D2.1
KNOWLEDGE BANK
FIRST VERSION
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D2.1 – KNOWLEDGE BANK

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DigiWind

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Executive summary

The Knowledge Bank: purpose and methodologies

Primary users of the Knowledge Bank are education professionals looking to develop and improve education offerings in the wind and energy systems sector and digitalisation. The purpose of the Knowledge Bank is to provide information and guidance that can help users tailor their education offerings in terms of target groups, scope, and training formats. The Knowledge Bank provides information in terms of demand for digital skills, gaps in the current education offers, and preferred training formats.

The digital objects included in the Knowledge Bank comprise of:

- Data from surveys and interviews;
- Database with overview of existing course offerings from the DigiWind HEI (Higher Education Institution) partners; and
- Analysis from the collected primary data.

The primary target respondent group of the Knowledge Bank data collection activities are wind and energy systems industry professionals working in digitalisation-related fields, with substantial technical leadership or hiring experience. The second target group for Knowledge Bank data collection is the "learners" – people currently enrolled in an educational program, are looking to enhance their skills, and/or want to improve their qualifications, regardless of their experience level.

Quantitative and qualitative data from both target groups was collected through surveys, interactive polls, and interviews. In addition, an overview of the existing education offerings from the DigiWind HEI partners was collected to identify gaps between training demand and supply. As per the time of completion of the present report, the information collected included:

- 74 responses from a survey focused on wind and energy systems professionals (also referred to as employer-oriented survey);
- 108 responses from a learners-oriented survey;
- Accumulated responses from 4 rounds of interactive polling sessions;
- Results from six semi-structured interviews;
- A database of existing course offerings at the DigiWind HEI partners – covering a total of over 100 unique courses

Main takeaways

- In modern wind and energy systems engineering, digital skills are fundamental skills in line with mathematics.
- Programming and software development skills are essential! However, what we need is skills that go beyond scripting: code documentation, version control, reusability, modularity, performance optimization.
- We need advanced digital skills AND domain-related knowledge. Domain knowledge is essential for properly applying digital skills to actual problem solving and obtaining insights from the results.
- To get a meaningful improvement in the skills, we need more substantial training (longer courses with more efforts). Most people interviewed suggested going for more extensive training programs.
- Some skills are given as less important, but this is highly specific for the job profiles we consider. As a special example, Cyber Security skills are deemed less critical, but the interviews uncovered that this is because Cyber Security should be a matter for specialist jobs and not the general-purpose engineers. The latter should be aware of the challenges and avoid threats, but not develop solutions themselves.
- The training formats need to be tailored to the life reality of the participants. Proper time needs to be allocated, including potential absence from daily work tasks. It may need to be country-specific due to different work-life balance in different countries.
- Out of the two most sought-after skills (numerical simulations and software engineering), there is far less existing education offers on the latter (especially for LLL).

Action points towards the next version of the Knowledge Bank

- Tailoring interview questions to course topics beyond software engineering
- A different survey and interview track on digital methods for training delivery
- Consider “train the trainers” education activities
- Action plan on boosting survey responses and obtaining more uniform geographical distribution of responses

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Definitions, Acronyms and Abbreviations

Acronym/ Abbreviation	Title
HEI	Higher Education Institution
LLL	Lifelong learning

1. Introduction: purpose, scope and structure of the knowledge bank

Purpose and goals

The DigiWind project aims at developing high-quality education offerings that contribute to closing the gap between demand for, and availability of, wind and energy systems professionals with advanced digital skills. One of the first steps towards fulfilling such ambitions is mapping the existing skills gaps, and identifying concrete industry needs that can be addressed by new training activities. The Knowledge Bank provides information in terms of the wind and energy systems sector's demand for digital skills, gaps in the current education offers, and preferred training formats.

Primary users of the Knowledge Bank are education professionals looking to develop and improve education offerings in the wind and energy systems sector and digitalisation. The purpose of the Knowledge Bank is to provide information and guidance that can help users tailor their education offerings in terms of target groups, scope, and training formats.

Types of information in the knowledge bank

- Data from surveys and interviews;
- Database with overview of existing course offerings from the DigiWind HEI (Higher Education Institution) partners; and
- Analysis from the collected primary data.

Scope and target groups for data collection

The primary target respondent group of the Knowledge Bank data collection activities are wind energy industry professionals working in digitalisation-related fields, with substantial technical leadership or hiring experience.

The second target group for Knowledge Bank data collection is the "learners" – people currently enrolled in an educational program, are looking to enhance their skills, and/or want to improve their qualifications, regardless of their experience level.

Quantitative and qualitative data from both target groups was collected through surveys, interactive polls, and interviews. In addition, an overview of the existing education offerings from the DigiWind HEI partners was collected to identify gaps between training demand and supply.

To ensure consistency, all data-collection activities use common skills definitions as provided in Table 1. These 12 categories give a summarized representation of the Key Capacity Areas from the Digital Europe Programme (DEP), shown on Figure 1. The categories are tailored to the specifics of the Wind Energy Systems technology field. Furthermore, Figure 1 refers to several domain areas, as one additional goal of the Knowledge Bank is to link the advanced digital skills with the domain areas where such skills are most essential.

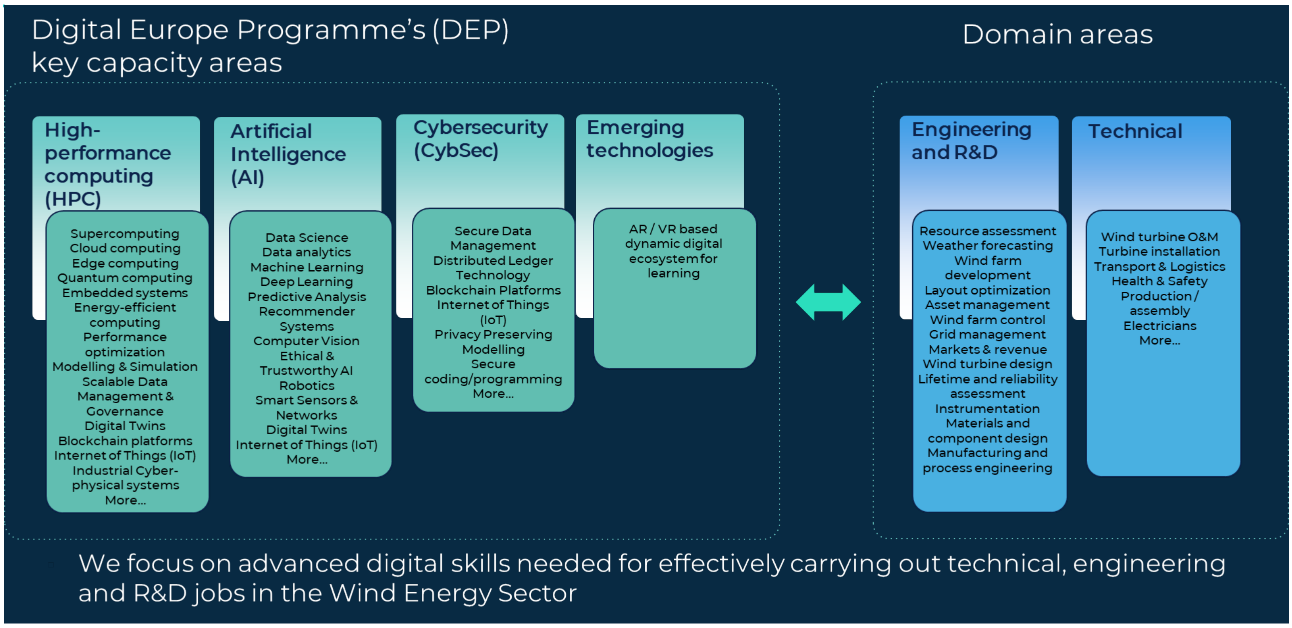

Figure 1 Key Capacity Areas from the Digital Europe Programme.

Table 1 List of digital skills categories used in the Knowledge Bank.

Digital skills categories:
High Performance Computing (HPC) and CPU and GPU applications
Scientific programming and software development
Generative AI and Large Language Models
Data engineering, semantics, interoperability and quality assurance
Machine learning, deep learning and data science
Advanced digital tools for research and innovation communication
Robotics and autonomous systems
IoT, sensors technology, Extended Reality
Blockchain technology and applications
Cyber security
Cloud computing
Numerical analysis, simulation, optimisation, modelling tools
Others

Overview of data links

The complete datasets and analyses are made accessible to all DigiWind partners in the project repository hosted on Teams. Summary of the methodologies and analyses of results are presented in this report as well as in multiple conference and event presentations.

2. Data collection methodologies

This section describes the procedures for data collection. Sections 2.1 to 2.3 focus on the primary data collection from external respondents through surveys and interviews, while Section 2.4 describes the data collection process for existing course offerings.

2.1. Theoretical framework

This section of the report outlines the methodologies and theoretical frameworks employed in data collection, to explore the perspectives of students and companies in the wind industry regarding educational needs and skills gaps. The description focuses on the data collected from individuals, coming primarily from organizations external to the DigiWind consortium. We also collected data on existing course offerings within the DigiWind consortium with a separate methodology – the reader is referred to Section 2.4 for further details.

The study utilises a combination of quantitative and qualitative methods. The various data collection activities where external respondents are involved are outlined in Figure 2.

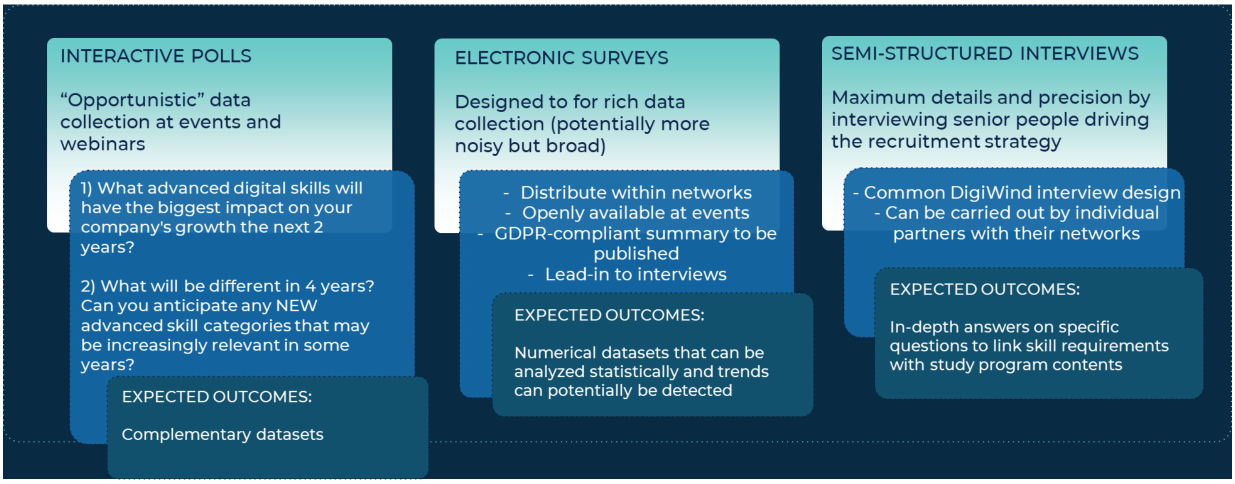

Figure 2 Overview of Knowledge Bank activities on data collection from external respondents.

A qualitative research methodology is employed to gain a deeper, more nuanced understanding of the individual and collective perspectives of students and companies. This approach includes semi-structured interviews and focus groups.

Semi-Structured Interviews: These interviews, guided by open-ended questions, explore the personal experiences and opinions of students and employers. They are essential for understanding how individuals construct their understanding of the skills needed in the wind industry through their personal experiences and social interactions.

Focus Groups: Focus group discussions will enable collective views to emerge, reflecting the social construction of knowledge and perceptions among groups of students and industry professionals. These discussions are particularly valuable for understanding how collective opinions are formed and shared in the context of wind industry education and skill requirements. The focus groups may be assembled from internal (to the consortium) participants such as students or teachers or may be a group of external stakeholders.

To collect sufficient primary data, multiple partners are involved in collection of both quantitative and qualitative data. This poses challenges in ensuring consistency between the responses collected by different partners, especially with respect to conducting interviews. To ensure maximum consistency between the interview outcomes and trace any discrepancies, the following measures were taken:

- A common interview guide was developed
- Common reporting schema with six key summary points to be filled in by the interviewers
- A common step-by-step procedure in conducting the interviews was outlined.
- All interviews were digitally recorded and automatically transcribed.

2.2. Quantitative data collection

Types of quantitative data collection activities considered

- Online surveys: designed for rich, quantitative data collection. Potentially noisier data but providing a broad picture and results allowing quantitative comparison.

- Interactive polls: similarly providing quantitative data but collected in more "opportunistic" settings with less opportunity for the respondents to get acquainted with the context and definitions.

