts indicated that eCommerce, DevOps, and Cybersecurity are needed now.

The Netherlands

Experts expect an increasing demand in number and diversity of roles related to software development. Roles related to security, ethics, and sustainability are also on their list. Again, understanding of the business and of the customer (DevOps approach) is stressed. Software developers need knowledge of the industries they have to develop for.

The employment of software developers, quality assurance analysts, and testers is projected to grow 22 percent from 2019 to 2029. Much faster than the average for all occupations. In the next 5 years an

Poland	increased demand for junior/mid LabVIEW developers and junior Python/C/C++ developers is forecasted. Based on the expert group findings an increase in demand for all kinds of technicians and specialists in the broad area of information technology - both on the software side and on the hardware side will be required.
 Slovenia	Experts highlighted the increase in demand for the following profiles among others: DevOps Experts, cyber security specialists, and test specialists, esp. higher-level testing. Roles in the fields of cybersecurity, and multimedia solution development will become important. The demand for different types of developers will increase (AR/VR/XR developer, unity developer, Ui Developer, UX, HMI developer, embedded and IoT SW developer), and in specific sectors, such as software developers in the field of medicine, nano-sciences, and pharmacology. ICT needs are as follows: 30% of organizations anticipate up to 49% growth in needs in 5 years, 45% of organizations anticipate up to 100% growth in needs, and 10% anticipate more than 100% growth. And in non-IT organizations needs are as follows: 35% of organizations anticipate up to 49% increase in needs in 5 years, 38% of organizations anticipate up to 100% growth in needs, 5% more than 100%.

4.4.2.2 Skills

Expert groups highlighted the need to move from “I”-shaped specialists (like software developers or security practitioners) to "T-shaped" (like Site Reliability Engineers and Test-Driven Developers) and "Π-shaped" professionals, who have a wide breadth of knowledge in other related practice areas such as testing in addition to having the depth of knowledge in an area of expertise, and also knowledge in other scientific fields (e.g., humanities, management, mechanical engineering, etc.). Hence, the key is multidisciplinary skillsets. Considerable emphasis is placed on multidisciplinary cooperation. Therefore, social scientists also need to learn the terminology of the field of software engineering and vice versa to facilitate communication and understanding, and foster cooperation. More open collaborative skills set, for example to embrace open source and inner source technologies will become more prevalent as companies seek to co-create.

With the unfolding “Green Agenda” the concept of “sustainable software” will become more prevalent. This will focus on **“**smart” coding to minimise the energy consumption to deliver services and solutions underpinned by technology. This topic was raised in several national expert groups. In addition, governance, risk, compliance, and standards will all become the norm rather than the exception.
All the above points to demand for highly developed technical and transversal skills that enable an individual in software roles to be successful. Both hard and soft skills need to be equally valued.

Experts have provided a rich list of hard/technical skills needed, focusing on increasing complexity on large scale, safety and security, ethics in the software field, connection to industry, focusing on users and customers, and technology. However, the understanding of business, complex organisations and business needs were also emphasized. Also, leadership skills and other soft skills (cognitive skills, entrepreneurial skills, communication, cooperation, self-directing, motivation, lifelong learning, etc.) are crucial for software roles. The majority of experts emphasized the importance of soft skills in general, and particularly creative and analytical thinking, utilising empathy, storytelling, real-life scenarios to understand the purpose of a solution and better solve complex problems. Only through understanding the purpose of the product can one build a good solution.

Equally important for software teams will be their ability to "sell" the solution concept internally, which demands a combination of communication, presentation, and negotiation skills.

Almost in every expert group the ability to learn as related to lifelong learning was mentioned.

Hard skills are important but not without other transversal and interdisciplinary skills that enable one in the software field to understand the issue in a wider context and cooperate with others to find and present the best possible solution, considering all the aspects connected with it.

Estonia

Experts pointed out that developer job profiles need to include both the hard skills and soft skills; so they need a deep understanding of the whole development life cycle to be able to respond to the customer demand.

Hungary

Experts estimate the relative importance of soft skills vs hard skills: 60%-40%. Besides problem solving, analytical and critical thinking and communication skills, some interesting additional soft skills that experts mentioned were among others: active learning/ lifelong learning and an ownership attitude and as additional profession-related skills: financial skills and business understanding.

France

Experts considered coding, programming and testing skills in Angular, Java, Net core and Python, as well as DevOps, DevSecOps and FinOps Skills the most important hard skills. Besides common profession-related skills such as project management and security management, the importance of change management, financial management, costing and monitoring of charges, production quality monitoring and performance management and reporting was mentioned among others. Related to soft skills, experts underlined the need for lifelong learning and self-continuous improvement. Also mastery of the English language was stressed.

Germany

Experts acknowledged that there is uncertainty about which concrete programming languages will become most important, which remains sector specific. Hard skills in terms of knowledge of programming languages is expected to remain important. Demand for Microsoft .NET, cross-platform development skills and skills related to DevOps is expected to increase. Experts were particularly keen on knowledge and skills in social responsibility, ethics, data protection, person rights as well on legal issues and handling of data, which they considered essential.

Ireland

The experts were very strong in their views that there is a considerable number of new competencies now required, e.g., when considering AI, Ethical AI is critical. A brand can be alienated overnight if the algorithms deployed are not socially acceptable.

Italy

Experts agreed that the hard skills required by the software market are evolving so quickly that it is really difficult to do forecasting for the next 5 years. On the other hand, these skills can be easily acquired with short terms training. Therefore, having right soft skills is very important; being open for continuous learning and ready for change, being able to solve problems and work quickly and effectively in an agile team in a multidisciplinary work environment.

The Netherlands

Experts stressed the importance of communication and leadership skills in general. Other skills mentioned are thinking in solutions beyond the own business unit, pragmatism, creativity, and again the capacity to learn and adapt are listed. Also, knowledge of and skills in continuous integration (CI) and continuous deployment (CD) were mentioned. Regarding hard skills, experts indicated that it is important to learn about the principles of basic computer science and also to know the principles behind programming, data, developing, architecture, etc.

Poland

The expert group stated that candidates that have a mix of technical skills and soft skills will receive the most interesting offers in the market. Hard skills mentioned relate to among others: cloud computing, data structure and algorithms, git and GitHub, containers, data analysis, data modelling, data drilling, RPA, MLP, AI, and skills in the area of security. And again, the basics of essential computer science concepts like data Structures, algorithms and computer network.

Slovenia

Experts highlight interdisciplinarity, complex problem solving, and the ability and willingness to learn as important skills. It was pointed out that not only IT staff is encouraged to communicate more effectively, but also profiles from other fields should gain basic knowledge of the IT field for easier understanding and

> communicating. Digitalisation of the workplace, business processes etc. was considered an important profession-related skill.

4.4.2.3 Education and training

Experts agree that Lifelong Learning will be essential. This means that students and employees need to develop new competences throughout their career path. That could be accomplished by providing students with real-life experience, authentic tasks and collaboration between universities, companies, through e.g., apprenticeships and work-based learning. Task for lower and higher VET is to prepare the student for a soft landing on the job market, therefore close contacts with companies is essential.

Learning should comprise of project-based, transitional training, experimental learning, playful and gamified in real-life scenarios by mentoring, explanations, peer-to-peer learning, and storytelling. Additionally, soft skills are developed in the real-life situations, as they cannot be taught from books – people develop them by practising. Regarding training needs, there is also an important emphasis on abstract and entrepreneurial thinking. The competence that everyone needs in each field is knowledge of the principles of work organization (acceptance of oral and written instructions, assessment of time to complete the task, etc.).

Experts are of the opinion that basic programming logic and understanding, and machine learning should be introduced from the beginning of the educational vertical (from elementary school). However, with the software profiles, caution is required - not to tie things to just one specific domain. It is necessary to keep in mind and think about how to offer the possibility of acquiring knowledge in other domains already during education. Experts report that it does not make sense to focus on specific domains early in education, as it is not known where a person will work. However, there are already possibilities for participants in educational programmes to acquire other domain knowledge (e.g., elective courses, additional training). Consideration needs to be given to how to adapt and implement this in the future.

The way of closing the gap between the labour market supply and demand is in re-skilling from other domains to ICT and up-skilling. More emphasis should be on up-skilling and re-skilling courses and programs, delivered either by IT companies or by private providers. Microcredentials and nanodegrees are important, as they provide the opportunity for people to consume lifelong learning at their own pace and time. In some experts' opinion, most of the specialisation will take place in the company, via work-based learning projects; mentored by colleagues.

Short cycle trainings will not provide a significant amount of labour force. Therefore, the university programme needs to be improved (for example a course between bachelor and master).

Some experts say, in most cases university courses can currently follow slowly the IT trends that are changing very rapidly. Employees tend not to participate in extensive training,

therefore there is a substantial need for short, intensive training covering a bit of theory and emphasizing practice and experience. To provide quality, training of high school teachers would be a very important first step (technology and methodologies).

Suggested ways of adapting to changes in the labour market are to add pathways for different skillsets, developing complementary and modular curricula, integrating project-based learning, enhancing internship periods in academic programmes, enabling learning practices in different companies, providing short 12-week training for gaining the fundamentals on the subject, microcredentials for lifelong learning and upskilling programmes. Various options for developing competences were mentioned, from short training courses to complete university BSc and MSc education.

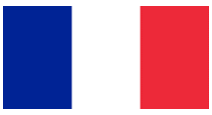
Rapid changes in technology, roles and positions mean educational institutions should confront the demands for developing competences in the software field. Trained educators, cooperation and flexible transition with the business environment, introducing more appropriate ways of teaching and learning and also creating new or upgrading existing programmes should be aligned with the vision for the future and the changing map of the competence needs on the labour market.

Hungary

Experts expect that short cycle training can help but will not provide a significant amount of labour force. Therefore, the university programme needs to be improved, awareness must be raised already at high school and there should be courses in secondary schools (for 14-19 years old), so young people can go to work.

Estonia

Experts' view on higher education is to provide an overview of the field; skills and competence itself will be acquired in the company. Higher education curricula will always lag behind. VET providers should cooperate with companies and provide short term courses. Evolving new trend: Community / networked learning (Devclubs).



France

Experts highlighted that when looking for junior software professionals, companies prefer upskilling people from other ICT professions, while for senior roles they prefer hiring them directly. Companies also prefer to source via freelance platforms that assess the knowledge and to train and mentor the experts. They also reported that it is important for large companies to train software professionals themselves through their internal enterprise academy or university for technical software skills and for some profession-related skills. They prefer external training for more specialist training, e.g., DevOps, Cisco. The experts also highlighted the need to include computer science, informatics, and coding in primary and secondary school.

In the expert group it was stated that the current university system lacks a preparation for company requirements, as it is focused too much on research and is too specialised. Experts

Germany	promote a more generalised education to create a solid basis for a software career. They consider the German Dual System with half of the training time provided in a vocational school and the other half in a company or organisation much better suited to the demand. Curricula should ensure i.a. training in writing business cases, social responsibility and ethics, and the skill to quickly learn new programming languages.
 Ireland	Experts recommended that already at secondary school should be started with teaching of coding. A successful programme to fill the skills gap in Ireland is the Future in Tech Programme. Since November 2020 over 400 unemployed people have been afforded an opportunity to start a career in tech. Supported by industry mentors, each pathway was built by industry for industry and includes industry certification. The eight pathways are the key skills sets in demand by industry in Ireland.
 Italy	Experts stressed the importance of teaching programming basics, additional short trainings in soft skills promoted by universities and internships.
 The Netherlands	Experts stated there is not so much a gap between the students graduating in ICT-curricula and the working environment: Any student that starts with an ICT-education is guaranteed to find a job. Companies themselves provide further training. The real challenge is to attract new ICT professionals. Furthermore, certification will remain important, but there should also be more focus on the industry specifics in the training. Education should also prepare for different hybrid environments.
 Poland	Experts stressed the outdated character of classic training. Education should be offered via web. The need for training is endless, so education and training providers should find means to fulfil this need. Also develop a "learning mindset" in their students.
 Slovenia	Experts emphasised strongly the importance of including the compulsory subject of computer science and informatics in primary and secondary education. This will affect the perception and understanding of students about what programming actually is, which can influence further career decisions in this direction.

4.4.3 European expert group

Partners were invited to nominate at least one expert for the European expert group or let the national expert group nominate an expert. In total, 14 experts from different countries

and various backgrounds took part in an online discussion session. The discussion was divided in three parts, each part focussing on one of the three central questions:

1. What will be the demand for the selected software roles in the next five years?
2. What skills will be important in those roles in the next five years?
3. What is the need for training in the next five years?

With each question, experts were first invited to post their thoughts, by using Mural's digital workspace, after which the discussion on the topic started.

4.4.3.1 Roles

Additionally, the experts from the European expert group emphasised that the concept of fusion of capabilities is becoming increasingly relevant. Specialists will need to be able to talk to the leadership team as well to the customers – a combination of soft skills with hard skills will be required.

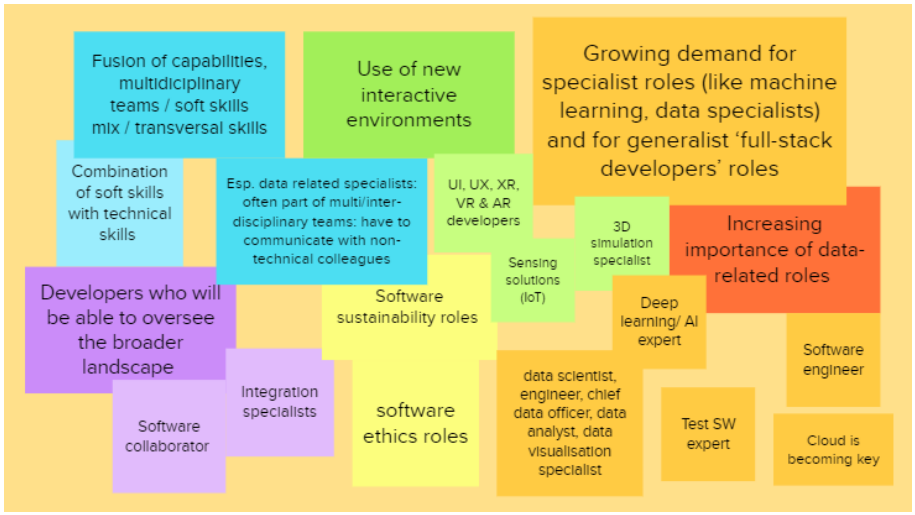


Figure 44 Summary of some key remarks on software roles

The discussion led to the topic of differentiating specialist roles from generalist roles. Specialists are harder to educate or train and it could be time-consuming to become a specialist in the field. Also, some specialist roles may not be transversal if they are specific to the needs of a certain company. While generalist roles have a transversal potential and could be easier to educate and train, hence providing a swift solution for the filling of the gap between supply and demand in the labour market. There is a need for generalists in the upcoming years, however the specialist role is in fact not expected to diminish; expertise in specific technologies will continue to be needed.

Besides this, specialists (esp. data related specialists) are often part of multi/inter-disciplinary teams, in which they have to communicate with non-technical colleagues. Software developers are not standing alone anymore, just to be able to code is not enough, they have to be able to work in agile environments. So, there will be a growing demand for developers who will be able to oversee the broader landscape (e.g., integration specialists, software collaborator role).

As environments with multi-disciplinary roles and multi/inter/trans-disciplinary teams will become an even more important part of businesses, a specific challenge lies in how such an environment or team can be successfully managed. The combination of technical and non-technical roles forming software teams, outside of leadership, will be in demand. The concept of a fusion of capabilities becomes more important.

Also, a future demand for software sustainability roles was recognised, with the green agenda unfolding, as well as software ethics roles.
The increasing importance of data-related roles was stressed as well (data scientist, engineer, chief data officer, data analyst, data visualisation specialist).

Besides this, a growing importance of developing new environments was mentioned; the use of new interactive environments, and interfaces that will become more important (User Interface (UI), User Experience (UX), Extended Reality (XR), Virtual Reality (VR) and Augmented Reality (AR) developers).
Related to developers, there is a growing demand for specialists (like machine learning, data specialists etc), and for generalists, "full-stack developers" roles.
There will be an ongoing demand for the more traditional roles like software developers, software engineers and software testing experts. The role then is the stable factor, its contents will gradually change over a period of 3 to 6 years; this is the so-called "role lifecycle".

4.4.3.2 Skills

EU-level experts highlighted the relationship between business and technologies, and that translating the needs is crucial. Emphasized was the integration of technology, when, where, what, and how technologies will be used; the integrating of technology to foster business. IT is no longer just a function but an integral part without which the business does not/cannot operate. There has to be an understanding of other disciplines and domains. Top level management is often mystified by new technologies. The management of new types of skills related to new technologies becomes important.

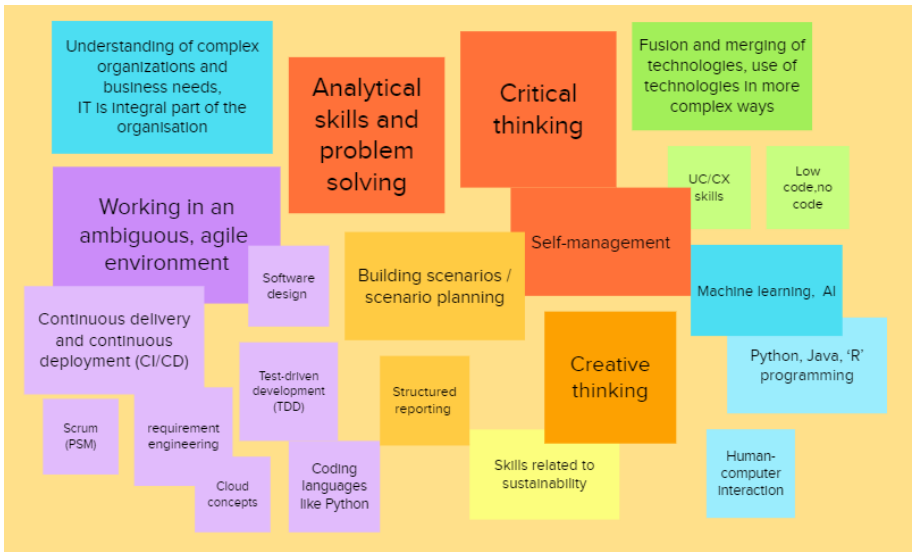


Figure 45 Summary of some key remarks on skills in software roles

A software developer does not stand alone anymore, working in an agile, ambiguous environment has become an important skill. This involves skills related to a broad range of e.g., software design, cloud concepts, scrum, requirement engineering, test-driven development (TDD), continuous delivery and continuous deployment (CI/CD), extra coding languages like Python and most importantly soft skills.

An absolutely critical set of skills mentioned by experts: critical and creative thinking, analytical skills, and problem solving. These allow people to transition between roles, and form the foundation for the development of several relevant hard skills. It is these types of skills that provide business competitive advantage. Specifically analytical skills were stressed: the ability to break problems down and find the right solution, using techniques like scenario planning and identify different solutions for problems.

Time management and self-management were also mentioned. Together with the management of intellectual property, relationship management and effective management of the value chain.

An understanding of the business and the business needs are also very important. The ability to translate these into technical specifications and deliver a valuable product, e.g., by using real-life scenarios. The ability to report in a structured way is even more important in this kind of environment. It is also important to think in a strategic way.

Data related roles (experts data science, machine learning) need more experience as compared to “normal” developers. Data related projects are different, so this involves a different skillset, being able to work with different disciplines and communicate with different stakeholders. Social intelligence and empathy being important factors here.

Technologies that will play a major role: experts mentioned Python, Java, and “R” programming. They noted that it is not always about something new, but the fusion of technologies and being able to use them in more complex ways. Low-code and no-code programming were mentioned, user experience (UX)/Customer Experience (CX) skills to make the handshake with business and due diligence for third party components are important. But also, the development of domain-specific languages (language engineering). Other hard skills mentioned were Cloud and cloud application development; Blockchain concepts and software programming; Security analysis, troubleshooting and site reliability.

A skillset related to sustainability will become important. This relates to the production of software in a more sustainable way, in terms of the consumption of natural resources. Leaders must prepare their teams for the new digital transformation wave.

Still gaining importance are: Human-computer interaction, customer experience, and gamification, so also the skills related to these will be important, including user interaction design, web technologies, 3D simulation and modelling, API design, XR experience design, animation and storytelling.

4.4.3.3 Education and training

Experts' key advice is to focus on foundation and entry levels in programmes, build-in practice, make modular programmes, seek cooperation with companies and incorporate the broader business perspective into programmes.
In addition to lifelong learning being essential, programmes should be more modular, offering much-needed flexibility and embracing changes and new technologies, so people can select electives and build a relevant programme. In this light also microcredentials and nanodegrees were mentioned, as well as the need to offer ultrashort lectures, called "microlessons" or "microlectures".

The need to look at what industry can do to close the gap was emphasized, e.g., between graduates who still need time to be trained further by companies. The cooperation of companies and the educational system will be essential. Collaborations between education and businesses, e.g., by apprenticeships, was mentioned as an example.

Another important aspect related to training and education is that this has to be combined with practice, as even basic developers need a lot more experience in the real world. Experimental learning was mentioned here, playful and gamified with real-life scenarios, and also teaching methods like mentoring, peer-to-peer learning, and storytelling.

An important consideration for educational providers is to what extent should the focus be on complex roles that require more experience, and to what extent on entry/junior level roles that would need to acquire the basics of e.g., AI/data, and then how can a curriculum or learning programme be built to move these individuals into more senior roles through continuous learning? The key is that foundations can and must be taught, so the focus is on the entry level talent and junior positions. Specialist roles are hard to educate for.

Business and technology together become key, so the broader business perspective has to be taught; the business needs; an understanding of complex organisations, IT is no longer a function, but an integral part of the business. Reskilling from other business functions into an IT role can be done. The other way around is much more difficult as this involves a business perspective. The broader business perspective is something that must be part of IT programmes.

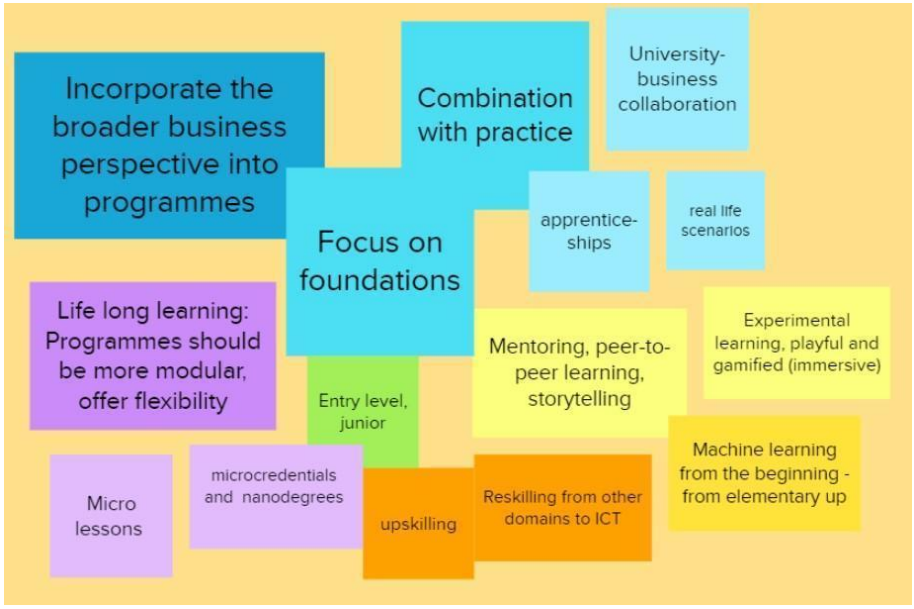


Figure 46 Summary of some key remarks on education and training for software roles

4.4.4 Main findings expert groups

Related to the development of software roles in the future, many experts at national and European level expect an ongoing still growing demand for developers, also for more generalist full-stack developers. . Many experts also expect a growing demand also for solution designers and DevOps experts. They suggest new roles will come up, which can actually be considered specialisations of already existing roles; developers specialising in specific areas such as cybersecurity, VR/AR, IoT, AI or in certain sectors, e.g., fintech, biotech.

Besides this, experts expect developers will need more and more skills related to data, cybersecurity, ethics and sustainability. Sustainable software and smart coding will gain importance. Besides this, understanding the business is considered important. There is a need to move from “I”-shaped specialists to "T-shaped" and "Π-shaped" professionals with multidisciplinary skillsets and understanding of other domains.
Also, the changing skillset for software professionals is stressed, with a growing importance of transferable, soft skills, esp. critical and creative thinking, analytical skills, and problem solving. Self-management; the ability to learn as related to lifelong learning is also considered an important skill and point of attention.

Related to education and training experts foresee that close contacts and cooperation between learning institutes and companies is important to close skills gaps and accomplish for example lifelong learning. Up-skilling and re-skilling courses and programs will become more important, delivered either by IT companies or by private providers. Modular programmes and small learning units are important and will become more important. The same holds for microcredentials.

4.5 Summary of findings on demand

4.5.1 Roles

The analysis of the roles that are involved in the production, deployment and maintenance of software led to some conclusions on the relevance of roles and on recruitment issues.

4.5.1.1 Developers needed most

It is no surprise that when focusing on software roles (software development and maintenance) the developer profile is in general the most important role. From the European labour market reports study it even became clear that, when looking at the ICT sector in general across Europe, the developer/ software engineer is even the profession most wanted of all possible ICT related jobs. This fact is also supported by the job vacancies study and the questionnaire. Respondents from the questionnaire stress the fact that it is not only the most important role, but also the role for which they need additional people for now and in the near future.

4.5.1.2 Role of developer is changing

In many countries, national labour market reports highlight the shift to new kinds of developers, like full stack developers and low code developers, as well as developers specialised in areas related to cybersecurity, AI, big data, blockchain, cloud, IoT, mobile and robotics. The most important insight is that developers are becoming more and more part of the regular organisation instead of a separate entity. Soft skills and knowledge of the business are therefore increasingly important for developers to be able to function. These trends are also supported by the literature study and by the national and European expert groups; experts emphasise the fact that these trends will continue in the future. In the literature, it was even suggested that there is a need for software developers to undertake multiple roles.

4.5.1.3 Rise of the DevOps expert

Both the experts and the questionnaire highlight the growing importance of the DevOps expert and also, albeit to a somewhat lesser extent, the Solution designer role. The growing attention for these roles can be explained by the need for better integration between software production and the rest of the organisation. A DevOps engineer/ developer integrates development, deployment and maintenance and is the developer in agile environments using e.g., continuous integration and continuous delivery (CI/CD). The solution designer proposes solutions taking into account the needs of the business.

4.5.1.4 Digital media specialist not relevant enough

The role of digital media specialist is according to the collected data (job vacancies study, questionnaire) not important in relation to software development, deployment and maintenance. Results from the questionnaire indicate even a decreasing need for this role in the future. An explanation could be that this role also can be viewed from a marketing perspective or as a modern version of graphic design and part of the graphical industry. In

some countries there are also separate educational programmes for this role that are not related to software, or even ICT in general, educational programmes. It can also be argued that digital media specialists do not create nor maintain software and therefore don't fulfil a software role. This is a reason to no longer include this role in the continuation of this project.

4.5.1.5 People in software roles need to have the right skills at the start

Organisations with software needs indicate in the questionnaire that it is a big challenge for them to find applicants that have the right skills for the job. On the other hand, it became clear that people in organisations don't have enough opportunities to train themselves while on the job e.g., because of a lack of time. This is a reason why organisations (also) like to hire people with the right skills, but at the same time the lack of applicants with the right skills is one of the main reasons why organisations have trouble or are even unable to find people for vacancies. The challenge for the educational field is therefore to educate and train people in such a way that they possess the right skills to enter jobs in organisations as much as possible. Organisations on the other hand should be more involved in indicating the required skills and support people to obtain them.

4.5.1.6 Strengthen the relation between organisations and educational institutions

Another finding from the questionnaire is that large organisations in any field have a need for people in software roles and of course organisations that are active in the software sector itself even more so. They also encounter a lot of problems in finding the necessary people for those roles. More and more large organisations, therefore, implement solutions like an own company academy to reskill and upskill their own personnel, but also to skill new personnel that do not have the right skills to start with. Experts suggest closer relationships between companies and educational providers. They state that partnerships between education and training providers and organisations with a need for software professionals in these kinds of initiatives can be of great help to close the gap between supply and demand. This s also an important recommendation in the literature.

4.5.2 Skills

The skills needed in software roles are certainly not restricted to "hard" software skills and other profession-related skills. There is a growing importance of soft skills that are needed to be successful as a software professional. The analysis led to conclusions on all three subgroups of relevant skills.

4.5.2.1 There is no gap related to programming skills

There is no gap between the current supply and demand for "hard" skills of which programming skills are most relevant in the context of this project. The study of the job vacancies and the results of the questionnaire both indicate that the most needed programming languages at the moment still are Java, Javascript, SQL, HTML, PHP, C++, C# and Python. These are also the programming languages that in most cases are part of educational programmes and for which there are plenty of training options.

4.5.2.2 Future-proof: understand programming principles

A problem might occur when educating for the future. It is not clear which new programming languages will last in the long run and become more important. It is also hard to predict how long popular languages will remain relevant. It is also a big task for people and organisations to find time to train for new programming languages. A way of making this process easier is to make sure that software professionals have a solid foundation in understanding programming principles. This will help to learn to adapt quickly to new languages and make software professionals more flexible and future proof. The importance of understanding the basics of programming and the logic behind it is emphasised both by experts on national level as on European level.