Definitions

Employers: Professionals with job responsibilities related to the process of hiring new employees. Adopting a broader definition, we consider as being part of the group all people that have insights on the skills required for the colleagues in their team. This places people like technical leads in the group, besides HR specialists and team managers.

Trainers: Professionals that deliver training or produce training content.

Learners: people currently enrolled in an educational program or looking to enhance their skills or improve their qualifications, regardless of their experience level.

Learning formats: Means of interaction between trainers and learners, teaching methods, and facilities/devices.

Skills: we use a list of advanced digital skills categories as outlined in Table 1 List of digital skills categories used in the Knowledge Bank. (and reprinted below).

Digital skills definitions:
High performance Computing (HPC) and CPU and GPU applications
Scientific programming and software development
Generative AI and Large Language Models
Data engineering, semantics, interoperability and quality assurance

Machine learning, deep learning and data science
Advanced digital tools for research and innovation communication
Robotics and autonomous systems
IoT, sensors technology, Extended Reality
Blockchain technology and applications
Cyber security
Cloud computing
Numerical analysis, simulation, optimisation, modelling tools
Others

Purpose and expected outcomes

The primary advantage of surveys is the possibility to quickly collect quantitative data that can be used to make quantitative analysis and objective comparisons. Large data quantity is essential for obtaining quality statistics, reducing biases, and making data slices (subsets) suitable for more detailed analysis. We therefore target more than 100 respondents (with 74 responses collected as of June 28th, 2024) The target groups and the expected outcomes from the survey data collection activities are outlined in Table 2.

Table 2 Themes governing the objectives of the DigiWind surveys

Theme	Target groups	Expected outcomes
Skills gap	Employers Trainers Learners (professionals and students)	Understand what digital skills are considered relevant by industry, in terms of new employee profiles and upskilling the existing workforce.
Preferred training formats	Employers Trainers Learners (professionals and students)	Map the preferred training/learning formats according to target groups, skills and education categories.
The learner's perspective	Learners	Understand what new skills potential learners would like to acquire, and if there is any mismatch with what employers consider relevant.

Completing the above table has resulted in the need of having two surveys – one focusing on the employers and trainers, and a second one focusing on the learners.

The surveys were implemented through the EU Survey platform (ec.europa.eu/eusurvey), and the versions distributed by June 2024 are included in Appendix B.

The survey questions focusing on quantifying the skill gap are formulated as a prioritization task. The respondents are required to prioritize up to three items (e.g., digital skills categories), giving them ranking in order of priority from 1 (highest) to 3 (lowest) – as illustrated in Figure 3. With such questions, the main goal is to establish differences between categories rather than evaluate each category independently. When necessary to evaluate each category independently, a different question format was used: the respondents were asked to rate each category (each corresponds to a row in the survey question) with a score between 5 (highest) to 1 (lowest). Such an approach was used for example for the questions on rating the suitability of training methods for delivering education in advanced digital skills (Figure 4). There are several additional questions relating to the respondents (job position, hiring and training experience) which are used for filtering and cross-section of the data. Specifically for the learners-oriented survey, data was collected by visiting classes at universities, and asking the class participants to answer the survey.

12 In your view, how important will digital competencies be when hiring ***new colleagues*** in the near future? Please select ***up to three*** competencies that you find most important. Rank your choices in order of importance by ticking the appropriate box.

between 1 and 3 answered rows

	Rank 1 (top)	Rank 2	Rank 3
Numerical analysis, simulation, optimisation, modelling tools	☑	☐	☐
Advanced digital tools for research and innovation communication	☐	☐	☐
Cloud computing	☐	☐	☐
Blockchain technology and applications	☐	☐	☐
Robotics and autonomous systems	☐	☐	☐
Data engineering, semantics, interoperability and quality assurance	☐	☐	☑
High-performance computing (HPC) with CPU and GPU applications	☐	☐	☐
IoT, sensors technology, Extended Reality	☐	☐	☐
Machine learning, deep learning and data science	☐	☐	☐
Cyber security	☐	☐	☐
Scientific programming and software development	☐	☑	☐
Generative AI and Large Language Models	☐	☐	☐

Figure 3 Illustration of a survey question with skills ranking.

18 What types of ***training facilitation*** do you find suitable for providing your current colleagues with new digital skills as part of a life-long learning training process?

	Highly suitable	Suitable in many cases	Partially suitable	Not suitable in most cases	Not suitable at all
Online educational programs	○	○	○	○	○
Short, standalone online courses	○	○	○	○	○
On-site in-person training	○	○	○	○	○
Off-site courses (e.g., at University)	○	○	○	○	○
Virtual training (extended reality, simulators and similar)	○	○	○	○	○

Figure 4 Illustration of a survey question where independent scores were sought for each category.

Interactive polls

The interactive polls considered two questions:

1) What advanced digital skills will have the biggest impact on your company's growth in the next 2 years?
2) What will be different in 4 years? Can you anticipate any NEW advanced digital skill categories that may become increasingly relevant?

The first poll question was designed to collect information like the survey questions about prioritizing digital skills. Hence, the skills list used in the question mirrored the skills list definition described in Table 1, however in a shortened form to make it

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suitable for interactive displaying. Figure 5 shows an example of responses collected to question 1).

Figure 5 Example interactive poll result view

2.3. Qualitative data collection through interviews

As with all data collection activities in the Knowledge Bank, the interviews are designed based on objectives formulated by the DigiWind partners. These objectives govern the scope of the interview questions. Further, the summary notes that the interviewers must fill after the interview are aimed at clarifying the respondent's answers with respect to the learning objectives of the interview.

Each in-depth interview takes approximately one hour to complete, which poses bandwidth (resource) limitations on the total number of interviews that can be conducted. To enable collecting more results, multiple DigiWind partners conduct interviews. Proper analysis of the results requires consistency in the interview procedures. Therefore, a point-by-point interview procedure and an interview guide with a concrete list of questions are developed. The remainder of this section gives an overview of the interview objectives, the procedure, and the summary questions. The full interview guide is provided in Appendix A.

Purpose and objectives of the interviews

1. Point out the specific gaps in advanced digital skills, and how are these gaps distributed among the workforce
2. Identify concrete measures (**course topics, training formats, collaboration models**) that should be implemented to close these gaps
3. Anticipate how the skill requirements will change in the next 5 to 15 years

Procedure for conducting the interviews

1) Fill in the name and organization of the person you want to approach, in a common online file. In this way, we keep track of all people being interviewed and avoid repeated inquiries to the same people.

2) Send a reach-out e-mail, including an invitation for an in-depth interview and clarification that the online survey should be answered as a lead-in to the interview. A suggested e-mail draft is distributed to partners.

3) Schedule interview. Normally there is a one-hour online Teams meeting.

4) One day before the interview, send a reminder e-mail to fill in the survey.

5) Prior to the interview, fill in the person's responses to four of the survey questions in a PowerPoint document. A PowerPoint template is provided.

6) Conduct the interview, following the guide document. Record the interview and take notes along the way, filling in the key summary questions provided in the last table in the guide. Display the supplementary PowerPoint file as background for the first 3-4 questions.

7) Upload the recording and the summary notes into a separate Teams folder

Interview Guide

Consisting of brief instructions and 16 questions. Available in Appendix A.

Reporting schema: Key summary points for the interviewer

Q1. List any concrete course topics or training gaps that the respondent has outlined:

Q2. Did the respondent suggest any new skills that will be relevant in 5+ years?

Q3. Any concrete preferred training format (location, methods, duration)?

Q4. Is the company willing to invest in advanced digital skills?

Q5. What is the company's preferred collaboration model with education providers (such as those in the DigiWind consortium)?

Q6. Did the respondent suggest any follow-up activities?

2.4. Creating an inventory of existing courses

2.4.1. Introduction

Part of the knowledge bank is the inventory of existing courses in wind and energy systems, and more specifically the digitals skills in existing wind and energy systems educations. A template has been created in excel for the inventory. This template incorporates the main aspects needed to assess the status of the digital skills covered in current wind and energy system education. Each HEI has submitted their courses that they felt were relevant for the inventory.

This chapter will begin with an explanation of the information gathered and includes several examples of how the data is entered into the inventory. Several analyses have been made as well; these will be discussed in the other parts of this chapter. The analyses are given per type of education: MSc, Master or Lifelong Learning (LLL). The difference between a MSc and a Master programme is that the latter is part-time education with a vocational dimension, that a MSc does not have. A Master consists of 60 ECTS and a MSc of 120 ECTS. To be able to join a Master programme a participant must have several years of relevant work experience as well as a Bachelor's Degree. Lifelong Learning (LLL) courses are courses for professionals that want to upgrade their skills or (technical) knowledge.

The amount of data fed into the inventory is too vast to discuss every possible analysis in this deliverable. The analyses given here are limited to only several highlights or remarkable aspects. The inventory is accessible to all DigiWind partners at a cloud storage location, making more detailed analyses possible in the future.

During the DigiWind project the same inventory building process will be repeated during Q1 and Q2 of each calendar year. This chapter contains the first inventory of Q1 and Q2 of year 1. Updates will be published after each consecutive inventory.

2.4.2. Information gathered

The main information that needed to be filled in the template can be divided in administrative and educational data.

Administrative data

Administrative data per course is important to identify in which curriculum the digital skills are addressed. It is quite common that a certain course is part of multiple curricula, either in multiple MScs, in multiple tracks within a MSc or in multiple profiles within tracks. To avoid double entries, these courses need to be marked in a certain manner.

In a separate tab in the template a high-level overview was created of the curricula of the SEPs.

Per SEP/curricula the following administrative information was gathered:

- HEI
- Track
- Profile
- Courses

Per course in this tab the following information needed to be filled in:

- Course name including code
- Mandatory or elective
- ECTS
- Part of another MSc, track or profile

If the course is indeed part of multiple profiles, tracks, or MSc, the cell of the course name was highlighted in a soft shade of yellow. Using a colour to highlight gives an immediate overview of the number of courses that are part of multiple MScs, etc.

An example is given in Figure 6.

	A	B	C	D	E	F	G	H	I	J	K	L
1	Programme				course information				part of other programme			
2	HEI	MSc	track	profile	name	mand./elec.	year	ECTS	HEI	MSc	track	profile
9	Delft University of Technology	Aerospace Engineering	Aerodynamics & Wind Energy	Wind Energy	AE4W09 Wind Turbine Design	mandatory	1	5	TUD	multiple		
10					AE4W13 Site Conditions for Wind Turbine Design	mandatory	1	3	TUD	European Wind Energy Master	Rotor Design	Aerodynamics
11					AE4W21-14 Wind Turbine Aeroelasticity	mandatory	1	2	TUD	European Wind Energy Master	Rotor Design	both
12					AE5051 Internship	mandatory	2	15				
13					AE5122 Thesis Aerodynamics & Wind Energy	mandatory	2	45				
14					WM0324LR Ethics and Engineering for Aerospace Engineering	mandatory	1	3	TUD	European Wind Energy Master	Rotor Design	both
15					AE4010 Research Methodologies	elective	1	2	TUD	European Wind Energy Master	Rotor Design	both
16					AE4117 Fluid-Structure Interaction	elective	1	4	TUD	European Wind Energy Master	Rotor Design	both
17					AE4130-22 Aircraft Aerodynamics	elective	1	4				
18					AE4136-22 CFD 2: Discretization techniques	elective	1	3				
19					AE4138-18 CFD 4: Uncertainty Quantification	elective	1	3				
20					AE4139 CFD 3: Large Eddy Simulation	elective	1	3				
21					AE4180 Flow Measurement Techniques	elective	1	3	TUD	European Wind Energy Master	Rotor Design	Aerodynamics
22					AE4260A Fundamental of Aeroacoustics	elective	1	2				
23					AE4260B Experimental Applications of Aeroacoustics	elective	1	2				
24					AE4463P-23 Advanced Aircraft Noise Modelling and Measurement	elective	1	4				
25					AE4W30 Wind Resource and Wind Farm Yield	elective	1	4				
26					AE4W31 Floating Offshore Wind Energy	elective	1	3	TUD	multiple		
27					ME45001 Advanced Heat Transfer	elective	1	4				
28					ME45030 Turbulence	elective	1	5				
29					WI3150TU Partial Differential Equations A	elective	1	3				

Figure 6: Example high level overview SEP

Educational data

The educational data gathered concerns the actual learning objectives of each course, the educational objectives and the digital skills that are covered by each course. This was done in separate tabs, one for MSc courses, one for Master courses and one for LLL courses.

Bloom's Taxonomy was used to gain insight into the degree to which the digital skills are covered in the courses. This taxonomy is well known in the world of academia when designing courses. It is also addressed in the SOP (Deliverable 2.2) that Bloom's Taxonomy should be used during course development in DigiWind. The taxonomy divides learning objectives into six level of educational objectives (see Table 3). Before reaching a learning objective at a certain level, the student must have mastered the related learning objectives of the lower ranking educational objectives. Please refer to DigiWind Deliverable 2.2 Standard Operating Procedures for a more elaborate explanation of Bloom's Taxonomy.

Table 3: Levels of Bloom's Taxonomy

Bloom's Taxonomy	
1	Remember
2	Understand
3	Apply
4	Analyse
5	Evaluate
6	Design

All learning objectives of each course needed to be entered in a separate row. For each learning objective the level of Bloom's Taxonomy needed to be filled in in the same row. If a digital skill applied this needed to be selected in the same row as well (see Figure 7 as example).

course information					Learning objectives	
name	mand./elec.	year	ECTS	digital skills	educational objectives	learning objectiv
A Workbook last modified: vr at 21:26	mandatory	1	3		2 understand	Understanding and operational knowle
AE4135 Rotor/wake aerodynamics	mandatory	1	4		1 remember	Provide an overview of the phenomen
				Numerical analyis, simulation, optimisation, modelling tools	3 apply	"Hands on" introduction to the differe
AE4202 CFD for Aerospace Engineers	mandatory	1	3	Numerical analyis, simulation, optimisation, modelling tools	2 understand	know and understand the methods and
				Numerical analyis, simulation, optimisation, modelling tools	3 apply	able to set-up and run CFD simulations
				Numerical analyis, simulation, optimisation, modelling tools	5 evaluate	critically analyze and evaluate CFD resu
AE4ASM506 fundamentals of Aeroelasticity	mandatory	1	3		2 understand	understand the physical processes whi
					3 apply	be able to formulate and solve aeroela
					4 analyse	be able to identify strengths and weak
					2 understand	be familiar with the role of aeroelastic
				Numerical analyis, simulation, optimisation, modelling tools	3 apply	be able to program and solve simplifie
AE4T40 Airborne Wind Energy	mandatory	1	3		1 remember	Give an overview of developments in a
					3 apply	developing mathematical models for k
					6 create	designing kite power systems for indus

Figure 7: Example learning and educational objectives, and digital skills per course (TUD)

By using filters, different analyses can be made in these detailed tabs containing the educational data. It is possible to analyse this data per type of digital skill, per learning objective, per HEI, per MSc, and so.

Again, to avoid double entries, the same colour code was used to indicate courses that are part of multiple study lines. Also, main administrative information useful when analysing the digital skills, learning and educational objectives is also shown in these tabs (Figure 8).

	A	B	C	D	E	F	G	H	
1	Programme				course information				
2	HEI	MSc	track	profile	name	mand./elec.	year	ECTS	digital skills
3	TUD	Aerospace Engineering	Aerodynamics & Wind Energy	Wind Energy	AE4120 Viscous Flows	mandatory	1	3	
4	TUD	Aerospace Engineering	Aerodynamics & Wind Energy	Wind Energy	AE4135 Rotor/wake aerodynamics	mandatory	1	4	
5									Numerical ana
6	TUD	Aerospace Engineering	Aerodynamics & Wind Energy	Wind Energy	AE4202 CFD for Aerospace Engineers	mandatory	1	3	Numerical ana
7									Numerical ana
8									Numerical ana
9	TUD	Aerospace Engineering	Aerodynamics & Wind Energy	Wind Energy	AE4ASM506 fundamentals of Aeroelasticity	mandatory	1	3	
10									
11									
12									
13									Numerical ana
14	TUD	Aerospace Engineering	Aerodynamics & Wind Energy	Wind Energy	AE4T40 Airborne Wind Energy	mandatory	1	3	
15									
16									

Figure 8: Example administrative data per course

Digital skills in inventory

The possible entries of the digital skills were fixed to the same specific digital skills that are mentioned in the survey for industry and for the students. Either one digital skill from the list was selected, or the cell was left blank if no digital skill applied to a certain learning objective. As seen in Figure 7, not all learning objectives of a certain course need to be related to a digital skill. There are also examples of several digital skills within one course, but each linked to a different learning objective (Figure 9).

course information					Learning objectives	
name	mand./elec.	year	ECTS	digital skills	educational objectives	learning objectiv
02807 Computational Tools for Data Science	elective		5	Machine learning, deep learning and data science	3 apply	Select or design algorithms for
				High-performance computing (HPC) and CPU and GPU applications	4 analyse	Compare, evaluate, and apply t
				Machine learning, deep learning and data science	3 apply	Implement algorithms for data
				Machine learning, deep learning and data science	4 analyse	Compare, evaluate, and apply c
				Scientific programming and software development	5 evaluate	Lookup, explore, and evaluate
				Scientific programming and software development	6 create	Combine computational tools a
				Scientific programming and software development	4 analyse	Analyze scalability of computat

Figure 9: Example multiple digital skills per course (DTU)

The different digital skills used in this inventory are given in Table 4 (identical to Table 1, apart from the "Others" options).

Table 4: Digital skills in inventory

Possible digital skills to select in inventory:
High performance Computing (HPC) and CPU and GPU applications
Scientific programming and software development
Generative AI and Large Language Models
Data engineering, semantics, interoperability and quality assurance
Machine learning, deep learning and data science
Advanced digital tools for research and innovation communication
Robotics and autonomous systems
IoT, sensors technology, Extended Reality
Blockchain technology and applications
Cyber security
Cloud computing
Numerical analysis, simulation, optimisation, modelling tools
Others

SEPs in inventory

The curricula, or Specialised Education Programme (SEP), that were entered in the inventory of existing courses are given in Table 5 per Higher Education Institute (HEI).

Table 5: SEPs part of inventory

HEI	SEP	Track/profile
DTU	MSc Sustainable Energy Systems	Digital Energy Systems
	MSc Sustainable Energy Technologies	Wind Energy
	MSc Wind Energy	
	Master Wind Energy (online)	
	MSc EWEM	Rotor Design
		Wind Farms and Atmospheric Physics
TUD	MSc Aerospace Engineering	Wind Energy
	MSc EWEM	Rotor Design
		Offshore Engineering
		Electrical Power Systems
	MSc Offshore & Dredging Engineering	Offshore Renewable Energy
NTNU	MSc Marine Technology	Marine Structures
		Marine Machinery
	Msc Electric Power Engineering	
	Msc EWEM	Offshore engineering
		Electric power systems
TUS	Master (of Science) Environmental Infrastructure	Energy Management
	Master (of Engineering) Energy Infrastructure	Energy Infrastructure
	MSc Environmental Management	
	MSc Energy Infrastructure	

3. Analysis of the inventory of existing courses

3.1. Analysis of MSc courses

In total there are more than 200 MSc courses in which one or more digital skills are part of the study programme. Most of the digital skills part of the current SEPs are 'Scientific programming and software development' and 'Numerical analysis, simulation, optimisation, modelling tools'. This is clearly seen in Figure 10.

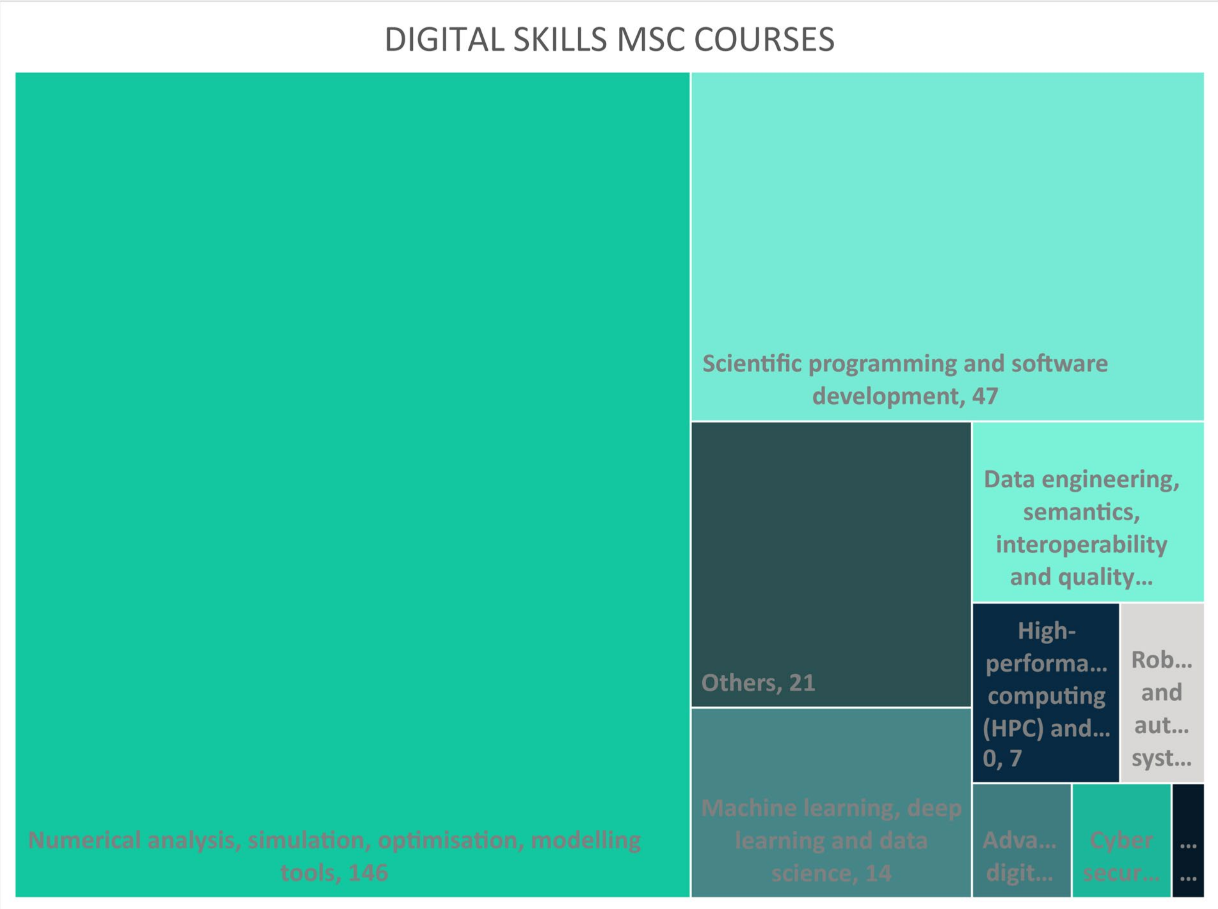

Figure 10: Distribution digital skills over MSc courses

Four of the digital skills are not covered by a single MSc at any of HEIs. Surprisingly, 'Generative AI and Large Language Models' are not seen in the inventory, while "Cyber Security" is not represented strongly. The other two digitals skills that are not found are 'Blockchain technology and applications' and 'Cloud computing'. The course distribution shown in Figure 10 is broadly consistent with the relative importance of digital skills for the industry, as identified from survey data. This is further discussed in Section 5.

An overview of the number of courses in which the digital skills are covered per HEI is given in Table 6. PG is also given in this overview, even though they do not have any SEPs on Wind Energy yet. They will develop these SEPs during the project. In the updates to come during the consecutive years, these courses will appear in the inventory and will be added to this overview.

Table 6: Number MSc courses per HEI per digital skill

MSc courses	**numbers of courses included in**					
		HEI				
Digital Skills	*Total*	*DTU*	*TUD*	*NTNU*	*TUS*	*PG*
High-performance computing (HPC) and CPU and GPU applications	7	3	3	1		
Scientific programming and software development	47	31	11	3	2	
Generative AI and Large Language Models	0					
Data engineering, semantics, interoperability and quality assurance	11	6	1	1	3	
Machine learning, deep learning and data science	14	11	1	2		
Advanced digital tools for research and innovation communication	3	3				
Robotics and autonomous systems	4	1	1	2		
IoT, sensors technology, Extended Reality	1	1				
Blockchain technology and applications	0					
Cyber security	3			3		
Cloud computing	0			0		
Numerical analysis, simulation, optimisation, modelling tools	146	48	43	51	4	
Others	21	3	3	15		

Only knowing which digital skills are covered the HEIs is not sufficient, though. It is also worthwhile knowing what the highest educational objective according to Bloom's Taxonomy is. In Table 7 these are given per HEI. More detailed analyses can be done per SEP, however as mentioned earlier only several high-level analyses are mentioned in this document.

Table 7: Highest educational objectives MSc courses per digital skill per HEI

MSc courses	**HEIs**			
Digital Skills	*DTU*	*TUD*	*NTNU*	*TUS*
High-performance computing (HPC) and CPU and GPU applications	6 create	6 create	6 create	
Scientific programming and software development	6 create	6 create	6 create	6 create
Data engineering, semantics, interoperability and quality assurance	5 evaluate	5 evaluate	6 create	5 evaluate
Machine learning, deep learning and data science	6 create	5 evaluate	6 create	
Advanced digital tools for research and innovation communication	6 create		-	
Robotics and autonomous systems	6 create	4 analyse	4 analyse	
IoT, sensors technology, Extended Reality	3 apply		-	
Numerical analysis, simulation, optimisation, modelling tools	6 create	6 create	6 create	6 create
Others	5 evaluate	4 analyse	6 create	

3.2. Analysis Master courses

When looking at the digital skills in Master courses, only 12 courses discuss digital skills. One course is by TUS and the other 11 are by DTU. These are also the only two HEIs that have entered Master courses in the inventory. And the number of courses entered the inventory is also significantly lower than that for MSc courses, thus this low number is not surprising.