4.5.2.3 Important profession-related skills

Today, there is a need for some profession-related skills like **security management, project management, software development lifecycle skills and data science and analytics skills**. Experts foresee a growing importance of project management and agile ways of working. Security is an issue that is already important and will be even more important, making security an integral part of the whole cycle of designing, developing, deployment and maintenance.

Although currently not considered highly important, experts also foresee that in the future sustainability management and **sustainable software development** will become important, as well as **ethics**.

These are the profession-related skills that are most important for software professionals to have and should therefore have a prominent place in educational programmes and be available training topics.

Besides these, the literature study and the experts point out that an **understanding of the business** and its needs will also become even more important.

4.5.2.4 High relevance of soft skills

Experts find it difficult to forecast the exact hard skills that will be required over 5 years. Given the growing importance of data and algorithms, one of them still might be Python, but this is not sure. However, there is sufficient supply in training offerings and these hard skills can be easily acquired with short training courses. Therefore, having the right soft skills is very important; being open for continuous learning and ready for change, being able to solve problems and work quickly and effectively in an agile team in a multidisciplinary work environment.

This observation is underpinned by the results from the questionnaire: There is more than a substantial need for skills in the areas of problem solving, critical thinking, teamwork, communication and self-management. The need for problem solving skills is even bigger than the need for actual programming skills.

4.5.2.5 Interpersonal soft skills are foundational

People in software roles need interpersonal soft skills since almost all activities in these roles nowadays require working together. The most relevant are **teamwork** and general **communication skills**. Both these skills are the most frequently mentioned soft skills in all job vacancies. In most cases these skills are already part of educational programmes, but they need to be the focus of more attention, especially in relation to working in a business environment. Experts point out that both these skills will remain highly relevant in the future as well.

A related conclusion is that English is important in a lot of jobs, so **English language skills** are equally important and may even be a foundational requirement especially in relation to mobility. At the same time a limiting factor for mobility is that in many cases it is also required to be able to speak the local language.

4.5.2.6 Personal soft skills are key

There is a consensus confirmed in every element in this study that personal soft skills are becoming increasingly important for people in software roles. The most important are **critical thinking & analysis, problem solving** and **self-management**. This finding is underpinned by every element of this study. These soft skills are also truly transversal since these three skills are also the top three skills which the World Economic Forum (2020) concludes will be increasingly in demand by 2025 in the total population of organisations. In other words: these skills are important for people in any working environment and certainly for software professionals.

4.5.2.7 Relevant e-competences

The e-CF competences were part of this study mostly by their corresponding (group of) skills. These competences can be considered core for software roles:

- A.6. Application Design
- B.1. Application Development
- B.3. Testing

Other relevant e-competences are:

- D.7. Data Science and Analytics
- E.2. Project and Portfolio Management
- E.8. Information Security Management

Followed by the somewhat less important competences Component Integration (B.2) and Problem Management (C.4). Other competences like Needs Identification (D.11), are considered less important by organisations and also not mentioned by experts as becoming more important in the near future. Although Documentation Production (B.5) is considered less important by organisations as indicated in the questionnaire, some experts think that documentation will remain important.

The competence Sustainability Management (A.8) requires special attention because it is considered not that important at the moment by organisations, but according to experts

and reports it will become more important in the near future. The awareness of the importance of sustainability management should therefore be raised.

4.5.3 Training

The current and future demand for software professionals and corresponding skills requires changes in the education and training available so there will be a sufficient supply of professionals with the right skills.

4.5.3.1 Time for training is limited

The time people in software roles have for training is limited. Respondents from the questionnaire indicate that a lot of the backlog in training people in software roles is attributed to the lack of time available to the people and/or the organisation. This means that upskilling people will be challenging. On the other hand, the need for new skills and higher EQF levels required for software roles, makes it necessary for current software professionals to upskill themselves to stay relevant in their field. Initial education is key to close the skills gap at entry level, because a lot of new professionals are needed given the very large demand for software professionals, and these young students do not face these time restrictions. Time for training in more senior-level positions should get more priority in organisations.

4.5.3.2 Short, modular programmes and micro credentials

Experts advise that short, modular training programmes and courses are required to keep people in software roles up to date as they have limited time. These programmes should be updated regularly and follow the newest technologies and trends. Micro credentialing will help to certify the skills people require in life-long learning situations.

4.5.3.3 Broader education (and training)

An important finding across the whole study is that software professionals should have more soft skills, but also need more broader education. Experts consider **T-shaped** professionals to be the future. These are professionals with specialised skills in a certain area, but also have a broad range of skills in other areas of the software profession or even the broader ICT profession in general. This means that especially initial education should provide a broad foundation in the field. Also the **Π-shaped professional** is gaining ground. This professional has (at least) two fields of expertise and can bridge the gap between both disciplines. It is becoming more and more important that software professionals know what and who they are programming for. In most cases this includes at least business in general, so every software professional should possess some business knowledge and skills. The ultimate situation would be that every software professional has a multidisciplinary skillset and a second degree or at least some education and training in another field. This also means that professionals from other fields should possess some software skills to be able to work successfully together and develop software fulfilling the business needs.

4.5.3.4 Education together with organisations

To bridge the gap between education and practice it is helpful that organisations and education providers are working together more closely. Businesses could support learning by providing real-life examples and environments to practice. Education providers could support businesses by providing better tailored education and training for example by participating in company academies. This is strongly advised by the experts and underpinned by the literature study.

4.5.3.5 Educate flexible lifelong learning software professionals

Experts state that ideally, educating software professionals starts in primary school with teaching programming logic. The rest of the initial education should steer in the direction of flexible software professionals with a fundamental understanding of hard and profession-related skills and good personal and interpersonal soft skills. This forms the foundation for life-long learning to stay an up-to-date software professional and adapt to new situations and technologies.

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05.
Supply Study

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5 Supply study

It is necessary to have insights in the supply, besides the demand for software skills, to determine whether there is a gap between both. The current supply of software skills consists of a large number of different programmes and training offerings (VET and higher VET). These offerings can be provided by public and private universities (of applied science), VET providers, vendors, or internal training departments. Desk research was used to map this supply. First, an overview was made of relevant providers, followed by a more detailed investigation on the programmes of selected providers.

5.1 Providers

5.1.1 Methods

As a first step, the current supply was mapped to gain an overview. Partners tried to detect as much as possible those providers with a relevant offering. This was done by desk research; by extracting information from websites, brochures etc. The aim was to have a complete overview of relevant providers and their offerings preferably for all EU member states, but at least for the countries of the partners.

The providers were subdivided into public, private and company institutions. The following general guidelines were used to ensure coherence in the selection of the right providers by their offerings:

- Offerings can be from any kind of provider. These can be public or private institutions. These can be universities (of applied science), VET providers, vendors with their own training programmes or internal training departments of companies.
- Offerings should educate for roles, competences, knowledge and/or skills that are indicated as central to this research.
- Offerings should be on VET or higher VET level, incorporating upper secondary VET (EQF3/4), post-secondary/ tertiary VET (EQF 4/5), and higher VET (EQF 5/7).
- In general, this means it must be an educational programme or training that is directly related and prepares for the occupational field. In most cases in ICT these programmes are on EQF 4 to 6 level. On the higher EQF levels extra attention had to be paid to the question whether it is really a VET programme or training and not scientific or general education.
- Offerings should provide formal education or training preferably completed with a certificate or other proof of knowledge and/or skills acquired.
- Offerings can be of any length, study load et cetera. VET can be used for skilling, reskilling and/or upskilling of people. It depends on the aim of the educational programme or training what its content will be. A training of one day can be relevant as can a programme of 5 ECTS or a complete bachelor programme.
- Providers can specialise in one of more areas. For example, software development, AI or testing.

5.1.2 Findings

Data on over 1000 providers in 14 countries was collected. It showed that there is no shortage of supply in training of the most relevant software skills (e.g., programming languages).

The (initial) educational programmes related to software roles are available with mostly "programming" as the main focal point on EQF 3/4/5 level, software engineering on EQF 6 level and more specialist programmes at EQF 7 level. In several countries, the programmes on EQF 3/4/5 level are regulated and standardised at state level. In some countries also, EQF 6 programmes are standardised either by the government or by collaborating universities of applied sciences. EQF 7 level programmes are less regulated.

5.2 Programmes

More detailed information about the contents of relevant programmes was gathered as well.

In general, one could state that there is enough supply for single skills, offered in specialised trainings and short courses, but that new professionals starting their first ICT job do not possess all the relevant skills needed in organisations with software needs. Educational programmes seem not to be aligned with those skills needs.

A study of the contents of relevant programmes provided an impression of which roles and skills are not covered (enough) in educational programmes.

5.2.1 Methods

Having a large number of possibly relevant providers, a selection had to be made for a study of the contents of relevant programmes. The selection of these programmes was made based on the number of graduates of those programmes. The number of graduates on the programme was chosen as a selection criterion, as one can argue that a perceived skills gap at such a large scale has to be caused by the skillset of a large number of entrants to the labour market.
The three largest programmes (based on the number of graduates) were selected for each of the following three groups of offerings: VET (EQF 4/5), bachelor (EQF 6) and master (EQF 7) in a certain country.

- The first group of offerings is about complete educational programmes at EQF 4 (or in some cases EQF 5) that usually have at least one-year full time workload. So minimal 60 ECTS, but often 120, 180 or even up to 240 ECTS. These programmes go by different names depending on the country (e.g., Mid-level Vocational Education) and are on upper secondary or post-secondary level. Typically, the names used for this kind of programmes are programmer, software developer, software tester and web designer.
- The second group of offerings is about complete bachelor programmes or other programmes that belong to tertiary VET at EQF 6. These programmes usually have

a 180 or 240 ECTS workload. Also at this level there are several different programme names of which software engineering is a popular one.
- The last group of offerings is about complete master programmes or other programmes that belong to tertiary VET at EQF 7 level. These programmes usually have a 60 ECTS workload. At this level the programmes are usually more specialised, but it is interesting to see whether (basic) skills are taught in these kinds of programmes. It is also sometimes not considered VET, but general education, but if the focus is clearly on preparing for a profession (and not on a career in science) it can be considered higher VET, like for example a master DevOps specialist or master software engineer.

The data gathered focused on some general information on the programmes, including size and number of students, followed by an overview of the skills taught, hard skills, profession-related skills, and soft skills.

The data gathered on the skills mirrored the data that was collected by the questionnaire. In this way potential matches and mismatches could be detected and conclusions related to the skills gap could be drawn. Data on details of the programme was collected for the following programmes:

- 23 VET/ EQF 4/5 programmes
- 22 Bachelor/ EQF 6 programmes
- 24 Master/ EQF 7 programmes.

5.2.2 Skills in programmes

5.2.2.1 Hard skills in programmes

The skill programming is present in all studied programmes on all levels. On EQF4/5 level it is in most cases part of courses and on bachelor level it is more common to have more than one complete course dedicated to programming skills.

The skill working with data structures and algorithms is part of a lot of EQF 4-5 courses and has a dedicated course on the bachelor level. Programmes at master level are more specialised in most cases, but a lot of programmes at this level also have one or more courses on data structures and algorithms.

DevOps skills have a limited presence in EQF 4/5 programmes but are included on other levels, in most cases as part of a course. They only have a dedicated course or courses in some programmes.

Media editing and web design skills are primarily part of programmes focused on this topic and not a standard part of other software-related programmes.

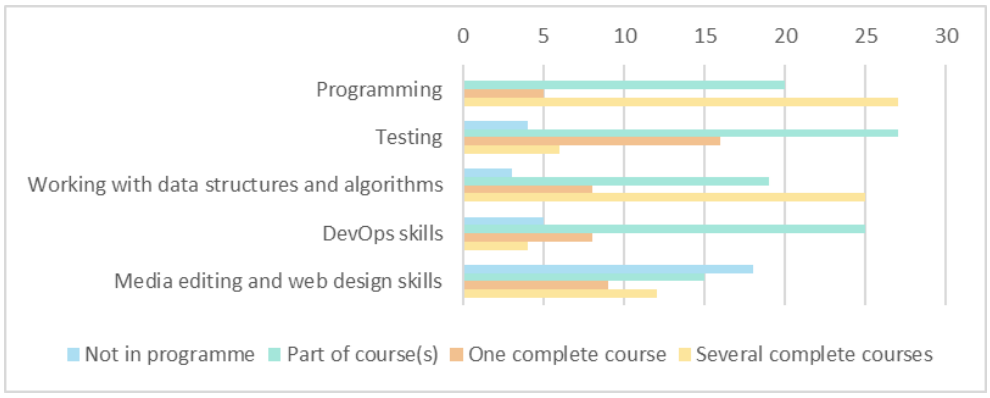

Figure 47 Hard skills in programmes

The most taught programming language is Java which is part of over 60% of the studied programmes. Also, SQL, HTML and Python are present in at least 50% of the programmes. C, C++, C#, Javascript, PHP and Ruby are taught in more than 10% of the cases. All other programming languages are only taught in a few programmes (less than 10%).

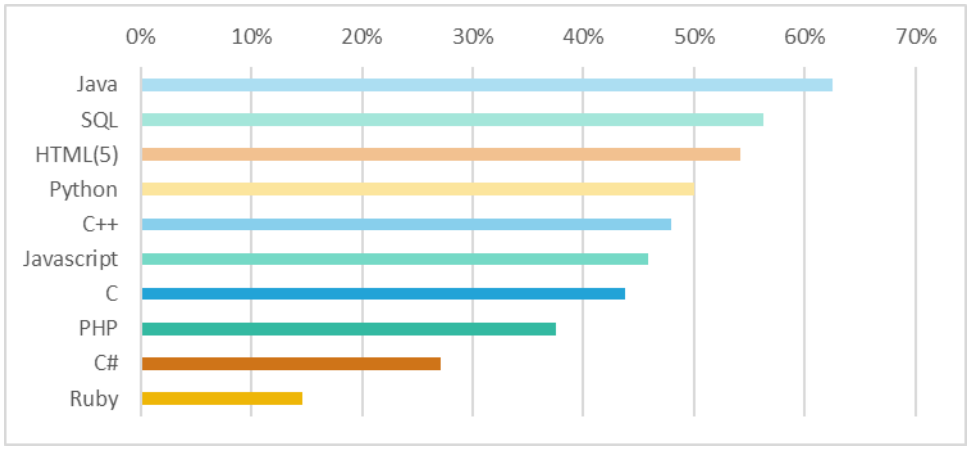

Figure 48 Programming languages in programmes

5.2.2.2 Profession-related skills in programmes

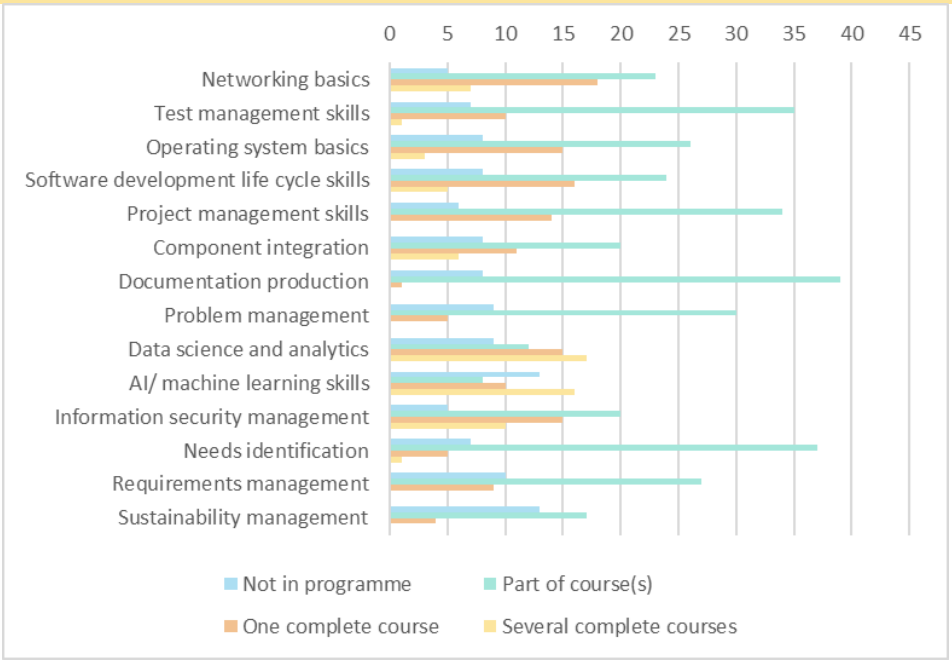

Figure 49 Profession-related skills in programmes

Data science analytics and machine learning skills are the skills that are the most a topic of several courses in a programme. These are mostly programmes on master level with apparently a big focus on these topics. On the other hand, these skills have a very limited presence on EQF 4/5 level. On EQF 4/5 level none of the profession-related skills have multiple courses dedicated to them and only a few have one dedicated course, but a lot of profession-related skills are present as part of courses.