In these 12 Master courses in total six different digital skills are covered, and seven digital skills are not mentioned in any course (Table 8). These seven include the four digitals skills that are also not covered in the MSc courses (Table 6).

Again, the digital skill 'Numerical analysis, simulation, optimisation, modelling tools' is the digital skills that is seen the most. In fact, it is part of 11 of the 12 Master courses. Apart from that digital skill, there is no particular one that stands out in number of courses it is covered. All numbers vary between 1 to 3 courses per digital skill. The numbers do give a different overall distribution, as can be seen in Figure 11.

Table 8: Number Master courses per HEI per digital skill

Master courses	**numbers of courses included in**					
		HEI				
Digital Skills	*total*	*DTU*	*TUD*	*NTNU*	*TUS*	*PG*
High-performance computing (HPC) and CPU and GPU applications	0					
Scientific programming and software development	1	1				
Generative AI and Large Language Models	0					
Data engineering, semantics, interoperability and quality assurance	1	1				
Machine learning, deep learning and data science	2	2				
Advanced digital tools for research and innovation communication	0					
Robotics and autonomous systems	3	3				
IoT, sensors technology, Extended Reality	0					
Blockchain technology and applications	0					
Cyber security	0					
Cloud computing	0					
Numerical analysis, simulation, optimisation, modelling tools	11	11				
Others	1				1	

One digital skill stands out in a different way. The absolute number of courses (three) in which 'Robotics and autonomous systems' are discussed is the same for both MSc and Master courses. However, in both overviews DTU is the only HEI, that has entered courses with these skills, thus perhaps the number is not that surprising.

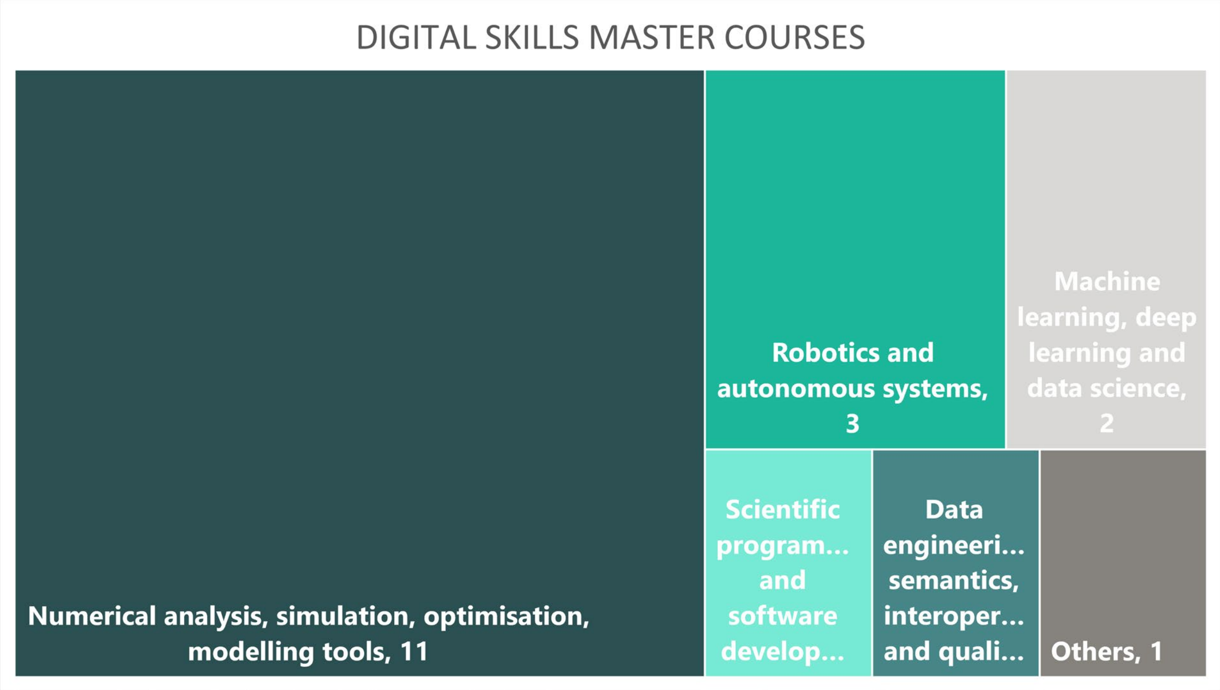

Figure 11: Distribution digital skills over Master courses

An overview has also been made of the highest educational objective according to Bloom's taxonomy per digital skill per HEI (Table 9). No particularities can be seen here when compared to those of the MSc courses (Table 7).

Table 9: Highest educational objectives Master courses per digital skill per HEI

Master courses	**highest educational objective**				
	HEI				
Digital Skills	*DTU*	*TUD*	*NTNU*	*TUS*	*PG*
High-performance computing (HPC) and CPU and GPU applications					
Scientific programming and software development	6 create				
Generative AI and Large Language Models					
Data engineering, semantics, interoperability and quality assurance	6 create				
Machine learning, deep learning and data science	4 analyse				
Advanced digital tools for research and innovation communication					
Robotics and autonomous systems	5 evaluate				
IoT, sensors technology, Extended Reality					
Blockchain technology and applications					
Cyber security					
Cloud computing					
Numerical analysis, simulation, optimisation, modelling tools	6 create				
Others				3 apply	

3.3. Analysis LLL courses

In the category of LLL courses, three HEIs have submitted courses in the inventory: TUD, NTNU and TUS. The lion's share of the submissions were from TUD, as they have a large portfolio on LLL or continuous education courses.

In total, about 20 courses have been submitted, and only two courses do not cover one of the mentioned digital skills. In the LLL courses, three digital skills not covered, but a different set of skills for the MSc courses (Table 6) and for the Master courses (Table 8). Here, the digital skills that not mentioned are: 'Robotics and autonomous systems', 'IoT, sensors technology, Extended Reality' and 'Cloud computing'. Cloud computing is thereby the only digital skill that is not covered in the entire inventory.

Table 10 gives an overview of the number of LLL courses that cover digital skills, per HEI and per digital skill.

Table 10: Number LLL courses per HEI per digital skill

LLL courses	**numbers of courses included in**					
		HEI				
Digital Skills	*total*	*DTU*	*TUD*	*NTNU*	*TUS*	*PG*
High-performance computing (HPC) and CPU and GPU applications	1		1			
Scientific programming and software development	1		1			
Generative AI and Large Language Models	3		3			
Data engineering, semantics, interoperability and quality assurance	3		2		1	
Machine learning, deep learning and data science	3		3			
Advanced digital tools for research and innovation communication	1				1	
Robotics and autonomous systems	0					
IoT, sensors technology, Extended Reality	0					
Blockchain technology and applications	2		2			
Cyber security	2		2			
Cloud computing	0					
Numerical analysis, simulation, optimisation, modelling tools	11		5	5	1	
Others	1		1			

It is also seen that the distribution of the digital skills is more even than for the other types of courses. 'Numerical analysis, simulation, optimisation, modelling tools' is still seen the most, but the difference with other digitals skills is less. This is clearly seen in Figure 12.

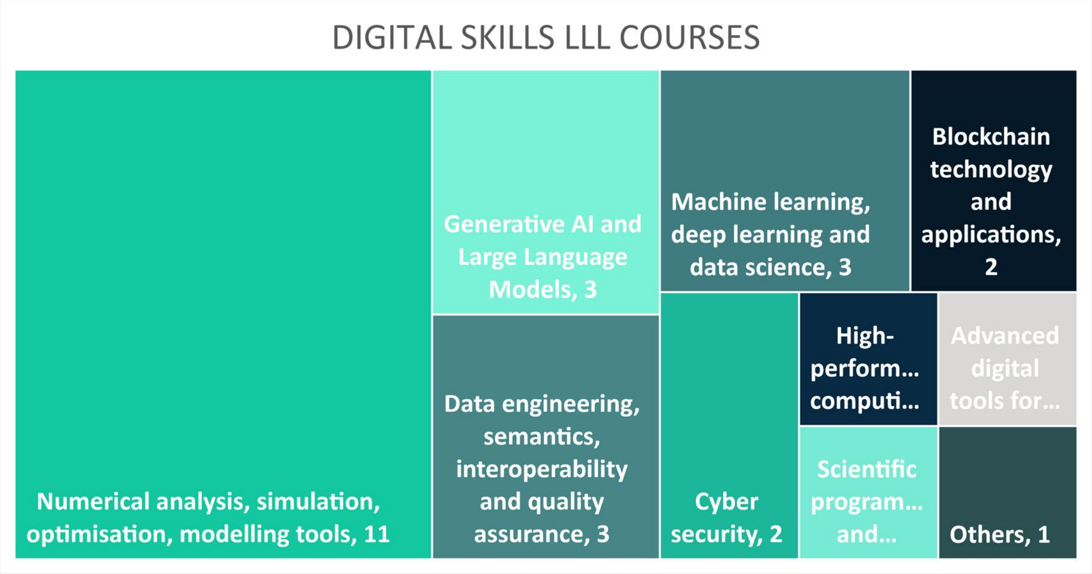

Figure 12: Distribution digital skills over LLL courses

Finally, when looking at the highest educational objectives, according to Bloom's Taxonomy, it is seen that overall these are lower ranking than for the MSc and Master courses (Table 7 resp. Table 9). Only two digital skills are covered to the highest ranking in Bloom's Taxonomy. This overview is given in Table 11.

Table 11: Highest educational objectives LLL courses per digital skill per HEI

LLL courses	**highest educational objective**				
	HEI				
Digital Skills	*DTU*	*TUD*	*NTNU*	*TUS*	*PG*
High-performance computing (HPC) and CPU and GPU applications		4 analyse			
Scientific programming and software development		3 apply			
Generative AI and Large Language Models		3 apply			
Data engineering, semantics, interoperability and quality assurance		6 create		4 analyse	
Machine learning, deep learning and data science		5 evaluate			
Advanced digital tools for research and innovation communication				5 evaluate	
Robotics and autonomous systems					
IoT, sensors technology, Extended Reality					
Blockchain technology and applications		2 understand			
Cyber security		4 analyse			
Cloud computing					
Numerical analysis, simulation, optimisation, modelling tools		6 create	5 evaluate	4 analyse	
Others		2 understand			

4. Analysis of survey and interview data

4.1 Survey data processing methodology

The part of the survey questions focusing on quantifying the skill gap are formulated as a prioritization task. The respondents are required to prioritize up to three items, giving them ranking in order of priority from 1 (highest) to 3 (lowest). The total numerical score p_i for a given skill category i is computed based on counting the total number of responses where the category is ranked amongst the top 3, with the following formula:

$$p_i = 3 * (Rank\ 1\ responses) + 2 * (Rank\ 2\ responses) + 1 * (Rank\ 3\ responses)$$

The above formula is essentially a weighted sum giving higher weights to higher-rank responses. Due to the technical characteristics of the EUSurvey platform, it was possible for respondents to give equal-rank responses (e.g., give three times "rank 1" for three different skills) without triggering an error. To evaluate the potential impact of such errors, we also tested a scoring function with equal weights of responses regardless of the rank indicated. The numerical results changed marginally but without a qualitative change in the conclusions or shifting of the relative importance of skills. Therefore, the weighted sum was retained as primary scoring approach. To facilitate the presentation of results, the scores were normalized by dividing each score with the total sum of scores:

$$p_{N,i} = \frac{p_i}{\sum_{j=1}^{N_{categories}} p_j}$$

Where $N_{categories}$ is the total number of skills categories (currently 12). In the results presentation section, the score p_N is referred to as "priority score".

Another type of ranking questions was used when the goal was to get an individual score for each category with every response (see Section 2.3 for details). Such a question was used for example for finding the suitability of training methods for delivering advanced digital skills education. The ranking in these cases started from 1 (lowest), to 5 (highest). For these questions, rank = 1 meant the method or activity is deemed inadequate for the purpose (e.g., a training method is not suitable at all). Therefore, we applied weighting scores starting from 0 points for rank = 1 (not suitable), to 4 points for rank 5 (highly suitable). In that way, one avoids assigning a positive score to a methodology which is unacceptable or unfit for purpose. Just as with the other ranking questions, the final scores are weighted and normalized with respect to the total number of responses, $N_{responses}$, so that the minimum score in each category is 0, and the maximum – 1. This score is referred to as "importance score". The formula for the normalized importance score is given below:

$$q_{N,i} = [4 * (Rank\ 1\ responses) + 3 * (Rank\ 2\ responses) + 2 * (Rank\ 3\ responses) + 1 * (Rank\ 4\ responses) + 0 * (Rank\ 5\ responses)] * \frac{1}{4N_{responses}}$$

4.2 Survey results overview

The currently reported survey results are based on 74 responses extracted on June 28th, 2024. The results overview starts with the general information about respondents. Figure 13 shows the distribution of responses by country - with a majority of responses coming from Poland and Denmark. While this is expected since both countries serve as bases for one or more DigiWind partners, ideally the responses should be more evenly distributed between countries to avoid country-specific bias in the summary results. Figure 14 and Figure 15 show the distribution of organization categories and hiring responsibilities, respectively. In both cases, there is a good spread with different categories of organizations and roles being represented. It is worth noting that the size of the "other" organization type is significant, meaning that the original list of organization types may not be exhaustive. In cases where respondents replied with "other" organization types they were asked to manually specify what is their organization category. An examination of the manual entries has revealed that potential additional categories could be "public authorities" and "tech developers".

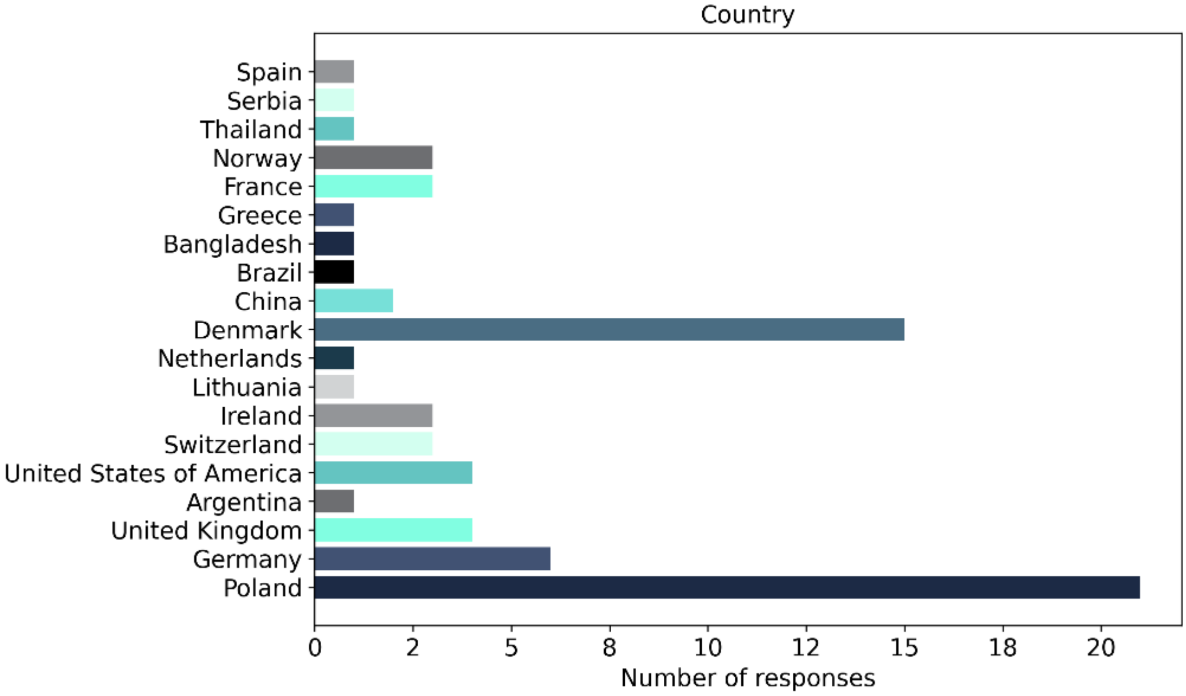

Figure 13 Number of responses per country

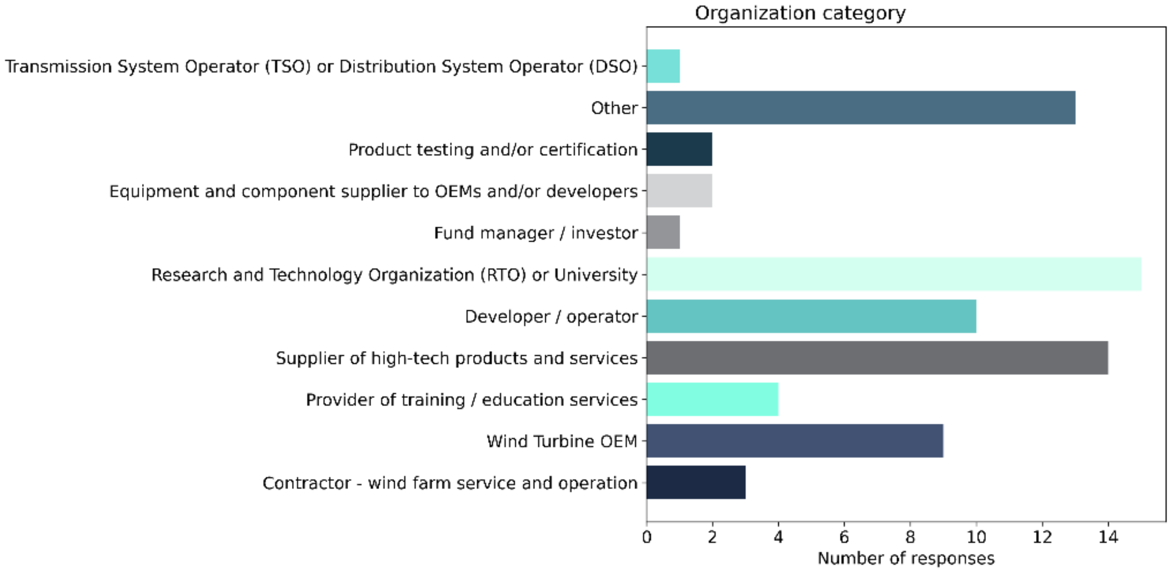

Figure 14 Number of responses per type of organization

Figure 15 Hiring responsibilities of survey respondents

The survey questions aiming at identifying the most important digital skills differentiated between skills relevant for new graduates (newly hired employees) vs. people that have been on the job market for a longer period. Both questions were given as a skills prioritization task by asking the respondents to choose at most three top-priority skills. The results for new graduates are shown in Figure 16. Rather than showing a similar figure for the current employees, we compare the results between the two categories with the bar chart shown in Figure 17. The graph shows overlapping bars with the scores, where the scores for new graduates are in blue, and for the current workforce in red. Orange colour means the score for the current workforce is higher than the score for the new graduates, with the orange portion of the bars showing the difference. Blue colour parts of the bars indicate where the difference is in the opposite direction. The most significant differences are that numerical analysis and software development are deemed more important for the new graduates, while communication is deemed more important for the current workforce.

The survey results just outline the differences and do not attempt to explain them. Potential explanations are sought through the in-depth interviews. Currently two factors are considered to have an influence:

- The members of the current workforce have been on the labor market for a number of years, meaning that they may have transitioned to more coordination-related tasks and programming and simulations is not as big part of their daily jobs as for the more junior employees;
- Differences in the school/university education content between generations may be leaving different skill gaps. For example, the current employees may have received more formal education in algorithms development and applied mathematics, while the current graduates' education could be more focused on hands-on experience with scripting.

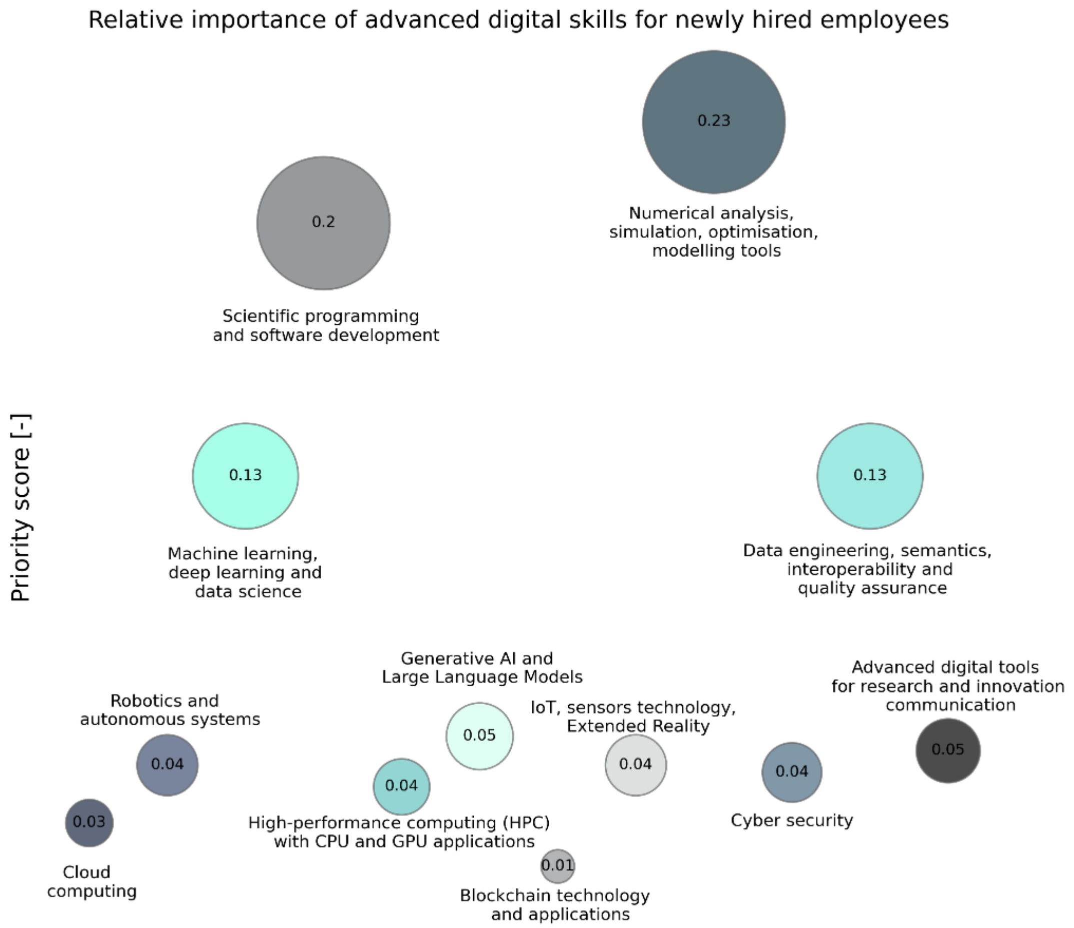

Figure 16 Prioritization of advanced digital skills for newly graduated engineers

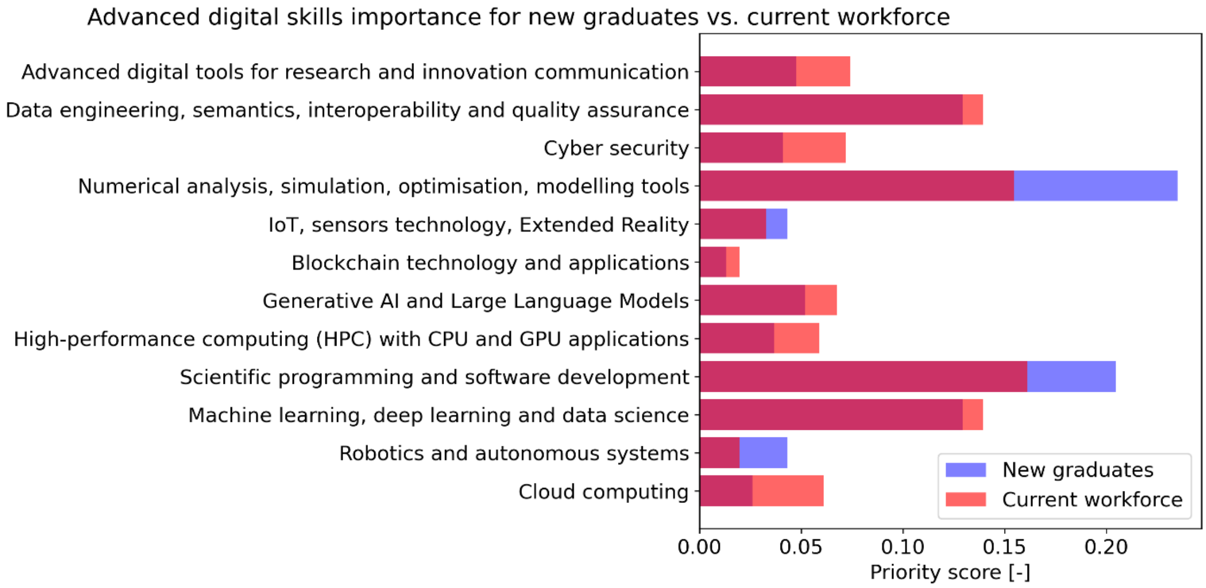

Figure 17 Comparison of skill importance for new graduates vs. current workforce. Orange bars represent the score for the current workforce, while blue bars represent the score for the new graduates. The overlapping parts of the score are shown as red. Hence, blue portions of the bars represent the difference between priority score for new graduates vs. current workforce, showing cases where the score is higher for the new graduates. Orange parts of the bars also represent the difference between skill relevance for new graduates and current workforce, but for skills where the score is higher for the current workforce.