Some skills almost have no dedicated course on any level in any programme. For example, documentation management is part of a lot of programmes, but only as part of courses. This is also the case for skills like test management, project management and needs identification. Other skills get less attention in the programmes, especially sustainability management which rarely appears on the programmes that were studied.

5.2.2.3 Soft skills in programmes

Soft skills are seldom the topic of a dedicated course in a software skills related programme. Critical thinking, problem-solving and creativity are part of a lot of programmes, but almost only as part of a course. There is more attention for these skills on the higher EQF levels. The more interaction focused skills communication and teamwork are also part of a lot of programmes and have somewhat more dedicated courses in comparison. These skills are more a part of the EQF 4-5 levels and somewhat less on the higher levels.

Skills like ethical behaviour, independent working, self-management, accountability and leadership are absent in a lot of programmes and included as part of courses in other

programmes. Leadership is for example absent on EQF 4-5 and part of a few programmes on the other levels with some dedicated courses.

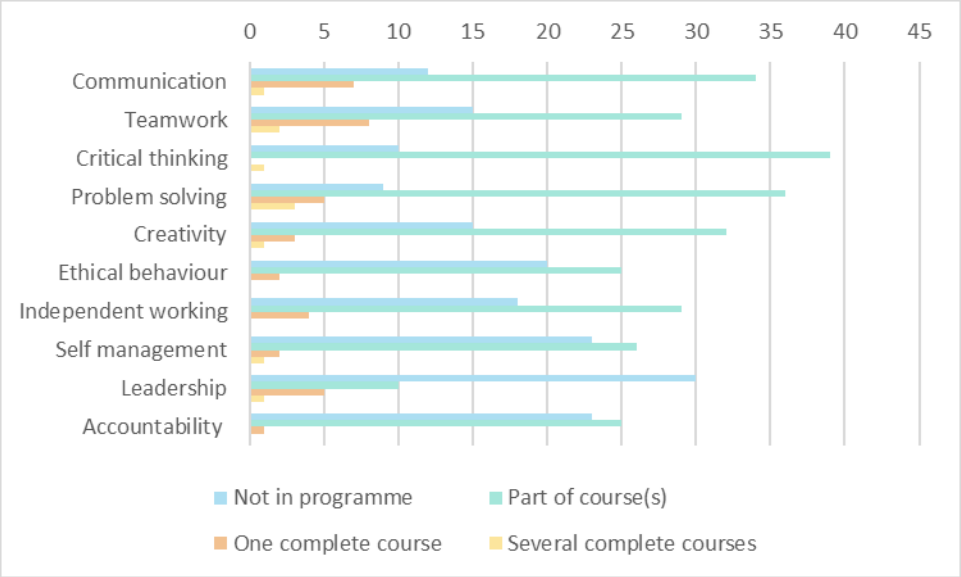

Figure 50 Soft skills in programmes

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06.
Conclusions

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6 Conclusions

The final step in a multi-method approach is to integrate the findings and, in this case, perform a gap analysis based on those integrated findings. This analysis leads to conclusions that need to be addressed in the European Software Skills Strategy. The primary conclusions are divided into conclusions on software roles, skills and education/training, although sometimes conclusions are related to more than one of these categories.

6.1 The most important software roles now and in the future

Looking at the CEN role profiles related to software professionals, this needs analysis shows that there is a difference in need for certain roles at the moment and in the future. To educate and train the right specialists it is important to know which are relative to each other the main roles to focus efforts on.

Table 1 Relative importance of software roles

Role	Now	In 5 years
Developer	*****	*****
DevOps expert	***	****
Solution designer	***	***
Test specialist	**	**
Technical specialist	***	**

The most important role for software professionals is developer. This emerged from all elements of the needs analysis. Not only now, but also in the future. DevOps experts are needed at the moment, but the projection is that the demand will even grow in the future. The demand for solution designers is expected to remain the same, while the demand for test specialists and technical specialists is somewhat lower, but still relevant.

One of the tasks of a sector skills alliance like ESSA is to establish occupational profiles or update existing ones when relevant. This Needs Analysis shows that attention especially on soft skills is important. In the next phase of the project, it will be investigated further whether the profiles of first of all developer, but also DevOps expert, solution designer and test specialist, should be updated.

6.2 Most needed skills now and in the future

Regarding skills the main conclusion is that a software professional needs a broad spectrum of skill. The hard skills directly relating to development and operation of software are considered becoming less important. A trend that is foreseen to continue in the future.
The most important groups of skills identified in this needs analysis are:
1. Interpersonal soft skills (teamwork, communication, English language)
2. Personal soft skills (Critical thinking & analysis, problem solving, self-management)
3. Understanding of the business

4. General profession related skills (e.g. agile project management, security, sustainability)

6.3 Needs for the delivery of education and training

This needs analysis shows that organisations find the following aspects the most important looking at the delivery of education and training:

1. Modular programmes in combination with micro credentials
2. Broader education in relation to soft skills and profession related skills
3. Working together with organisations to improve understanding of the business

7 Glossary

This glossary provides a list of key terms that are used in this document and their definitions for the purposes of this document. It is not meant to provide an exhaustive list of all the terms related to the subject of this study.

Term	Definition
Accreditation of an education or training programme	Process of quality assurance through which a programme of education or training is officially recognised and approved by the relevant legislative or professional authorities following assessment against predetermined standards. (Cedefop, 2014)
Accreditation of an education or training provider	Process of quality assurance through which an education or an education training provider is officially recognised and approved by the relevant legislative or professional authorities following assessment against predetermined standards. (Cedefop, 2014)
Assessment (of learning outcomes)	Process of appraising knowledge, know-how, skills and/or competences of an individual against predefined criteria (learning expectations, measurement of learning outcomes). Assessment is typically followed by certification. (Cedefop, 2014)
Associate degree	Qualification awarded after successful completion of the so-called short cycle in the Qualifications Framework of the European Higher Education Area (EQF). The short cycle fits within or is linked to the first cycle (or bachelor's level). The degree requires approximately 120 ECTS credits. (European Consortium for Accreditation, 2021)
Bachelor's degree	Qualification awarded after successful completion of the first cycle in the Qualifications Framework of the European Higher Education Area (EQF). The degree usually requires a minimum of 180 and a maximum of 240 ECTS. (European Consortium for Accreditation, 2021)
Certification (of learning outcomes)	Process of issuing a certificate, diploma or title formally of learning outcomes attesting that a set of learning

	outcomes (knowledge, knowhow, skills and/or competences) acquired by an individual have been assessed by a competent body against a predefined standard. (Cedefop, 2014)
Comb-shaped professionals	Professionals who have a depth of knowledge and skills in many specific domains of expertise or fields (all the vertical bars of the comb-shape) and have broad knowledge and skills across multiple fields or disciplines (the horizontal bar of the comb-shape). that allows them to cross collaborate and effectively leverage someone else's expertise in that area. (Adapted from Friedlein, 2013; Grupman, J., 2 021)
Curriculum	Type of learning programme, based on a predefined selection and organisation of content, offered in a certain way by an educational institution, such as a school, college, or university. (CEN/TC 428, TS 17699, 2022)
Competence	Demonstrated ability to apply knowledge, skills, and attitudes for achieving observable results. (CEN/TC 428, EN 16234-1 (2019)
DevOps	Development methodology aimed at bridging the gap between Development (Dev) and Operations (Ops), emphasizing communication and collaboration, continuous integration, quality assurance, and delivery with automated deployment utilizing a set of development practices. (Jabbari et al., 2016)
Digital badge	Validated indicator of accomplishment, skill or competences, that can be displayed, accessed, and verified online, which describes a specific performance that the recipient has done to earn it. They often represent the completion of a microcredential. (Carey, 2012)
Doctorate degree	Qualification awarded after successful completion of the third cycle in the Qualifications Framework of the European Higher Education Area (EQF). The degree usually requires a three to four years of study, mostly as a period of research. (European Consortium for Accreditation, 2021)
e-Competence Framework (e-CF)	Standard established as a tool to support mutual understanding and provide transparency of language through the articulation of competences required and deployed by Information and Communication Technology (ICT) professionals. (CEN/TC 428, EN 16234, 2019)

Educational credential	Documented statement that acknowledges a person's learning outcomes. (European Micro-Credential Terminology, 2022)
Educational profile	Structure that enables a competence-oriented learning programme design and development, thus providing a link between competences needed in a professional environment and learning outcomes of education and training. It assists planning education and professional accomplishment at individual and institutional levels. (CEN/TC 428, TS 17699, 2021)
E-shaped professionals	Professionals who have a depth of knowledge and skills in a specific domain or field (expertise) and also have broad knowledge and skills across multiple fields or disciplines (experience), which enables them to collaborate across disciplines with experts in other areas. Besides expertise and experience these professionals also possess knowledge and skills related to the tangible (execution) and intangible (exploration), implying having both a big-picture outlook and an attention to detail from being a practitioner. (Adapted from DaVanzo, 2010)
European Qualification Framework (EQF)	Overarching framework that makes transparent the relationship between European national (higher) education frameworks of qualifications and the qualifications they contain. It is an articulation mechanism between national frameworks. (Bologna Working Group on Qualifications Frameworks, 2005)
European Skills, Competences, Qualifications and Occupations (ESCO)	The multilingual ESCO classification identifies and categorises skills, competences, qualifications, and occupations relevant for the EU labour market and education and training. It systematically shows the relationships between the different concepts. (ESCO, 2022)
Formal learning	Learning that occurs in an organised and structured environment (such as in an education or training institution or on the job) and is explicitly designated as learning (in terms of objectives, time or resources). Formal learning is intentional from the learner's point of view. It typically leads to certification. (Cedefop, 2014)
Formal recognition (of learning outcomes)	Process of granting official status to learning outcomes knowledge, skills and competences either through: • validation of non-formal and informal learning; • grant of equivalence, credit units or waivers;

	• award of qualifications (certificates, diploma or titles). (Cedefop, 2014)
Hard skills	Strictly job-specific, closely connected with knowledge, easily observed, measured and trained skills. They constitute the core occupational requirements of a job. (Dall'Amico, E. & Verona, S., 2015)
Higher or upper VET	Composed of: a) post-secondary level VET, offered outside higher education; b) higher-level continuing VET (CVET) offered within or outside the formal education system (usually after entry into working life); qualification here often gives access to nationally recognised qualifications but the target is adult learners; qualifications are often based on professional experience and examinations (competence tests); c) higher-level CVET provided outside the formal education system (by adult education centres, public employment services or private companies), which do not fall into the above categories. Higher VET relates to EQF levels 5 to 8. (Cedefop, 2019)
ICT Body of Knowledge (ICT BoK)	Structured set of information including, terminology, concepts, models, and theories which represent the accepted and agreed upon core knowledge base required by the ICT profession. (CEN/TC 428, EN 17748-1, 2022)
ICT Professional Role Profiles	These profiles reflect a collection of typical tasks, competences and responsibilities that are to be fulfilled and each profile is given a common use title for ease of identification. They provide a broad picture of the activities performed by individuals engaged in the multitude of positions that make up the ICT profession. ICT Professional Role Profiles are key components of ICT jobs. (CEN Workshop Agreement 16458, 2018)
ICT sector	Combination of manufacturing and services industries whose products primarily fulfil or enable the function of information processing and communication by electronic means, including transmission and display. OECD (2022)
Informal learning	Learning resulting from daily activities related to work, family or leisure. It is not organised or structured in terms of objectives, time or learning support. Informal learning is in most cases unintentional from the learner's perspective. Informal learning outcomes may be validated and certified; Informal learning is also referred to as experiential or incidental/random learning. (Cedefop, 2014)

Information and Communication Technology (ICT)	Diverse set of technological tools and resources used to transmit, store, create, share or exchange information. (UNESCO, 2009)
Initial education	Formal education of individuals before their first entrance to the labour market, i.e., when they will normally be in full-time education. It thus targets individuals who are regarded as children, youth, and young adults by the society to which they belong. It is typically provided by educational institutions in a continuous educational pathway. (UNESCO, 2012)
International Standard Classification of Education (ISCED)	Global reference classification for education systems and it provides a comprehensive framework for organising education programmes and qualification by applying uniform and internationally agreed definitions to facilitate comparisons of education systems across countries. (ISCED, 2022)
Knowledge	Theoretical or practical understanding and awareness of phenomena such as facts, terminology, concepts, models, or theories that are related to a field of work or study. Knowledge is the outcome of the assimilation of information through learning and is theoretical and/or factual. (CEN/TC 428 EN 17748-1, 2022; Council of the European Union, 2017)
Learning	Process by which an individual assimilates information, ideas and values and thus acquires knowledge, know-how, skills and/or competences. Learning occurs through personal reflection, reconstruction and social interaction. It may take place in formal, non-formal or informal settings. (Cedefop, 2014)
Learning environment	Any environment that allows a person to learn in providing certain conditions or procedures to do so; this can be an educational institute, a training facility or a workplace, as well as a face-to-face, hybrid or a virtual environment. (CEN/TC 428, TS 17699, 2022)
Learning outcome	Statements of what a learner knows, understands and is able to do on completion of learning process, which are defined in terms of knowledge, skills and competence. (Cedefop, 2014)
Learning programme	Coherent set of learning activities with the aim of providing learners with certain knowledge, skills or behaviour over a certain period of time. (CEN/TC 428, TS 17699, 2022)
Learning path	Specific route that reflects a person's subsequent learning activities undertaken in a specific learning environment throughout his/her life, career or study. (CEN/TC 428, TS 17699, 2022)