Further survey questions dealt with finding what domain areas could benefit most from utilization of advanced digital skills. The domain areas were divided between those characteristics of typical white-collar (engineering and R&D jobs) and blue-collar (technical) jobs. Figure 18 shows the prioritization results for the engineering and R&D jobs. There is no clear most significant category, and five different domain areas get a relatively high score. Figure 19 shows the results for technical jobs. In this case, jobs related to wind turbine operations & maintenance activities are expected to have the biggest benefit from advanced digital skills.

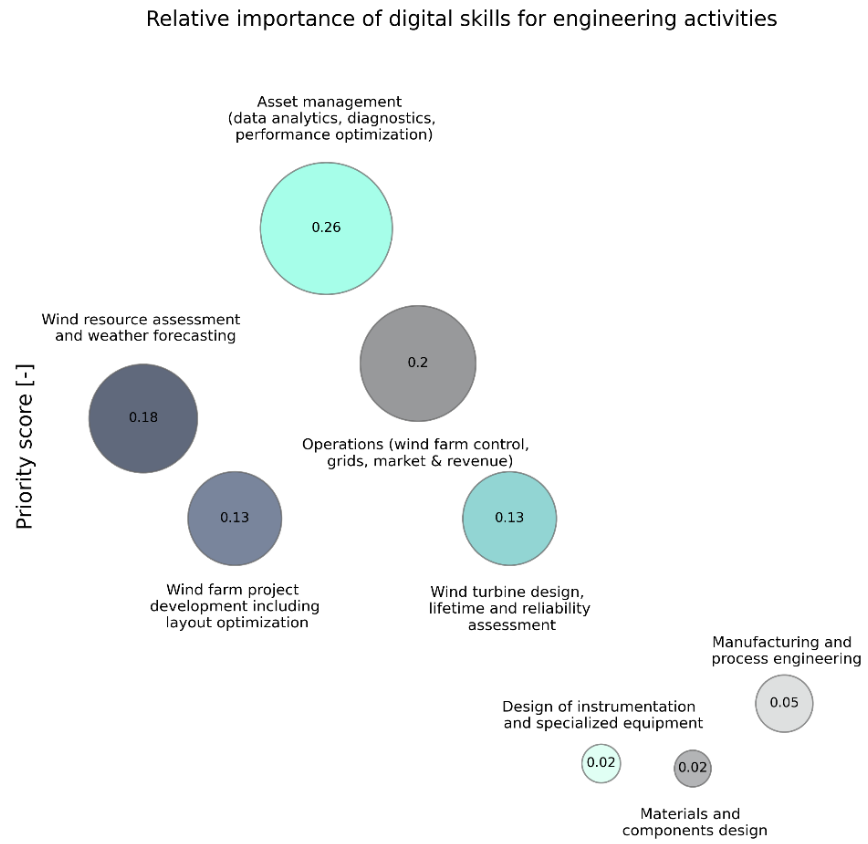

Figure 18 Relative importance of advanced digital skills for engineering and R&D activities

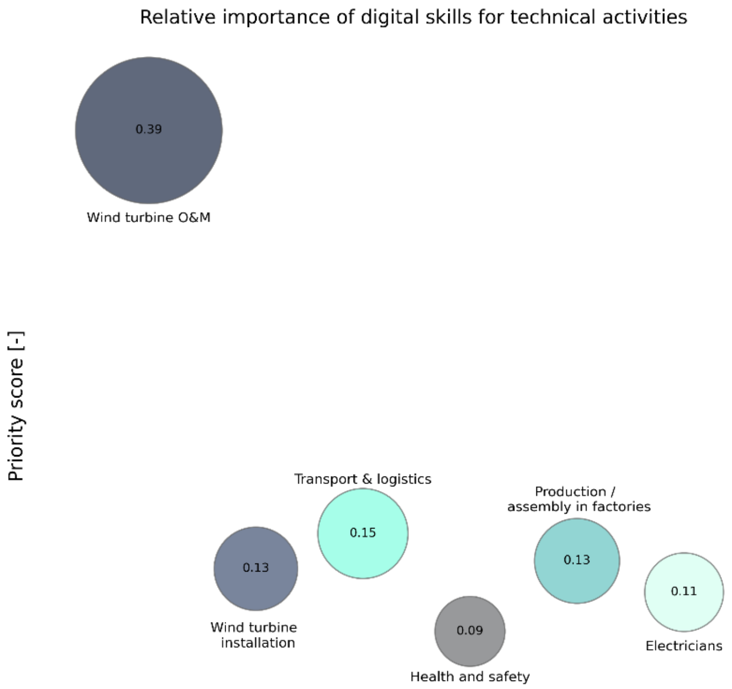

Figure 19 Relative importance of advanced digital skills for technical work activities

The final quantitative question included in the employers-oriented survey attempts to gauge the suitability of training methods for delivering education in advanced digital skills, for people that are currently employed in industry. As discussed earlier, this question was designed to get a score for each individual training option. The results are outlined in Figure 20. There is not a clear preferred training methodology, however one should keep in mind that the goal of the question is to establish the suitability of each training methodology by itself. The results point to multiple methodologies being suitable for the DigiWind training purposes.

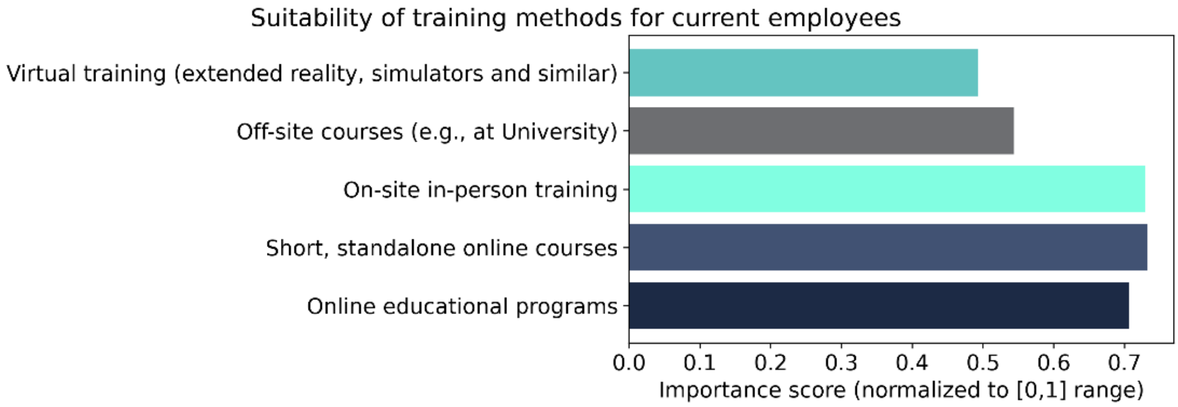

Figure 20 Suitability of training methods for delivering digital skills training

4.3 Learner-oriented survey results overview

The first questions in the learner-oriented survey are identical to those from other surveys, collecting information about the respondents. Figure 21 shows the countries where the respondents are located. Denmark is clearly the most represented country. This is easily explained with the way the survey responses were collected – by visiting classes at universities and asking the class attendants to fill in the survey. This technique was only used at DTU, leading to the observed results.

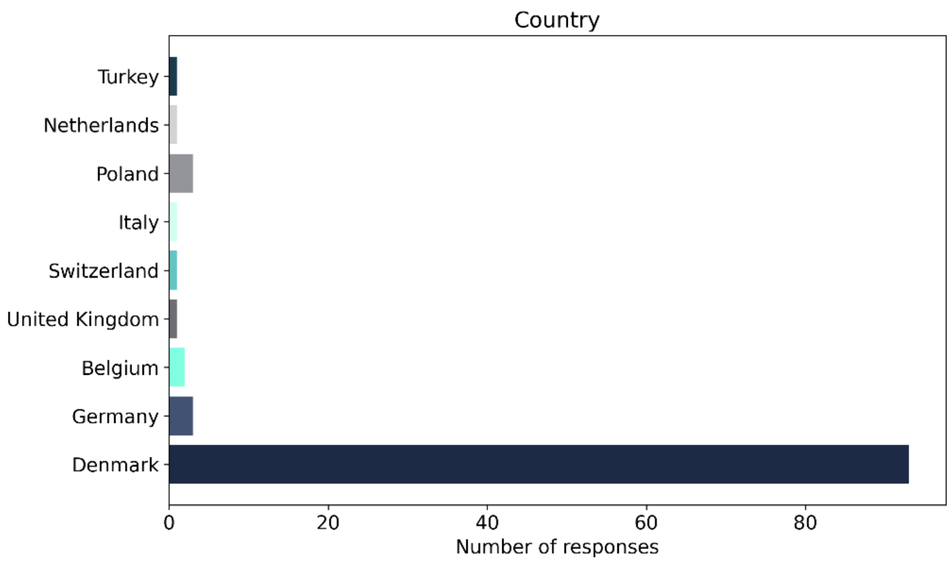

Figure 21 Country location distribution from learners' survey

As shown in Figure 22, the learners had a broad distribution of organization types where they would like to work. Notably, more than 10% of the respondents also considered research organizations as potential workplaces.

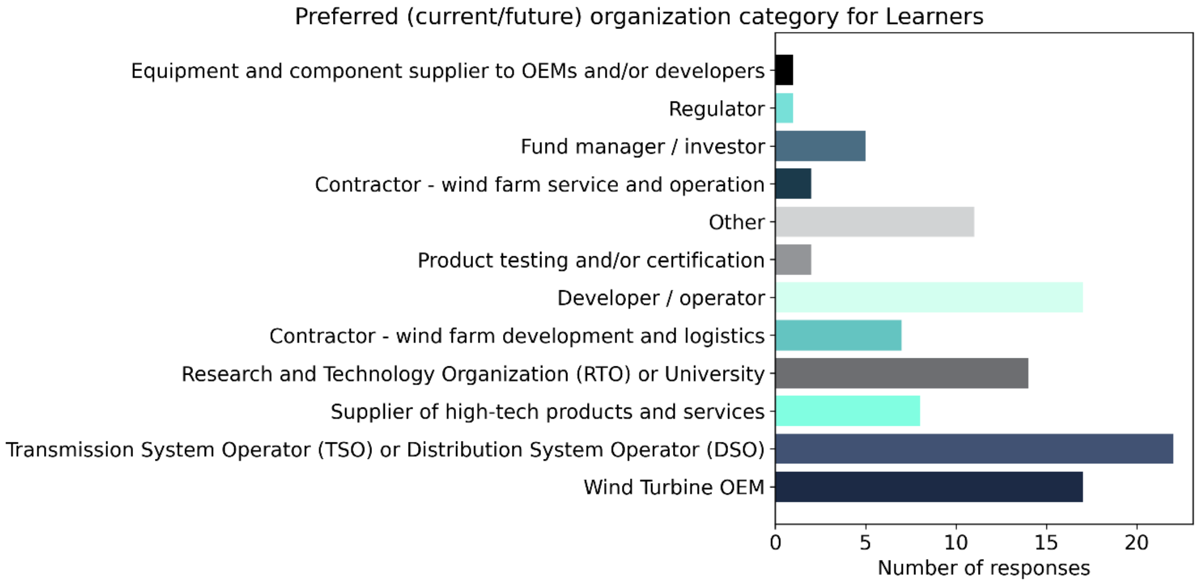

Figure 22 Preferred future workplace for learners.

A question unique to the learners' survey included a self-assessment of one's digital proficiency (Figure 23). The majority of respondents are at least a proficient user of such technology, but a significant part also considers themselves capable of creating own digital solutions.