Lifelong learning	All learning activity undertaken throughout life, with the aim of improving knowledge, skills/competences and/or qualifications for personal, social and/or professional reasons. (Cedefop, 2014)
Master's degree	Qualification awarded after successful completion of the second cycle in the Qualifications Framework of the European Higher Education Area (EQF). The degree usually requires a minimum of 90 ECTS, of which at least 60 ECTS at master's level. (European Consortium for Accreditation, 2021)
Microcredentials	Sub-unit of a credential that could accumulate into a larger credential or degree or be part of a portfolio. Microcredentials are frequently portrayed and promoted as a new way for individuals to build their own skills profile (portfolio) by collecting and "stacking" learning in flexible ways, at their own pace and according to their own priorities. Micro-credentials certify the learning outcomes of short-term learning experiences, for example a short course or training. They offer a flexible, targeted way to help people develop the knowledge, skills and competences they need for their personal and professional development. (European Micro-Credential Terminology, 2022; Cedefop, 2021 & European Approach to Micro-Credentials, 2022)
Non-formal learning	Learning which is embedded in planned activities not explicitly designated as learning (in terms of learning objectives, learning time or learning support), but which contain an important learning element. Non-formal learning is intentional from the learner's point of view. It typically does not lead to certification. (Cedefop, 2014)
Post-secondary, non-tertiary education	Encompasses qualifications that are considered to be beyond secondary education but are not included in the tertiary sector. Post-secondary non-tertiary education provides learning experiences building on secondary education, preparing for labour market entry as well as tertiary education. Students entering will have usually completed upper secondary education. Programmes usually have a full-time equivalent duration of between 6 months and 2 years. Post-secondary, non-tertiary education relates to EQF levels 4 and 5 and ISCED level 4. (UNESCO, 2011)
Prior learning	The knowledge, know-how and/or competences acquired through previously unrecognised training or experience. (Cedefop, 2014)

Profession-related skills	Skills that are necessary to fulfil professional tasks and are relevant for a broader range of different roles related to a certain profession. They are not related solely to one specific role. (ESSA Consortium, 2022)
Qualification	An official record (certificate, diploma) of achievement which recognises successful completion of education or training, or satisfactory performance in a test or examination; and/or the requirements for an individual to enter, or progress within an occupation. (UNESCO, 1984)
Qualification system	All activities related to the recognition of learning outcomes and other mechanisms that link education and training to the labour market and civil society. These activities include: • definition of qualification policy, training design and implementation, institutional arrangements, funding, quality assurance; • assessment and certification of learning outcomes. Comment: a national qualifications system may be composed of several subsystems and may include a national qualifications framework. (Cedefop, 2014)
Reskilling	Training enabling individuals to acquire new skills and knowledge giving access either to a new occupation or to new professional activities. (Cedefop, 2014)
Short cycle tertiary education	Programmes at this level are often designed to provide participants with professional knowledge, skills, and competences. Typically, they are practically based, occupational-specific and prepare students to enter the labour market. However, these programmes may also provide a pathway to other tertiary education. programmes. Short cycle tertiary education relates to EQF level 5 and ISCED level 5. (UNESCO, 2011).
Skilling	Training enabling individuals to acquire new skills and knowledge giving access either to an occupation or to professional activities. (Cedefop, 2014).
Skills	Ability to apply knowledge and use know-how to complete tasks and solve problems. Skills can be cognitive (involving the use of logical, intuitive, and creative thinking) or practical (involving manual dexterity and the use of methods, materials, tools and instruments). (Council of the European Union, 2017)
Skills for software professionals	Skills necessary to perform tasks that lead to the design, development, deployment and/or maintaining of software. They can be grouped in

	hard, profession related and soft skills. (ESSA Consortium, 2022).
Skills gap	Situation where an individual does not have the kind and/or level of skills required to perform their job adequately. (Cedefop, 2014).
Soft skills	Patterns of thought, feelings and behaviours that are socially determined and can be developed throughout the lifetime to produce value. These are cross-cutting skills across jobs roles and sectors that relate to personal competences (confidence, discipline, self-management) and social competences (teamwork, communication, emotional intelligence). (Borghans, 2008; Dall'Amico, E. & Verona, S., 2015).
Software	Computer programs, procedures, and possibly associated documentation and data pertaining to the operation of a computer system (IEEE 828, 2012).
T-shaped professionals	Professionals who have a depth of knowledge and skills in a specific domain or field (the vertical bar on the letter T) and also have broad knowledge and skills across multiple fields or disciplines (the horizontal bar on the letter T), which enables them to collaborate across disciplines with experts in other areas. (Adapted from Gardner, 2017; Brown, 2009).
Tertiary education	Third level education that encompasses bachelor, master and doctorates or equivalents. Vocationally oriented education and training at tertiary qualifications level means education and training that can contain aspects of both academic and vocational areas typically with the majority of vocational aspects (e.g., Universities of applied sciences, Polytechnic institutes). It is usually located at levels equivalent to EQF levels 6 to 8 and ISCED levels 6 to 8. (Cedefop, 2011)
Transferable skills	Skills learned in one context that are useful for another. They can serve as a bridge from study to work and from one career to another, as they enable subject and research-related skills to be applied and developed effectively in different work environments. (European Science Foundation, 2009).
Upper-secondary education	Encompasses educational institutions that focus on general or vocational education. Programmes at this level are typically designed to complete secondary education in preparation for tertiary education, or to provide skills relevant to employment, or both. Pupils enter this level typically between ages 14 and 16. Upper

	secondary education relates to EQF levels 3 to 5 and ISCED level 3. (Cedefop, 2014;2020).
Upskilling	Short-term targeted training typically provided following initial education or training, and aimed at supplementing, improving or updating knowledge, skills and/or competences acquired during previous training. (Cedefop, 2014).
Validation (of learning outcomes)	Confirmation by a competent body that learning outcomes (knowledge, skills and/or competences) acquired by an individual in a formal, non-formal or informal setting have been assessed against predefined criteria and are compliant with the requirements of a validation standard. Validation typically leads to certification. (Cedefop, 2014).
Vocational Education and Training (VET)	Education and training which aims to equip people with knowledge, know-hows, skills and/or competences required in particular occupations or more broadly on the labour market. Vocational Education and Training covers upper-secondary, post-secondary, non-tertiary, and tertiary levels of education. (Cedefop, 2008; Erasmus+ Programme Guide, 2019).
Work-based learning	Learning that takes place through some combination of observing, undertaking, and reflecting on productive work in real workplaces. It may be paid or unpaid and includes a diversity of arrangements like apprenticeships, dual programmes, traineeships, internships, job shadowing, and other work placements used as part of school-based VET programmes. (OECD, 2016; UNESCO, 2015).
π-shaped professionals	Professionals who have a depth of knowledge and skills in two specific domains or fields (the two vertical bars of the π-shape) and have broad knowledge and skills across multiple fields or disciplines (the horizontal bar of the π-shape), which enables them to bridge the gap between the two domains or fields and also to collaborate with experts in other areas. (Adapted from Friedlein, 2013).

8 References and resources

Beckett, R., & Daberkow, T. (2019). Work 4.0 and the Identification of Complex Competence Sets. MWAIS 2019 Proceedings, 0–6. https://aisel.aisnet.org/mwais2019/33/

Bologna Working Group on Qualifications Frameworks (2005). A Framework for Qualifications of the European Higher Education Area. Ministry of Science, Technology and Innovation, Copenhagen.

Bullock, B. B., Nascimento, F. L., Doore, S. A., & Nascimento, F. (2021). Computing Ethics Narratives: Teaching Computing Ethics and the Power of Predictive Algorithms. ACM Technical Symposium on Computer Science Education, 1020–1026. https://doi.org/10.1145/3408877.3432468

Cedefop (2008). Terminology of European education and training policy - A selection of 100 key terms. Luxembourg: Office for Official Publications of the European Communities

Cedefop (2011). Vocational education and training at higher qualification levels. Luxembourg: Publications Office of the European Union. Luxembourg: Publications Office of the European Union. Cedefop research paper; No 15.

Cedefop (2014). Qualifications at level 5: progressing in a career or to higher education. Luxembourg: Publications Office of the European Union. Cedefop working paper; No 23.

Cedefop (2014). Terminology of European education and training policy - A selection of 130 key terms. 2nd ed. Luxembourg: Publications Office of the European Union.

Cedefop (2017). The changing nature and role of vocational education and training in Europe – Vol. 1: Conceptions of vocational education and training: an analytical framework. Luxembourg: Publications Office of the European Union.

Cedefop (2019). The changing nature and role of vocational education and training in Europe - Vol. 6: Vocationally oriented education and training at higher education level; Expansion and diversification in European countries. Luxembourg: Publications Office of the European Union.

Cedefop (2020). European qualifications framework. Initial vocational education and training: focus on qualifications at levels 3 and 4. Luxembourg: Publications Office of the European Union. Cedefop research paper; No 77.

Cedefop (2021). Spotlight on VET - 2020 compilation: vocational education and training systems in Europe. Luxembourg: Publications Office of the European Union, 2021

CEN - European Committee for Standardization (2018). European ICT professionals role profiles - Part 1: 30 ICT profiles. Brussels: CEN-CENELEC. CEN Workshop Agreement - CWA 16458-1:2018 (E).

CEN - European Committee for Standardization (2018). European ICT professionals role profiles - Part 2: User guides. Brussels: CEN-CENELEC. CEN Workshop Agreement - CWA 16458-2:2018 (E).

CEN - European Committee for Standardization/ TC 428 (2019). e-Competence Framework (e-CF) – A common European Framework for ICT Professionals in all sectors - Part 1: Framework. Brussels: CEN-CENELEC. European norm EN 16234-1:2019.

Cico, O., Jaccheri, L., Nguyen-Duc, A., & Zhang, H. (2021). Exploring the intersection between software industry and Software Engineering education - A systematic mapping of Software Engineering Trends. Journal of Systems and Software, 172, 110736. https://doi.org/10.1016/j.jss.2020.110736

Clear, A., Parrish, A. S., Impagliazzo, J., & Zhang, M. (2019). Computing Curricula 2020. https://doi.org/10.1145/3287324.3287517

Engelbrecht, L., Landes, D., & Sedelmaier, Y. (2018). A didactical concept for supporting reflection in software engineering education. IEEE Global Engineering Education Conference (EDUCON).

European Commission, Education and Culture (2008). The European Qualifications Framework for Lifelong Learning (EQF). Luxembourg: Office for Official Publications of the European Communities.
European Commission. Digital Economy and Society Index (DESI) 2020 - The EU ICT Sector and its R&D Performance.
European Commission. European Skills/Competences, qualifications and Occupations (ESCO). https://ec.europa.eu/esco/
European Commission/EACEA/Eurydice (2018). The Structure of the European Education Systems2018/19: Schematic Diagrams. Eurydice Facts and Figures. Luxembourg: Publications Office of the European Union.
European Consortium for Accreditation (2021). ECApedia. http://ecahe.eu/ (accessed 08-07-2021)
Eurostat (2008) NACE Rev. 2. Statistical classification of economic activities in the European Community. Luxembourg: Office for Official Publications of the European Communities. Eurostat Methodologies and Working papers.
Föll, P., Hauser, M., & Thiesse, F. (2018). Identifying the skills expected of IS graduates by industry: A text mining approach. International Conference on Information Systems 2018, ICIS 2018, 1–17.
Garousi, V., Giray, G., Tüzün, E., Catal, C., & Felderer, M. (2019). The Journal of Systems and Software Aligning software engineering education with industrial needs: A meta-analysis. The Journal of Systems and Software, 156, 65–83. https://doi.org/10.1016/j.jss.2019.06.044
Günay, C., Doloc-Mihu, A., Barakat, R., Gluick, T., & Moore, C. . (2018). Improving Critical Thinking in Software Development via Interdisciplinary Projects at a Most Diverse College. SIGITE 2020 - Proceedings of the 21st Annual Conference on Information Technology Education.
Higgins, C., Dublin, T. U., Ie Ciaran, C. H., Leary, O. ', Hanratty, O., Mtenzi, F., O'leary, C., & Mcavinia, C. (2017). A Conceptual Framework for a Software Development Process A Conceptual Framework for a Software Development Process based on Computational Thinking based on Computational Thinking A CONCEPTUAL FRAMEWORK FOR A SOFTWARE DEVELOPMENT PROCESS BASED ON COMPUTATIONAL THINKING. 978–984. https://doi.org/10.21125/inted.2017.024
Hoover, A. K., Spryszynski, A., & Halper, M. (2019). Deep learning in the IT curriculum. SIGITE 2019 - Proceedings of the 20th Annual Conference on Information Technology Education, 49–54. https://doi.org/10.1145/3349266.3351406
Jacobs, J., Brandt, J., Mech, R., & Resnick, M. (2018). Extending Manual Drawing Practices with Artist-Centric Programming Tools. Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems. https://doi.org/10.1145/3173574.3174164
Joint Quality Initiative (2004). Shared "Dublin" descriptors for Short Cycle, First Cycle, Second Cycle and Third Cycle Awards.
Kirsch, M. and Beernaert, Y. (2011). Short Cycle Higher Education in Europe Level 5: the Missing Link. Brussels: EURASHE.
Leathrum, J. F., Sokolowski, J. A., Shen, Y., & Audette, M. (2019). Software Skills Required by M&s Graduates for Des Development. Proceedings of the Winter Simulation Conference, 3285–3294.
Licorish, S. A., & MacDonell, S. G. (2021). Exploring software developers' work practices: Task differences, participation, engagement, and speed of task resolution. Information and Management, 54(3), 364–382. https://doi.org/10.1016/j.im.2016.09.005
MichaelPage (2021). The world's most in demand professions. https://www.michaelpage.co.uk/minisite/most-in-demand-professions
Quezada-Sarmiento, P. A., Enciso, L., Mayorga-Diaz, M. P., Mengual-Andres, S., Hernandez, W., Vivanco-Ochoa, J. V., & Carrion, P. V. T. (2018). Promoting innovation and entrepreneurship skills in professionals in software engineering training: An approach to the academy and bodies of knowledge context. IEEE Global Engineering Education

Conference, EDUCON, 2018-April, 796–799. https://doi.org/10.1109/EDUCON.2018.8363312

Reinhart, A., & Genovese, C. R. (2020). Expanding the scope of statistical computing: Training statisticians to be software engineers.

Ryan, K. (2020). We should teach our students what industry doesn't want. Proceedings - International Conference on Software Engineering, 103–106. https://doi.org/10.1145/3377814.3381719

Shaba, E., Guerci, M., Gilardi, S., & Bartezzaghi, E. (2019). Industry 4.0 technologies and organizational design - Evidence from 15 Italian cases. Studi Organizzativi, 1, 9–37. https://doi.org/10.3280/so2019-001001

Stanton, W. W., & Stanton, A. D. A. (2020). Helping Business Students Acquire the Skills Needed for a Career in Analytics: A Comprehensive Industry Assessment of Entry-Level Requirements. Decision Sciences Journal of Innovative Education, 18(1), 138–165. https://doi.org/10.1111/dsji.12199

The Council of the European Union (2017). "Council Recommendation of 22 May 2017 on the European Qualifications Framework for lifelong learning and repealing the recommendation of the European Parliament and of the Council of 23 April 2008 on the establishment of the European Qualifications Framework for lifelong learning". Official Journal of the European Union, 15.6.2017, C 189/15

Thorat, S. A., & Kshirsagar, D. P. (2021). Developing logic building, problem solving, and debugging programming skills among students. Journal of Engineering Education Transformations, 34(Special Issue), 402–406. https://doi.org/10.16920/jeet/2021/v34i0/157188

UNESCO Institute for Statistics (2011). International Standard Classification of Education - ISCED 2011. Montreal.

Webster, J., & Watson, R. T. (2002). ANALYZING THE PAST TO PREPARE FOR THE FUTURE: WRITING A LITERATURE REVIEW. In MIS Quarterly (Vol. 26, Issue 2).

World Economic Forum (2020). The future of Jobs Report.

Zabavnik, J., Riel, A., Marguč, M., & Rodič, M. (2019, July 3). Knowledge and skills requirements for the software design and testing of automotive applications. SAAEI. https://hal.archives-ouvertes.fr/hal-02335566

9 Annexes

1. Annex A - Role profiles descriptions and alternative names

The titles and descriptions of the role profiles are derived from: CEN/CWA 16458-1 "European ICT Professionals Role Profiles - Part 1: 30 ICT profiles". Alternative names are based on ESCO, the European Skills/Competences, qualifications and Occupations classification.

Role profile	Solution Designer
Description	Provides the translation of business requirements into end-to-end IT solutions. Proposes and designs solutions in line with technical architecture which fit business requirements and support change.
Alternative (ESCO) role names	• Digital games designer • ICT application configurator • Instructional designer • Software analyst
Role profile	**Developer**
Description	Designs and/ or codes components to meet solution specifications. Ensures building and implementing of ICT applications. Contributes to low-level design. Writes code to ensure optimum efficiency and functionality and user experience.
Alternative (ESCO) role names	• Digital games developer • Embedded systems software developer • ICT system developer • ICT application developer • Industrial mobile devices software developer • Mobile app developer • Software developer • User interface developer
Role profile	**Test Specialist**
Description	Designs and performs testing plans. Ensures delivered or existing products, applications or services comply with technical and user needs and specifications. For existing systems, applications, innovations and changes; diagnoses failure of products or services to meet specification.
Alternative (ESCO) role names	• Digital games tester • ICT accessibility tester • ICT integration tester • ICT system tester • ICT test analyst • ICT usability tester • Software tester

Role profile	DevOps Expert
Description	Implements processes and tools to successfully deploy DevOps techniques across the entire solution development lifecycle. Applies a cross-functional, collaborative approach for the creation of customer-centric software solutions. Introduces automation throughout the software production system to deliver better software faster.
Alternative (ESCO) role names	n.a. ESCO: DevOps is considered knowledge - The DevOps development approach is a methodology to design software systems and applications focused on the collaboration and between software programmers and other ICT professionals and automation.
Role profile	**Digital Media Specialist**
Description	Integrates digital technology components for internal and external communication purposes. Designs and codes social media applications and websites. Makes recommendations on Application Programming Interface (API) and supports efficiency through appropriate content management systems.
Alternative (ESCO) role names	• 3D animator • 3D modeller • Digital media designer • Search engine optimisation expert • User interface designer • Web developer

2. Annex B - List of skills

Hard skills		Profession-related skills	Soft skills
• Programming • Testing and debugging • Working with data structures and algorithms • DevOps skills • Media editing and web design	*Programming languages* • C • C++ • C# • 4 • Go • HTML(5) • Java • Javascript • Kotlin • Objective-C • PHP • Python • Ruby • Scala • SQL • Swift • Typescript • Other	• Networking basics • Test management • Operating system basics • Software development life cycle • Project management • Component integration • Documentation production • Problem management • Data science and analytics • Information security management • Needs identification • Requirements management • Sustainability management	• Accountability (efficiency, reliability, diligence) • Communication • Creativity • Critical thinking • Ethical behaviour • Independent working • Leadership (coaching, motivating, strategic thinking) • Problem solving • Self-management (adaptability, personal development) • Teamwork

3. Annex C - EQF details

Framework for Qualifications of the European Higher Education Area - European Qualification Framework – EQF

An overarching framework that makes transparent the relationship between European national higher education frameworks of qualifications and the qualifications they contain. It is an articulation mechanism between national frameworks (Bologna Working Group on Qualifications Frameworks (2005).

Levels represent a series of sequential steps (a developmental continuum), expressed in terms of a range of generic outcomes, against which typical qualifications can be positioned (Bologna WG on Qualifications Frameworks (2005). Each level is defined by a set of descriptors indicating the learning outcomes relevant to qualifications at that level in any system of qualifications (European Commission, 2008).

EQF level 4
is defined by the following set of descriptors indicating the learning outcomes relevant to qualifications at that level in any system of qualifications: [*knowledge*] factual and theoretical knowledge in broad contexts within a field of work or study, [*skills*] a range of cognitive and practical skills required to generate solutions to specific problems in a field of work or study, and [*competence*] exercise self-management within the guidelines of work or study contexts that are usually predictable, but are subject to change and supervise the routine work of others, taking some responsibility for the evaluation and improvement of work or study activities (adapted from: European Commission, 2008).

EQF level 5
is typically related to the associate degree or equivalent degrees and is defined by the following set of descriptors: [*knowledge*] comprehensive, specialised, factual and theoretical knowledge within a field of work or study and an awareness of the boundaries of that knowledge, [*skills*] a comprehensive range of cognitive and practical skills required to develop creative solutions to abstract problems, and [*competence*] exercise management and supervision in contexts of work or study activities where there is unpredictable change and review and develop performance of self and others (adapted from: European Commission, 2008).
EQF level 5 corresponds with the “Dublin” descriptor of the short cycle (Joint Quality Initiative, 2004; European Commission, 2008).

EQF level 6
is typically related to the bachelor degree or equivalent degrees and is defined by the following set of descriptors: [*knowledge*] advanced knowledge of a field of work or study, involving a critical understanding of theories and principles, [*skills*] advanced skills, demonstrating mastery and innovation, required to solve complex and unpredictable problems in a specialised field of work or study, and [*competence*] 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 (adapted from: European Commission, 2008).

EQF level 6 corresponds with the "Dublin" descriptor for the first cycle (Bologna WG on Qualifications Frameworks, 2005; European Commission, 2008).

EQF level 7
is typically related to the master's degree or equivalent degrees and is defined by the following set of descriptors: [*knowledge*] 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 and critical awareness of knowledge issues in a field and at the interface between different fields, [*skills*] 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, and [*competence*] manage and transform work or study contexts that are complex, unpredictable and require new strategic approaches and take responsibility for contributing to professional knowledge and practice and/or for reviewing the strategic performance of teams (adapted from: European Commission, 2008).
EQF level 7 corresponds with the "Dublin" descriptor for the second cycle (Bologna WG on Qualifications Frameworks, 2005; European Commission, 2008).

EQF level 8
is typically related to the doctorate degree or equivalent degrees and is defined by the following set of descriptors: [*knowledge*] knowledge at the most advanced frontier of a field of work or study and at the interface between fields, [*skills*] the most advanced and specialised skills and techniques, including synthesis and evaluation, required to solve critical problems in research and/or innovation and to extend and redefine existing knowledge or professional practice, and [*competence*] demonstrate substantial authority, innovation, autonomy, scholarly and professional integrity and sustained commitment to the development of new ideas or processes at the forefront of work or study contexts including research (adapted from : European Commission, 2008).
EQF level 8 corresponds with the "Dublin" descriptor for the third cycle (Bologna WG on Qualifications Frameworks, 2005; European Commission, 2008).

4. Annex D - Full paper analysis

Ref.	Knowledge	Skills	Related key words	Roles/function	Delivery method(s)	Paper type	Other remarks
Cico et al. (2021)		Software Implementation, Usability and Value, Global Software Engineering (GSE), and Lean Software Startup are getting more common Skills in trends not taught yet: biology and computing, system of systems GSE and Lean Software Startups are emerging SE Trends, minimal researc h addressed them, with even less collaboration between industry and education.	Agile, development, prototype, industry practices, programming, practices, project management, teams, Kanban XP Scrum, human-centered, Test driven development, Prototype Lean Customer focus Innovation Entrepreneurship International focus (GSE) and ability to work in diverse teams		Project based learning (most common) Gamified learning Blended learning Experiential learning. Few considered the impact of the practical element of the course settings in delivering useful final products. The proposed models should take care that simulations pro- vide realistic, stakeholder participation in obtaining valid learning enhancement. Use of models (e.g. FOSS) and real life case studies were useful.	literature review. Reflection and discussion on industry engagement with education	Industry engagement and project based learning has high risk of being superficial and having potentially negative effects (e.g. lack of focus on quality of product in classroom setting)
Quezada-Sarmiento et al. (2018)	agile; business theory; business models; businesss model canvas; entrepreneurial culture; innovative culture; knowledge on business structures that make a business or a company productive; marketing and sales; organizational culture; human resources; finance.	entrepreneurship; testing and evaluation of software prototypes;	Kanban		Project based learning (most common)	Case study in Ecuador	One of the main challenges in software engineering is to find the correct entrepreneurship competencies that should be promoted when training professionals, once the latter have finished their studies and started working. Boosting and promoting creativity to generate improvements and innovations that meet the real needs of the software industry.
Pöll et al. (2018)	Software dev. for car drive system knowledge; Software dev. for aerospace industry; Banking & Insurance industry knowledge	Industry specific skills; Information Systems (IS) Support; IS Consulting; IS Operation; Data Analysis; Project Management; Innovation Management; Software Management; Process Optimization; Content Management; Software Application Training Provision; Maintenance & Repair; E-Commerce; Embedded Systems; Java Development; Infrastructure Web Development; Front- and Backend Web Development; Administration; Enterprise Specific Development; Object Oriented Development; Database Management; Testing; Requirements Analysis; Systems Architecture; Software Implementation; Development methods; Backend development; User Interface; Quality Assurance; Web Optimization; Customer Relations; Strategic Management; Supply Chains; Finance & Controlling; Sales; Microsoft Office skills; SAP customization; Business Intelligence;	XP	developer, IT security specialist, business and systems analyst, service desk agent, and project manager	Gamified learning Blended learning	text-mining approac h is used to analyze both job vacancies (in Germany) as well as scientific literature.	To build the re curriculum framework (fig.4 in the paper) "three categorizing approaches [were used]: (i) the Guidelines for Education in Business and Information Systems Engineering at Tertiary Institutions (Jung and Lehrer, 2017); (ii) the European e-Competence Framework (CEN, 2014); and (iii) the Skills Framework for the Information Age (SFIA Foundation, 2015)."
Beckett (2019)	The article is not specific about what knowledge is needed, but in general one could assume the knowledge needed is the knowledge required for the skills mentioned.	Internet of Things, data driven decision making & support, data-analytics, data integrity, machine learning, big data, automation, artificial intelligence, smart machines, smart transactions & system integrity, interconnected sensors, 'digital twins', data security (secure links), human-computer interface, organisational agility, new competency requirements, competency mapping. Communication. Collaboration skills.	Scrum, human-centered,			Literature review: Thirty-nine academic articles identified using the keyword competency combined with other terms like industry 4.0, work 4.0, agile and digital transformation	This paper explores challenges in the identification of current and future competency requirements and in competency mapping to facilitate agile operations. .

Ref.	Knowledge	Skills	Related key words	Roles/function	Delivery method(s)	Paper type	Other remarks
Shaba et al. (2019)	The article is not specific about what knowledge is needed, but in general one could assume the knowledge needed is the knowledge required for the skills mentioned.	Communication, teamwork and collaboration skills. Automation, personalised CAD, IT interface, Internet of Things, sensors, Artificial Intelligence, (collaborative) robots, Virtual Reality, Big Data, Digital Twins, Smartfactory, Smart devices (watch), Management systems, Social media, communication Devices, 3D technology, Augmented reality, Logistics (digitalizing), Cloud technology, On the machine built-in camera's/tablets, Barcoding, Exoskeleton, Automated warehouse, E-commerce, GEO-technology,	Test driven development,			The paper is based on 15 case studies carried out in Italian manufacturing companies and data was collected from 70 semi-structured interviews to relevant roles involved in the implementation of digital technologies	The aim of the paper is to explore how organizations are re-designed when Industry 4.0 technologies are implemented.
Garousi et al. (2018)	SE Economics, Mathematical foundations, Engineering foundations, SE process, SE Models and methods, SE Professional Practice, Computation foundations, quality management	Maintanance, Configuration manager, Requirements, Testing, Development, Design, Project manager	Prototype			Literature review (38 papers), and the data from the papers are summarized.	This paper explores the gap between software engineering (SE) education and industry needs. It identifies the different knowledge and skills in a two dimensional space: importance and gap (low importance- low gap, low importance- high gap, high importance- low gap, high importance- high gap). Many skills are in the last (high importance- high gap) category.
Zabavnik et al. (2019)	UML (Universal Modeling Language), quality managmen. the new development and testing processes in industry Application Lifecycle Management (ALM) tools (like Polarion, Doors, etc.) and use of version-control systems (Git, SVN	architecture, requriements, testing, development, programming. the new development and testing processes in industryApplication Lifecycle Management (ALM) tools (like Polarion, Doors, etc.) and use of version-control systems (Git, SVN). It	Lean			Literature review, mainly ISO standards, automotive SPICE standard and the tip of the V-model.	In this paper the automotive application development is inspected with HiL (hardware in the loop).
Albino et al. (2019)	The article is not specific about what knowledge is needed, but in general one could assume the knowledge needed is the knowledge required for the skills mentioned.	Big Data, Artificial Intelligence Nanotechnology. Robotization. Internet of Things. Augmented technology. Diigitalization. Mobil etechnologuies. Tablet + Smartphone applications. IT Infrastructure. Agile methodoloy. Data quality and integrity. Customer needs analysis. Mobile technology. Sensor and connectivity technology.	Customer focus			Systematic Literature Review. Finally 15 articles were examined in detail.	Earlier quality scientific studies found that companies going through a digital transformation struggle to deal with a resisting culture and the reluctance to share and collaborate. Furthermore, the business does not have the skills or resources needed and face a talent gap. This SLR investigates the results of earlier studies.
Reinhart et al. (2019)	statistical methods, numerical approaches	data management, collaboration, software engineering, software design, programming (R, SQL, C++, Clojure, Racket)	Innovation			Based on own experience about starting a STEM (data science and AI related) course, outcomes since 2015.	The aim of this paper is data science, statistics, which is related to Artificial Intelligence (AI). The paper shows the experience of a group, who intruduced SE for statisticans. The STEM course was delivered for MSc and PhD students with success.