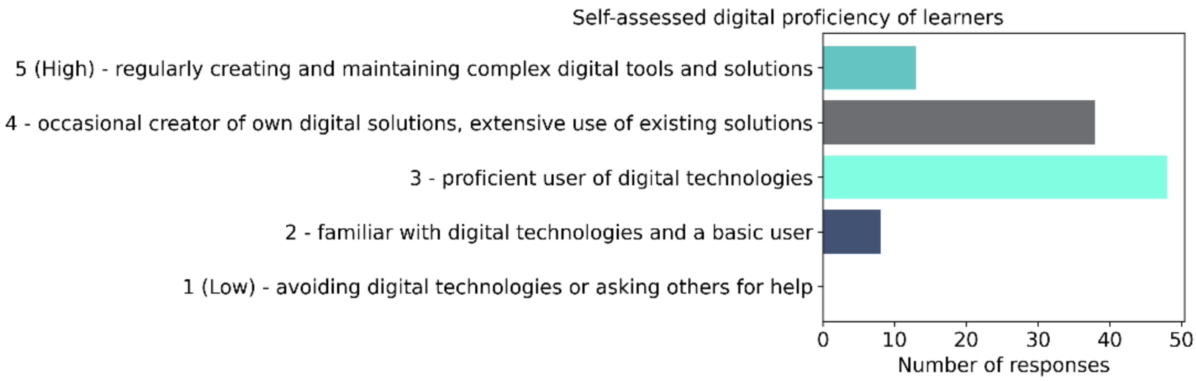

Figure 23 Learners' self-assessment of digital proficiency

The next Figure 24 considers the importance of advanced digital skills in terms of career impact, as defined by learners. This question asks for ranking each skill on a scale from 1 to 5. In contrast, the next question in the survey asked for picking a top 3 skill categories that the learners would like to be trained in. The results from this question are shown in Figure 25.

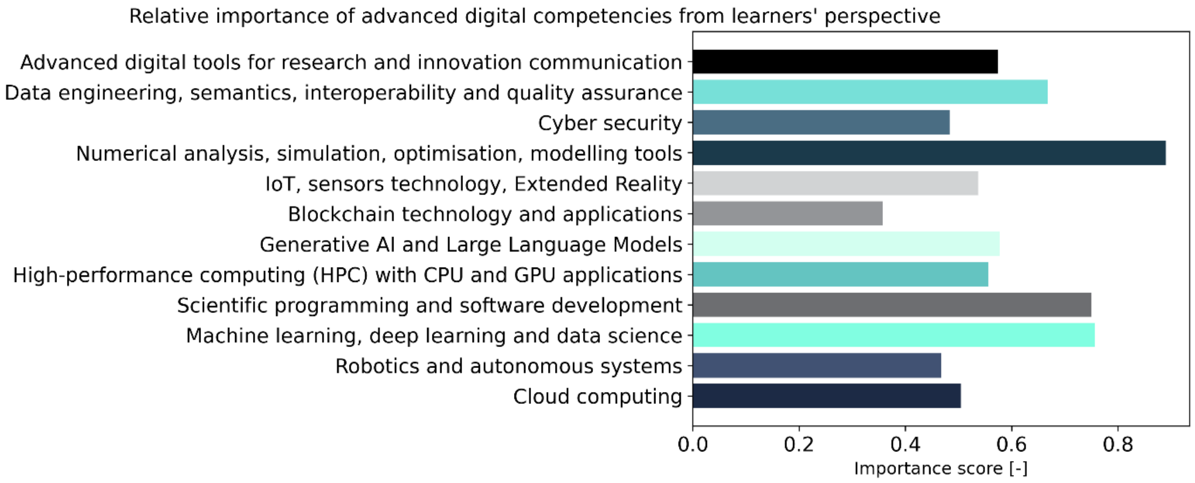

Figure 24 Relative importance of advanced digital skills in terms of career impact according to learners.

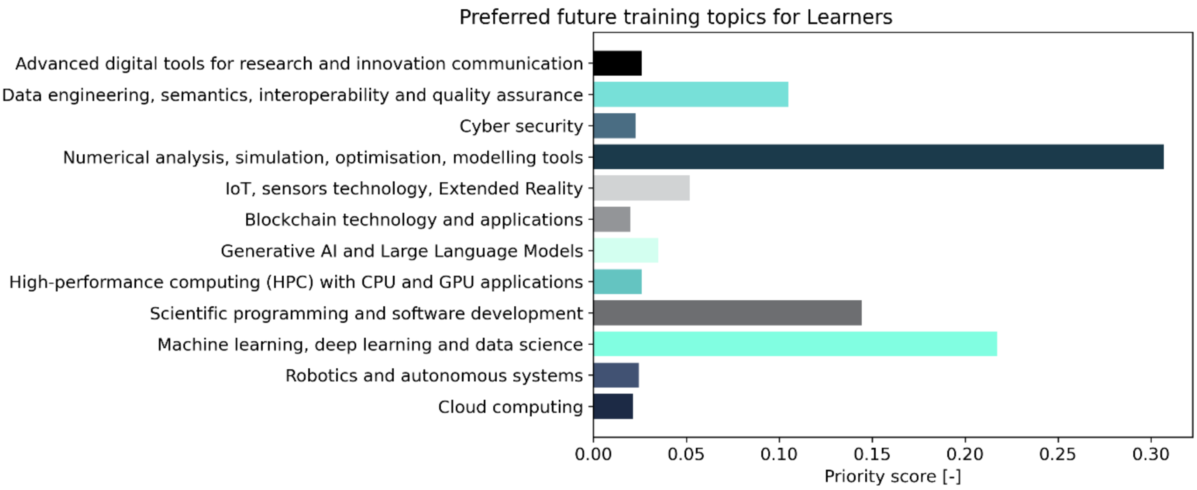

Figure 25 Preferred future training topics for learners

Comparing Figure 24 to Figure 25, the ranking of the preferred future training topics differs significantly from the ranking of what the same respondents consider important. This may be related to the different question formulation – but in our view it may also indicate an uncertainty - are the results in Figure 25 really preferred future training topics, or a reflection of the learners' already known study plans?

Finally, Figure 26 shows the learners' opinion on what are the biggest obstacles towards acquiring new digital skills. For this question, the respondents were allowed to select all answers that apply, hence the total number of answers exceeds the number of the respondents. Maybe unsurprisingly, lack of time is considered the biggest challenge. Time allocation was similarly a point of discussion in a number of in-depth interviews with industry stakeholders. While the background for learners' and employers' opinions on the lack of time may be different, we see a common conclusion that, in order to ensure efficient training and motivation among the people being trained, proper time allocation (including absence from the daily job tasks) needs to be ensured.

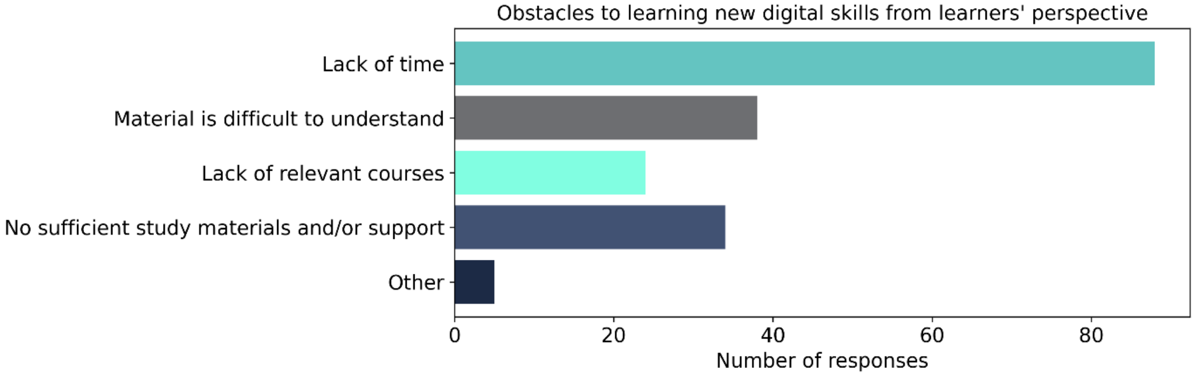

Figure 26 Perceived obstacles to learning new digital skills

4.4 Interview results processing

All interviews are stored in terms of audio or video files, as well as transcripts. This is a rich dataset which provides possibilities for in-depth analysis. However, such a full-scale analysis is time demanding, and ideally requires more interview results in order to be complete. Therefore, we plan to conduct more complex analysis setups with the next version of the knowledge bank. For the current version of the knowledge bank, two approaches were applied:

1) Manually summarizing the results as a follow-up step from each interview, following the reporting schema with six summary questions as outlined in Section 2.3; and
2) A word cloud (a visualization of the relative frequency of appearance of words in a text). The word cloud was created by automatic transcription of the interview video files and word counting, followed by manual removal of filler words and words appearing due to transcription errors.

Figure 27 sketches the main conclusions based on the manual interview summaries. This summary, together with the survey results and the comparisons between datasets (Section 4.5), is used to compile the main takeaways from the current version of the Knowledge Bank.

The word cloud from the in-depth interviews is shown in Figure 28. The most common words are related to the general scope of the discussions – i.e., skills, training, digitalisation.

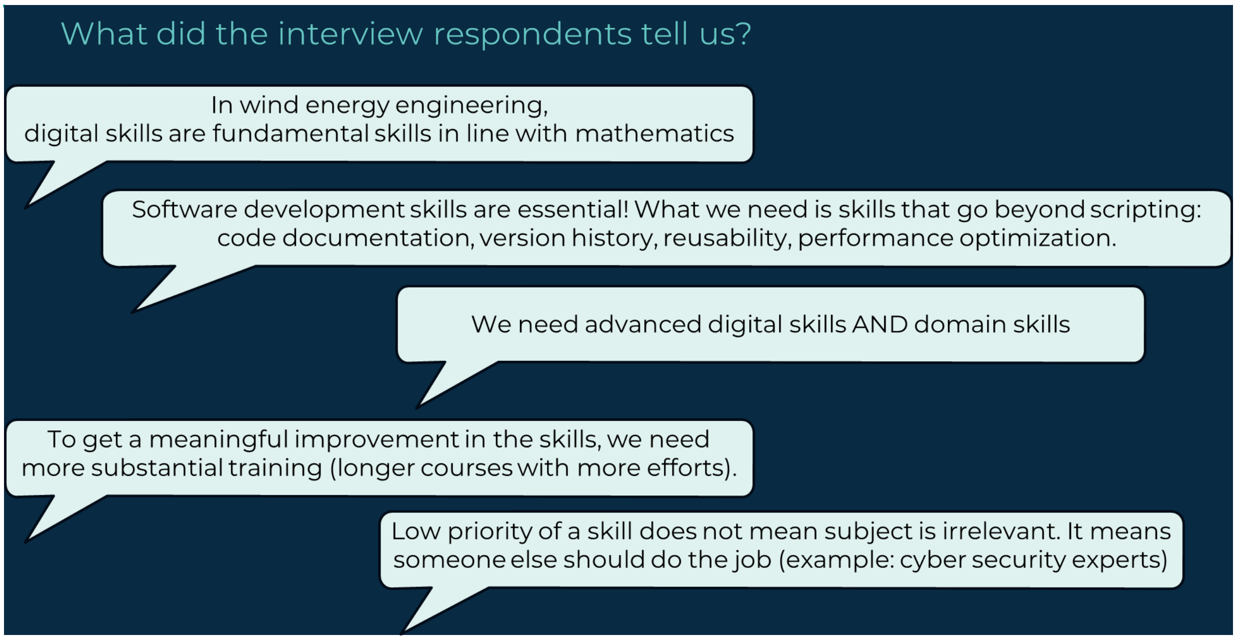

Figure 27 Summary of the main takeaways from interviews

Figure 28 Word cloud from in-depth interviews

4.5 Results comparison across data sources

Table 12 shows a comparison of the relative ranking of skills from the different survey and poll sets that used these skills definitions: two questions from the survey (considering new graduates, current workforce respectively) and the interactive polls. Note that for the interactive polls the option of “Advanced digital tools for research and innovation communication” was not available.

Table 12 Comparison of ranking of skills across different datasets and questions

Digital skills definitions:	**Rank**		
	Survey, new hires	**Survey, current workforce**	**Interactive polls**
Numerical analysis, simulation, optimisation, modelling tools	1	2	3*
Scientific programming and software development	2	1	5
Machine learning, deep learning and data science	3	4	1
Data engineering, semantics, interoperability and quality assurance	4	3	2
Generative AI and Large Language Models	5	6	3*
Robotics and autonomous systems	6	11	7
Cyber security	7	7	6
Advanced digital tools for research and innovation communication	8	5	N/A
IoT, sensors technology, Extended Reality	9	10	8
High performance Computing (HPC) and CPU and GPU applications	10	9	10
Cloud computing	11	8	9
Blockchain technology and applications	12	12	11
* two categories have the same score			

Table 13 shows another comparison across datasets, considering the relative importance of skills as indicated in the surveys, versus the relative availability of M.Sc. and LLL courses on the same topics. As the table indicates, there is a reasonable correlation between the few most popular course topics and the most essential digital skills according to the survey. A notable exception is the topic of programming and software development, which is less represented in the current course curriculum, specifically for LLL courses. Note that, especially for M.Sc. courses, the difference in course numbers between the top 2 categories (see Table 6) and the rest is much more significant than the differences from survey responses. It should also be noted that some of the Digital skills courses listed in Table 13 might be provided by other departments of the DigiWind HEIs, e.g., computer engineering and not directly connected to the domain of wind and energy systems. For courses such as Generative AI and Large Language Models, DigiWind HEIs plan to collaborate with other departments to the relevant extent and adopt them to be included in the list of elective courses within DigiWind.