Ref.	Knowledge	Skills	Related keywords	Roles/function	Delivery method(s)	Paper type	Other remarks
Licorish et al. (2016)		programming, SE	Entrepreneurship	programmers, team leads, admins; project managers, multiple roles (from the previous ones)		Experiments with test subjects were carried out with a specific release (1.0.1) of Jazz (based on the IBM Rational Team Concert TM (RTC)), a fully functional environment for developing software and for managing the entire software development process. In the test 1 261 practitioners' messages that were contributed in relation to 250 randomly selected software tasks were involved. The details of the quantititave analysis is discussed in subsection 5.2. Statistical and deeper content analysis methods were applied.	This paper examines the following questions: - How are software tasks distributed in a large software project, and how do team members participate in the different ecosystems of tasks? - Do the level and type of team members' engagement covary with the nature of the task they are performing?
Duan et al. (2020)	The article is not specific about what knowledge is needed, but in general one could assume the knowledge needed is the knowledge required for the skills mentioned.	Information systems technology. Security of IS. Trust of IS. Digital privacy. Information acquisition of IS. Process automation. Digital worksimilation techniques. Business analytics. Social networks. Cloud computing. Mobile computing. Virtual reality.Sensor embedding wearible devices. Telepresence systems. Robotic process automation. New mobile technology. Virtual offices. Smart devices. Telecommunication technology.				A systematic review is executed. of existing studies (finally 62 are identified) to identify critical issues adopting digital work in organizations.	This paper presents an integrated framework for better understanding for adopting digital work in organizations.
Sipior et al.	The article is not specific about what knowledge is needed, but in general one could assume the knowledge needed is the knowledge required for the skills mentioned.	Data quality. Data security. Data trust. Cloud computing. Machine learning. Deep learning. Neural networks. Statistics. Forecasting. Analytics. Software development. Atrificial Intelligence. Java, AWS, DevOps.					This paper describes a teaching case of a fictious company. The case introduces students to ShipIt2Me.com ("ShipIt2Me"), a fictitious American e-commerce company that developed an AI human resources recruiting tool to help it hire cloud computing talent. The teaching case summarizes AI concepts and the opportunity for students to examine the advantages and disadvantages of using AI tools in human resources recruiting.
Engelbrecht et al. (2018)	a multi disciplinary approach is needed as software environment becomes more complex	complex software systems	reflection, context specific competences			A discussion paper on changing education needs in software	context and comprehensive competences are needed. This is challenging
Günay et al. (2020)	Software development life cycle	software design	critical thinking. It must be domain specific			Case study of improving how to teach critical thinking to software students	In a very diverse college so methods should be useful in many contexts
Heintz et al. (2018)	teacher professional development, digital competence, programming, computational thinking	dealing with complexity; dealing with ambiguity and open problems; adapting solutions to new situations; evaluating own and other solutions; experimenting and troubleshooting;	have experience working with different types of problems and attitudes related to computational thinking; recognize computational thinking as a problem-solving process together with computers that are based on a set of concepts and attitudes; be able to assess his/her own level of computational thinking.			school age children but relevant insights	

Ref.	Knowledge	Skills	Related key words	Roles/function	Delivery method(s)	Paper type	Other remarks
Young Schmidt (2020)	Software Lifecycle; Course Project; Teamwork; Critical and Creative Thinking, , object-oriented software, Java, Junit,	planning before implementing, making software testable, maintaining strong communication among team members	communication skills,grit; communication and collaboration.		Replacing student-led review lectures with a comprehensive collaborative software engineering exercise to serve as a review of Computational science and engineering education (CS1) programming concept. Students engineer an application representative of real-world software		
Thorat et al. (2021)		logic building, problem solving, and debugging skill			This work identifies loopholes in existing method of teaching computer programming course. It is observed that if these skills are addressed properly then realistic improvement in programming skills of students can be achieved. We observed improvements in academic results of computer programming course after implementation of the proposed method. The approach proposed here can make learning computer programming a joyful experience for the students		review of one course mainly focussed on engineers; to retain interest programming must be taught
Ryan (2020)	Students show low awareness of ethics. .Need knowledge about nature of responsibilities to employer and society. Role of whistle blowing. Role of professional bodies and codes of ethics		critical thinking. There is a serious lack of professional ethics awareness and large variety of attitudes in terms of responses to ethical dilemmas students were provided). Educators should help students become reflective practitioners, committed to lifelong learning and self development and equipped to, as the ACM Code of Ethics and Professional Conduct says, 'contribute to society and to human well-being, acknowledging that all people are stakeholders in computing'	Role of software engineer is for wider society not just employer	quizes useful in ethics teaching as they anonymous and non threatening		critical paper written by very experienced educator based on teaching one course over 20 years, software profesional ethics (in Ireland); Be aware of conflicts between education and industry. Remember that industry can be in conflict wiht ethics. Educates students for wider spical awareness also.
Hoover et al. (2019)		Deep Learning; Machine Learning; Artificial Neural Network; Creative Artificial Intelligence; Generative Adversarial Neural Network	Specific AI skills will be needed in the future.		the use of deep learning in applications mimicking human creativity can serve the purposes of getting students excited about machine learning and also help enhance their core knowledge of programming and the utilization of standard library tools.	Case study	

5. Annex E - Summary of findings in the ACM library

Ref.	Knowledge	Skills	Important insight
Young Schmidt (2020). *Reviewing CS1 Materials through a Collaborative Software Engineering Exercise: An Experience Report*.	Software Lifecycle; Course Project; Teamwork; Critical and Creative Thinking, communication skills, object-oriented software, Java, Junit,	planning before implementing, making software testable, maintaining strong communication among team members	Replacing student-led review lectures with a comprehensive collaborative software engineering exercise to serve as a review of Computational science and engineering education (CS1) programming concept. Students engineer an application representative of real-world software
Porcheron, et al. (2018). *Voice Interfaces in Everyday Life*	AmazonEcho; Big data, conversational agent; conversational user interface; conversation analysis; intelligent personal assistants;	Technical skills on natural language processing Voice User Interfaces (VUI) . Talking to Computers. Studying Technology in the Home.	Future technical skills on the implementation of computer-human interaction.
Bragg et al. (2019). *Sign Language Recognition, Generation, and Translation: An Interdisciplinary Perspective*.	computer vision, computer graphics, natural language processing, human-computer interaction, linguistics	Technical skills on the implementation of human-computer interactions	Future technical skills on the implementation of computer-human interaction
Jacobs, et al. (2018). *Extending Manual Drawing Practices with*	Procedural art; generative art; programming;	The software engineer is an artist. Manage complex structures, automate processes, generalize and reuse operations,	Incorporation of soft and artistic skills in the software engineering process.

Artist-Centric Programming Tools.	computational geometry; machine learning	exploration and experimentation, reflection on aesthetic relationships and process, transform manual drawings, generative designs	
Heintz and Mannila (2018). *Computational Thinking for All – An Experience Report on Scaling up Teaching Computational Thinking to All Students in a Major City in Sweden.*	teacher professional development, digital competence, programming, computational thinking	dealing with complexity; dealing with ambiguity and open problems; adapting solutions to new situations; evaluating own and other solutions; experimenting and troubleshooting; grit; communication and collaboration.	have experience working with different types of problems and attitudes related to computational thinking; recognize computational thinking as a problem-solving process together with computers that are based on a set of concepts and attitudes; be able to assess his/her own level of computational thinking.
Hoover et al. (2019). *Deep Learning in the IT Curriculum*.	Deep Learning; Machine Learning; Artificial Neural Network; Creative Artificial Intelligence; Generative Adversarial Neural Network.	Extending the use of AI on more challenging scenarios	Specific AI skills will be needed in the future.
Yan et al. (2008). *The Internet of Things: From RFID to the Next-Generation Pervasive Networked Systems*	New knowledge on pervasive networked systems	The use of RFID technology within software applications	Vision of needed skills in pervasive networked systems of the future.
Reinfurt et al. (2016). *Internet of things patterns*.	Internet of Things;	constrained devices, intermittent connectivity, technological heterogeneity, or privacy and security concerns	building automation, industrial manufacturing, logistics and mobility, healthcare, or public utilities, for private consumers, businesses, or government.

			Device Gateway, Device Shadow, Device Wakeup Trigger, Remote Lock
Bertino (2016). *Internet of Things (IoT): Smart and Secure Service Delivery.*	Internet of Things; Applied Cryptography, Network Security.	Precision agriculture, environment monitoring, smart health, smart manufacturing, and smart cities.	Skills to combine and integrate various new technologies to achieve smart services.
Jonas et al. (2017). *Occupy the cloud: distributed computing for the 99%.*	Distributed Computing; AWS Lambda; PyWren.	Fault Tolerance, Simplicity	Skills to develop applications that operate across virtualised environments.

6. Annex F - Type of organisations with own demand for software skills

ICT organisations

- ICT – programming
  - These are organisations focused on programming activities (NACE J62.01). This includes writing, modifying and testing software.
- ICT – consultancy
  - These are organisations mainly focused on the planning and designing of computer systems and other consultancy. It is possible that an organisation offers software programming as part of their services.
- ICT - data processing, hosting, etc.
  - This group of organisations includes the provision of infrastructure for hosting, data processing services and related activities.
- ICT - web portals/ platforms
  - These are organisations that provide portals and platforms services.
- ICT - other companies
  - These are organisations that don't fall in the categories above. This can be for example organisations that focus on (cyber) security or the installation of systems including (off the shelve) software.

Non-ICT organisations

- Non-ICT - large/ multinational companies
  - Large organisations (over 250 people) outside ICT that have their own need for software roles and skills. These organisations typically have an ICT department that not only provides user support (helpdesk etc.), but also programmes and/or maintain software.
- Non-ICT - SME companies
  - These are companies smaller than 250 people outside ICT that have their own need for software roles and skills.
- Non-ICT - governmental organisations
  - These are non-profit, governmental or government related organisations with their own need for software roles and skills.
- Other
  - These are organisations that for some reason cannot be categorised in one of the other non-ICT groups.

7. Annex G - Overview of national labour market reports

1. Accenture (2021) Talent for Tomorrow -Reskilling to Power Ireland's Economy, https://www.accenture.com/_acnmedia/PDF-146/Accenture-Ireland-Skills-Report2020.pdf.
2. AICA, Anitec-Assinform, Assintel, Assinter Italia, and AgID (2018) Osservatorio delle competenze digitali 2018_ Professioni ICT, https://competenzedigitali.org/pubblicazione/.
3. AICA, Anitec-Assinform, Assintel, Assinter Italia, and AgID (2019) Osservatorio delle competenze digitali 2019_ Professioni ICT, https://competenzedigitali.org/pubblicazione/.
4. Bánszkiné dr. Verók, A, (2020) A munkaerőpiac, a szakképzés és a felnőttképzés összefüggései az informatikai ágazatban Csongrád-Csanád megyében, https://csmkik.hu/storage/documents/December2020/bzbjBvcOsf9xwzO6T9ei.pdf.
5. Bavarian Industry Association (2019) Arbeitslandschaft 2025, https://fks-plus.de/pdfs/Studie_Arbeitslandschaft-2025.pdf.
6. Bingöl, U., Mete, H. and Özkan, Y. (2019) Comparative qualitative analysis of Turkey and Estonia in the IT sector vacancies, Eastern Journal of European Studies, 10, 197–220, https://www.ceeol.com/search/article-detail?id=843340.
7. Bitkom (2019) AKTUELLE UND ZUKÜNFTIGE EINWANDERUNGSBEDARFE VON IT-FACHKRÄFTEN NACH DEUTSCHLAND: Wie attraktiv sind die Bundesländer?, https://www.bitkom-research.de/de/Studie-Fachkraeftesituation-IT-Berufe-2019.
8. Bitkom (2020) 86.000 offene Stellen für IT-Fachkräfte, https://www.bitkom.org/Presse/Presseinformation/86000-offene-Stellen-fuer-IT-Fachkraefte.
9. Bitkom (2021) Erwerbstätige in der ITK-Branche, https://www.bitkom.org/sites/default/files/2021-01/erwerbstatige_2017_2021.pdf.
10. CA-ICT (2019) ICT Labour Market and Top Sectors, https://www.caict.nl/wp-content/uploads/2019/09/190703-Eindrapport-Arbeidsmarktonderzoek-ICT-met-topsectoren-Berenschot-kwalitatief-1.pdf.
11. Cedefop (2015) Malta Skill Supply and Demand up to 2025, https://www.cedefop.europa.eu/en/publications-and-resources/country-reports/malta-skills-forecasts-2025.
12. CentERdata (2020) Arbeidsmarktonderzoek ICT met topsectoren 2020, https://www.caict.nl/wp-content/uploads/2020/11/200720-Vervolgonderzoek-Arbeidsmarkt-ICT-met-topsectoren-2020-CentERdata-eindrapport.pdf.
13. Codecool (2017) Pályakezdő informatikusok kilátásai a foglalkoztatók szemszögéből. Codecool article, 19. februar, https://codecool.com/hu/blog/codecool-kutatas-palyakezdo-informatikusok-kilatasai-a-foglalkoztatok-szemszogebol/, accessed 13 May 2021.
14. Codecool (2019) Scaling up - How can Romania become the strongest technology hub in Europe, https://codecool.com/wp-content/uploads/2019/10/studiu-codecool.pdf.
15. Codecool (2020) The Future Is IT, https://codecool.com/wp-content/uploads/2020/10/the-future-is-it-full-2020.pdf.

16. Coursera (2020) Coursera 2020 Impact Report, https://about.coursera.org/press/wp-content/uploads/2020/09/Coursera-Impact-Report-2020.pdf.
17. CSMKIK (2020) A munkaerőpiac, a szakképzés és a felnőttképzés összefüggései az informatikai ágazatban Csongrád-Csanád megyében, https://csmkik.hu/storage/documents/December2020/bzbjBvcOsf9xwzO6T9ei.pdf.
18. Cyber Ireland (2021) Cyber Security Skills Report 2021 – National Survey, https://www.cyberireland.ie/wp-content/uploads/2021/02/Cyber-Ireland-Skills-Report-2021.pdf.
19. DEKRA Akademie GmbH (2019) Arbeitsmarkt-Report 2019, https://www.dekra-akademie.de/media/dekra-arbeitsmarkt-report-2019.pdf.
20. Department of Education (2020) Ireland's National Skills Strategy 2025, https://www.education.ie/en/publications/policy-reports/pub_national_skills_strategy_2025.pdf.
21. Digital Innoation Hub Slovenia (2020) Oblikovanje predlogov vsebin za študijske programe, https://dihslovenia.si/assets/images/OBLIKOVANJE-PREDLOGOV-VSEBIN-ZA-%C5%A0TUDIJSKE-PROGRAME-Poro%C4%8Dilo-priloga.pdf.
22. Digital Innovation Hub Slovenia (2021) Napovedovanje potreb po kadrih na področju digitalnih profilov, https://dihslovenia.si/assets/images/20210215_Napovedovanje-potreb-po-kadrih-na-podro%C4%8Dju-digitalnih-prodilov-poro%C4%8Dilo_v2.pdf.
23. eSkills (2017) Malta ICT Skills Audit 2017, https://eskills.org.mt/en/Documents/Eskills_audit.pdf.
24. Estonian Qualification Authority (2019) Job vacancy prognosis 2019-2027, https://oska.kutsekoda.ee/wp-content/uploads/2020/05/T%C3%B6%C3%B6j%C3%B5%C3%B5uprognoosi-l%C3%BChiaruanne_veeb.pdf.
25. Estonian Qualification Authority (2020) The National OSKA report, https://oska.kutsekoda.ee/wp-content/uploads/2021/01/OSKA-ulevaade-valdkonnaspetsiifiliste-IKT-oskuste-vajadusest_16.06.2020.pdf.
26. European Commision (2019) Analysis of shortage and surplus occupations based on national and Eurostat Labour Force Survey data 2019, https://ec.europa.eu/social/main.jsp?catId=738&langId=en&pubId=8269&furtherPubs=yes.
27. European Commision (2019) Monitoring Progress in National Initiatives / Country Report / Syprus, https://ec.europa.eu/information_society/newsroom/image/document/2019-32/country_report_-_cyprus_-_final_2019_0D322D64-DDF7-AC6E-D1E61A12F0FD2A0D_61231.pdf.
28. European Commision (2020) Analysis of shortage and surplus occupations 2020, https://op.europa.eu/en/publication-detail/-/publication/22189434-395d-11eb-b27b-01aa75ed71a1/language-en.
29. European Commission (2017) Digital Skills and Jobs Conference – Digital Opportunities for Europe, https://digital-strategy.ec.europa.eu/en/library/digital-skills-and-jobs-conference-7-december-2017.
30. European Commission (2018) Digital Economy and Society Index (DESI)1, https://ec.europa.eu/information_society/newsroom/image/document/2018-20/el-

desi_2018-country-profile_eng_B43FFD54-01E0-8E08-F2E10DCA6B668AAE_52218.pdf.
31. European Commission (2019) Monitoring Progress in National Initiatives / Country Report / Greece, https://ec.europa.eu/information_society/newsroom/image/document/2019-32/country_report_-_greece_-_final_2019_0D30BA6D-A5FB-5608-9F34E267E7515DDE_61207.pdf.
32. Federal Employment Agency (BA) (2019) IT-Fachleute, https://statistik.arbeitsagentur.de/DE/Statischer-Content/Statistiken/Themen-im-Fokus/Berufe/Generische-Publikationen/Broschuere-Informatik.pdf.
33. Foundation for Family Businesses (2018) Fachkräfte für die digitale Transformation - Arbeitsmarktsituation und Gestaltungsmöglichkeiten, https://www.familienunternehmen.de/media/public/pdf/publikationen-studien/studien/fachkraefte-fuer-die-digitale-transformation/Fachkraefte-fuer-die-digitale-Transformation_Stiftung-Familienunternehmen.pdf.
34. German Economic Institute (2020) MINT-Frühjahrsreport 2020, https://www.gesamtmetall.de/sites/default/files/downloads/mint-fruehjahrsreport_2020.pdf.
35. Government of Ireland (2019) Future Jobs Ireland 2019, https://www.enterprise.gov.ie/en/Publications/Publication-files/Future-Jobs-Ireland-2019.pdf.
36. Government of Ireland (2019) Technology Skills 2022 Ireland's Third ICT Skills Action Plan, https://www.education.ie/en/Publications/Policy-Reports/technology-skills-2022.pdf.
37. Government of Ireland (2021) Statement of Strategy 2021-2023, https://www.gov.ie/en/organisation-information/3f066-statement-of-strategy-2021-2023/.
38. IKT Horizontalna mreža, SRIP PMIS (2019) Razvoj človeških virov, Katalog IKT kompetenc, vmesno poročilo, internal report.
39. IT for Business (2020) Marché de l'emploi IT et rémunération des métiers de l'IT en 2021, 25 September, https://www.itforbusiness.fr/mache-de-lemploi-it-et-remuneration-des-metiers-de-lit-en-2021-40931#:~:text=D'ailleurs%2C%2086%25%20des,de%202%20mois%20en%202020.&text=Autrement%20dit%2C%20les%20Data%20Analyst,une%20p%C3%A9nurie%20de%20talents%20persistante, accessed 15 May 2021.
40. Jelenkori társadalmi és gazdasági folyamatok (2019) Informatikai alkalmazások és IT-szakemberigény összefüggései a magyarországi vállalkozások körében, 15 June, http://www.analecta.hu/index.php/jelenkori_tars-gazd_folyamatok/article/view/33169, accessed 13 May 2021.
41. LINDEN-IT (2019) ICT Labour market report Dutch market, https://linden-it.com/arbeidsmarktrapportage-ict-in-nederland/.
42. Manpower Group (2021) Renouveler, réorienter, redéployer : les 3 "r" de la révolution des compétences 2.0, https://futureofwork-manpowergroup.fr/livres-blancs/revolution-des-competences-2-0/.
43. Michael Page (2021) Marché de l'emploi IT : quels sont les nouveaux enjeux de recrutement?, https://www.michaelpage.fr/advice/tendances-de-

march%C3%A9/march%C3%A9-de-l%E2%80%99emploi-it-quels-sont-les-nouveaux-enjeux-de-recrutement.
44. Nagyné Halász, Z. and Miklós, G. (2018) IT szakmák és kompetenciák a felsőoktatás szemszögéből, LOGISZTIKA – INFORMATIKA – MENEDZSMENT, 3(1), 102–115, https://www.researchgate.net/publication/333143155_IT_szakmak_es_kompetenciak_a_felsooktatas_szemszogebol.
45. National Statistics Office Malta (2021) Labour Force Survey: Q4/2020, https://nso.gov.mt/en/News_Releases/Documents/2021/03/News2021_054.pdf.
46. No Fluff Jobs (2020) IT Job Market in Poland 2020, https://nofluffjobs.com/insights/report-it-job-market-in-poland-2020-salaries-specializations-and-job-requirements/.
47. Onisep (2020) LES MÉTIERS ET L'EMPLOI DANS L'INFORMATIQUE ET LES RÉSEAUX, 28 September, https://www.onisep.fr/Decouvrir-les-metiers/Des-metiers-par-secteur/Informatique-et-reseaux/Les-metiers-et-l-emploi-dans-l-informatique-et-les-reseaux, accessed 17 May 2021.
48. Programozd a jövöd (2021) Adat monitorozás és trendelemzés készítése, https://programozdajovod.hu/files/Portal/G311_Munkaeropiaci_6os_zaro_tanulmany.pdf.
49. Programozd a jövöd (2021) Ágazati digitalizációs mérési módszertan kidolgozása, tesztelése és alkalmazása, https://programozdajovod.hu/files/Portal/G311_Agazati_6.mrfdk_Osszefoglalo_jelentes_es_javaslatok.pdf.
50. Programozd a jövöd (2021) GAP-elemzés: a munkaerő-piaci keresleti kutatás és a kínálati prognózis eredményeinek összehasonlítása, https://programozdajovod.hu/files/Portal/G311_Munkaeropiaci_%205os_osszegzo_tanulmany.pdf.
51. Programozd a jövöd (2021) IKT szakemberként dolgozó munkavállalók kvantitatív felmérése, https://programozdajovod.hu/files/Portal/G311_Munkaeropiaci_4es_zaro_tanulmany.pdf.
52. Programozd a jövöd (2021) Informatikai végzettségre, kompetenciákra vonatkozó munkaerőpiaci igények felmérése, https://programozdajovod.hu/files/Portal/G311_Munkaeropiaci_1es_zaro_tanulmany.pdf.
53. Research Centre PRAXIS (2018) Labour force and skills needs in cyber security in Estonia, http://www.praxis.ee/wp-content/uploads/2018/04/K%C3%BCberturbe-uuring.-L%C3%BChikokkuv%C3%B5te_eng.pdf.
54. Solas (2020) Solas Monitoring Ireland's Skills Suply 2020, https://www.solas.ie/f/70398/x/4b784bbda9/monitoring-irelands-skills-supply-2020.pdf.
55. Srednja trgovska šola Ljubljana (2018) Priloga 3_Obrazec za pripravo programov usposabljanj, http://sts-lj.splet.arnes.si/files/2018/11/13_Spletni-programer-%E2%80%93-nadgradnja-e-ve%C5%A1%C4%8Din.pdf.
56. STEP-Wise (2020) Custom software development trends 2021, 7 January, https://stepwise.pl/2021/01/07/custom-software-development-trends-for-2021/?gclid=EAIaIQobChMIw6zg2uWb8AIV4oBQBh1qiQS9EAAYASAAEgK6_PD_BwE, accessed 25 April 2021.

57. The Cyprus Computer Society (2019) Cyprus ICT 2019-2021 Forecast and 2018 Analysis, https://ccs.org.cy/assets/uploads/IDC%20Report/ICT%20CYPRUS%20REPORT%202019.pdf.
58. Titko, J., Smatkova, I. and Cerkovskis, E. (2016) Demand for IT Students in Latvian Labour Market: Viewpoint of Employers, https://www.researchgate.net/publication/312532898_Demand_for_IT_Students_in_Latvian_Labour_Market_Viewpoint_of_Employers.
59. Kovács Balázs, B. (2017) Az informatikai szakmacsoport munkaerőpiaci helyzete: Elemzés statisztikai és empirikus adatok vizsgálatára támaszkodva, TUDÁSMENEDZSMENT, 18(1), 87–102, https://www.researchgate.net/publication/323152878_Az_informatikai_szakmacsoport_munkaeropiaci_helyzete_Elemzes_statisztikai_es_empirikus_adatok_vizsgalatara_tamaszkodva_2017_Szerzo_Benkei-Kovacs_Balazs_In_TUDASMENEDZSMENT_181_pp_87-102.
60. UWV (2019) Ict-beroepen: Factsheet arbeidsmarkt, https://www.uwv.nl/overuwv/Images/factsheet-ict-beroepen-2019.pdf.
61. World Economic Forum (2020) The Future of Jobs Report 2020, http://www3.weforum.org/docs/WEF_Future_of_Jobs_2020.pdf.
62. YER Technology (2019) The WAR on TALENT continues, https://www.yer.nl/8152454/Arbeidsmarktrapport-2019.html.
63. Zavod Republike Slovenije za zaposlovanje (2020) Napovednik zaposlovanja 2020/II, https://www.ess.gov.si/_files/13704/Porocilo_Napovednik_zaposlovanja_2020_II.pdf.
64. Zavod Republike Slovenije za zaposlovanje (2021) Mladi in trg dela, https://www.ess.gov.si/_files/14103/Analiza_Mladi_in_trg_dela_2021.pdf.

8. Annex H Overview of national databases

1. Emplois Informatiques (2020) JobBoard for IT, https://www.emplois-informatique.fr/offres-emploi/technicien-bureau-d-etude.
2. Federal Employment Agency (2021) Eckwerte Arbeitsmarkt, https://statistik.arbeitsagentur.de/DE/Navigation/Statistiken/Interaktive-Angebote/Dashboard-Eckwerte-Arbeitsmarkt/Dashboard-Eckwerte-Arbeitsmarkt-Nav.html.
3. Federal Employment Agency (2021) Faktencheck zum Arbeitsmarkt, https://arbeitsmarktmonitor.arbeitsagentur.de/faktencheck/fachkraefte/tabelle/515/91755/0/?r=&b=&o=indikatoren.
4. Hays Holding GmbH (2021) Fachkräfte-Index - Information Technology, https://www.hays.de/personaldienstleistung-aktuell/fachkraefte-index-information-technology.
5. MeetFrank (2019) ICT development jobs prediction, Lithuania, https://meetfrank.com/blog/meetfrank-insights/software-development-jobs-in-lithuania-all-you-need-to-know/.
6. NL CA-ICT (2021) Inflow ICT Students (by type) in Dutch market, https://pr-edict.nl/ict-onderwijs.
7. NL CA-ICT (2021) Number of ICT jobs by Profession, by NL region, https://pr-edict.nl/ict-arbeidsmarkt.
8. NL CA-ICT (2021) Top 25 Personal factor Knowledge & Skills in ICT Vacancies, https://pr-edict.nl/ict-vacatures.
9. OECD (2018) Skills for jobs, https://www.oecdskillsforjobsdatabase.org/data/country_notes/Latvia%20country%20note.pdf.
10. Osservatorio delle Competenze Digitali (2021) Developer, https://competenzedigitali.org/scheda-professione/developer/.
11. Osservatorio delle Competenze Digitali (2021) Devops Expert, https://competenzedigitali.org/scheda-professione/devops-expert/.
12. Osservatorio delle Competenze Digitali (2021) Digital Media Specialist, https://competenzedigitali.org/scheda-professione/digital-media-specialist/.
13. Osservatorio delle Competenze Digitali (2021) Solution Designer, https://competenzedigitali.org/scheda-professione/solution-designer/.
14. Osservatorio delle Competenze Digitali (2021) Test Specialist, https://competenzedigitali.org/scheda-professione/test-specialist/.
15. POLE EMPLOI (2021) Enquête Besoins en Main-d'Œuvre, https://statistiques.pole-emploi.org/bmo/bmo?fe=M1Z80&la=0&pp=2021&ss=1.
16. Research Centre for Education and the Labour Market (ROA) (2020) ROA statistics, https://roastatistics.maastrichtuniversity.nl/AIS/home.aspx.
17. Statbel Belgium Government (2021) Number of ICT jobs by profession, https://statbel.fgov.be/nl/nieuws/cijfers-beeld-ict-specialisten-op-de-belgische-arbeidsmarkt.
18. Statistični urad Republike Slovenije (2021) Recruitment of ICT experts and education of employees for acquiring ICT skills from 2018 - 2021, https://pxweb.stat.si/sistat/sl.
19. Statistični urad Republike Slovenije (no date) Standard Classification of Occupations, https://www.stat.si/skp/Esearch.aspx.

20. Zavod Republike Slovenije za zaposlovanje (2020) Vacancies in the field of computer science, programming and IT in the period 2018 - 2021, Slovenia, https://www.ess.gov.si/trg_dela/publicistika/letna_porocila.

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