Table 13 Comparison of skills importance ranking from surveys and relative availability of courses on the same topics.

Digital skills definitions:	Rank			
	Survey results, new hires	**Existing courses, MSc**	**Survey results, current workforce**	**Existing courses, LLL**
Numerical analysis, simulation, optimisation, modelling tools	1	1	2	1
Scientific programming and software development	2	2	1	7*
Machine learning, deep learning and data science	3	3	4	2*
Data engineering, semantics, interoperability and quality assurance	4	4	3	2*
Generative AI and Large Language Models	5	N/A	6	2*
Robotics and autonomous systems	6	6	11	N/A
Cyber security	7	7*	7	5*
Advanced digital tools for research and innovation communication	8	7*	5	7*
IoT, sensors technology, Extended Reality	9	8	10	N/A
High performance Computing (HPC) and CPU and GPU applications	10	5	9	7*
Cloud computing	11	N/A	8	N/A
Blockchain technology and applications	12	N/A	12	5*

* Multiple categories have the same score

5. Main takeaways

In modern wind and energy systems engineering, digital skills are fundamental skills in line with mathematics.

Programming and software development skills are essential! However, what we need is skills that go beyond scripting: code documentation, version control, reusability, modularity, performance optimization. Our surveys and interviews indicate a significant gap between the current course offerings and the specific skills demanded by the industry. Despite many courses focusing on numerical analysis, they seemingly fail to fully address the comprehensive programming and software development competencies that are critical for modern engineering roles.

We need advanced digital skills AND domain-related knowledge. Domain knowledge is essential for properly applying digital skills to actual problem solving and obtaining insights from the results.

To get a meaningful improvement in the skills, we need more substantial training (longer courses with more efforts). Most people interviewed suggested going for more extensive training programs.

Some skills are given as less important, but this is highly specific for the job profiles we consider. As a special example, Cyber Security skills are deemed less critical, but the interviews uncovered that this is because Cyber Security should be a matter for specialist jobs and not the general-purpose engineers. The latter should be aware of the challenges and avoid threats, but not develop solutions themselves.

The training formats need to be tailored to the life reality of the participants. Proper time needs to be allocated, including potential absence from daily work tasks. It may need to be country-specific due to different work-life balance in different countries.

Out of the two most sought-after skills (numerical simulations and software engineering), there is far less existing education offers on the latter (especially for LLL).

6. Suggestions for next versions of the Knowledge Bank

Tailoring interview questions to course topics beyond software engineering

The first round of interviews has clearly identified that software engineering is a key training topic in demand. This means that large parts of the interview discussions have circulated around the topic, leaving less place for discussing other potentially important training scopes. It is therefore suggested that in future interviews the questions are adjusted so that the discussion can progress beyond the software engineering as a key training topic. Additionally, we aim to focus more on the intersection of domain science and digitalisation in the following interviews to ensure a more comprehensive understanding of all the relevant training needs in the industry

A different survey and interview track on digital methods for training delivery

The current survey design favoured topics related to training scope and had less focus on methods for delivering content. Further, as seen from survey results, the current questions on training formats did not give completely informative results. We suggest that the next updates of the Knowledge Bank introduce an additional survey and interview track – that focuses more on digital learning for a predefined content (what is the best digital delivery method for a given content). The outcomes of this effort will be typically tailored to lifelong learning.

Consider "train the trainers" education activities

Identify the training requirements for future educators, including vocational schoolteachers for even higher impact.

Action plan on boosting survey responses and obtaining more uniform geographical distribution of responses

1. Increase Data Collection: Gather more data to ensure comprehensive coverage.
2. Achieve Geographical Balance: Ensure sufficient data from each country to avoid country-specific bias.

Appendix A: Complete interview guide

DIGIWIND

DIGIWIND KNOWLEDGE BANK IN-DEPTH INTERVIEW GUIDE

Date: May 1st 2024

Venue: Online

Participants:	Interviewers:
Tuhfe Göçmen (DTU)	Nikolay Dimitrov (DTU)
Jennifer Rinker (DTU)	Karsten Kryger (DTU)

Practical

Please remember to:

- Ask for consent for recording the interview and start recording.
- Use a Teams meeting or other tool that records automatic transcripts.
- Fill in the reporting schema with summary
- In the first question, clearly define the term 'advanced digital skills'. The following questions will refer to this definition. It can be done by displaying a supplementary Powerpoint slide with the respondent's answers to the survey.

Purpose and objectives

4. Point out the specific gaps in advanced digital skills, and how are these gaps distributed among the workforce
5. Identify concrete measures (**course topics, training formats, collaboration models**) that should be implemented to close these gaps
6. Anticipate how the skill requirements will change in the next 5 to 15 years

Interview questions

Introduction and lead-in questions
1. How would you define "advanced digital skills"?

We use the term in DigiWind (refer to the supplementary document with survey responses). Does your definition match ours?

2. To what degree is (training in) advanced digital skills relevant for your company's success?
How do you see the development of digital competence from a business perspective?

3. In the DigiWind survey, you were asked about prioritizing advanced digital skills. Which one did you choose as number one? Could you explain your choice?

4. In the DigiWind survey, you were also asked to prioritize domain skills that could benefit from combining with digital skills. Could you explain your choices?

More details on the skills gap

5. Can you give us example(s) of a task / role in your organization that would benefit from more digital skills?
Support questions:
Maybe there was a case where you saw a delay/missed opportunity due to the people not having enough skills to deal with a problem?

6. How are digital skills of newer graduates different than older ones? Do you see any differences between generations?
Support questions:
Any particular skillset that a group (e.g., currently active engineers) is lacking?
Anything that newly educated employees are natively equipped with, but lacks with the current workforce (or vice versa)?

Identifying concrete training topics and formats

7. Could you list any course topics that your colleagues would be likely to take?
Support questions: Any particular topics for which you are aware of existing interest? For example, a data science course, or a course in digital tools for resource assessment...

8. Are there any learning topics that are currently missing from the training market?
Support questions: Any situations where your colleagues have been looking for training in a specific topic, but could not find a relevant offer?

Anticipating future developments

9. Which trends do you see in the global wind and energy systems sector when it comes to the need for digital competences?

10. What do you anticipate as the crucial digital skills in the future – 5, 10 or 15 years ahead?
Support questions:

11. Do you see a growing need for lifelong learning offerings tailored to employees in the wind energy sector (within the next 3-6 years)? *Support questions:*
Collaboration models **12. What would be the ideal teaching method(s), locations, and duration of LLL module(s) for your company?** *Sub questions:* *Which forms of LLL would you prefer – online, F2F, hybrid, self-paced, livestream, etc.?* *Do you prefer in-company session, or sessions with a mixed group of people from the wind and energy systems industry (to enhance networking)?* *Do you rather prefer a short module of just one day, a module 2 to 3 days consecutively or multiple days spread over multiple weeks?* **13. Is your company planning to or willing to invest in upgrading the digital skills of your employees?** *Support questions:* *How much time and money would you invest?* **14. How do you see the future role of universities when upgrading the digital skills of employees?** *Support questions:* *Would you like closer collaboration with universities – e.g., LLL collaboration, guest lectures, supervision, formulation of cases?* **15. To what extent do you value input from industry experts in LLL modules?** *Sub questions:* *Who should deliver the module (e.g., universities, commercial providers, guest lecturers/industry experts with best practises, or colleagues with much experience on the matter)?* *Do you value a mixture of theory and industry practises?* **16. What is the ideal follow-up to that interview?** *Support questions:*

Reporting schema

Key questions **Q1. List any concrete course topics or training gaps that the respondent has outlined:** **Q2. Did the respondent suggest any new skills that will be relevant in 5+ years?**

Q3. Any concrete preferred training format (location, methods, duration)?

Q4. Is the company willing to invest in advanced digital skills?

Q5. What is the company's preferred collaboration model with education providers (such as those in the DigiWind consortium)?

Q6. Did the respondent suggest any follow-up activities?

Appendix B: Surveys

DigiWind Employers' and Learners' Survey as distributed by June 2024.

DigiWind skills survey

Fields marked with * are mandatory.

Disclaimer
The European Commission is not responsible for the content of questionnaires created using the EUSurvey service - it remains the sole responsibility of the form creator and manager. The use of EUSurvey service does not imply a recommendation or endorsement, by the European Commission, of the views expressed within them.

Welcome to the DigiWind survey!
Please read this introduction carefully as it contains useful guidance as well as information about data handling.

There is evidence that certain gaps exist between the competencies taught at higher education institutions and what is currently needed by the industry. This gap is especially pronounced when it comes to advanced digital skills, as seen in recent surveys (https://oreskills.eu/ (https://oreskills.eu/)).

We would like to reshape our educational offerings to reflect this situation and close the skills gap. Our aim is to develop new Life Long Learning (Professional Education) programs as well as university degree programs at Master's and M.Sc. levels. Your support is especially important, to help identify the competencies and the learning methodologies that are desired in the Wind and Energy Systems jobs of the future.

Thank you for your willingness to support our work. We expect that completing the survey will take between 5 and 10 minutes.
For additional information, please visit our online pages:
Website: DigiWind on the web (https://www.digiwind.org/)
LinkedIn page: DigiWind on LinkedIn (https://www.linkedin.com/company/digiwind/)

Data privacy notice:
By responding to this survey, you agree that your personal information (name, e-mail, and affiliation) is shared within the DigiWind project team. The data are handled in a GDPR-compliant manner, used solely for analysis of survey results and follow-up inquiries. Personal data will not be published and not shared further.

*
☐ I hereby consent to my personal data (name, e-mail, occupation, affiliation) being used for the purpose of the DigiWind knowledge bank, including analysis of survey results and follow-up inquiries.

DTU acts as data controller, and data are shared only within the DigiWind consortium. The complete data privacy policy can be found here:
DigiWind communication on collection of personal data. (https://digiwind.org/wp-content/uploads/2024/03/Communication-about-collection-of-personal-data-by-DTU.pdf)

You may withdraw your consent at any time by contacting us at info@digiwind.org

1 General information about the respondent and organization

* 1 Name of your organization

* 2 Which category describes your company/organization best?
- ◯ Wind Turbine OEM
- ◯ Developer / operator
- ◯ Fund manager / investor
- ◯ Equipment and component supplier to OEMs and/or developers
- ◯ Supplier of high-tech products and services
- ◯ Product testing and/or certification
- ◯ Contractor - wind farm development and logistics
- ◯ Contractor - wind farm service and operation
- ◯ Transmission System Operator (TSO) or Distribution System Operator (DSO)
- ◯ Regulator
- ◯ Provider of training / education services
- ◯ Research and Technology Organization (RTO) or University
- ◯ Other, please specify below

* 4 What is the size of your company / organization?
- ◯ < 10 FTE (full time employees)
- ◯ 10 - 49 FTE

Views
Standard Accessibility Mode

Languages
English

Contact
Contact Form (/eusurvey/runner/contactform/521a7fb5-762c-60d2-dc2e-d9bcadb31cec)

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* 5 Please specify the name of your current team or department within the organization. If you are part of multiple teams or departments, please list all that apply.

* 6 Which country are you and your team located in? Please select from the drop-down list.

* 7 Your position or title

* 8 How are you involved in the hiring process in your organization? Please choose the option which best describes your responsibilities.

- Responsibility on HR and administrative matters
- Responsibility as team lead
- Responsibility as technical manager or project coordinator
- Both personnel and technical leadership responsibility
- Strategy / executive manager
- No hiring responsibilities
- Other, please specify below

* 10 How are you involved in the training activities in your organization? Please choose all options that apply.

- Delivering training through courses or similar
- Developing training sessions and materials (e.g., lectures, videos)
- On-the-job training such as mentoring
- Procuring or approving training activities for colleagues
- Designing training programs and strategies
- Attending in training activities
- Not directly involved in the training process
- Other, please specify below

2 Digital Skills

12 In your view, how important will digital competencies be when hiring ***new colleagues*** in the near future? Please select ***up to three*** competencies that you find most important. Rank your choices in order of importance by ticking the appropriate box.

between 1 and 3 answered rows

	Rank 1 (top)	Rank 2	Rank 3
Scientific programming and software development	☐	☐	☐
Blockchain technology and applications	☐	☐	☐
Data engineering, semantics, interoperability and quality assurance	☐	☐	☐
IoT, sensors technology, Extended Reality	☐	☐	☐
Cloud computing	☐	☐	☐
Machine learning, deep learning and data science	☐	☐	☐
Cyber security	☐	☐	☐
Generative AI and Large Language Models	☐	☐	☐
High-performance computing (HPC) with CPU and GPU applications	☐	☐	☐
Advanced digital tools for research and innovation communication	☐	☐	☐
Robotics and autonomous systems	☐	☐	☐
Numerical analysis, simulation, optimisation, modelling tools	☐	☐	☐

13 In your view, what are important digital competencies where your ***current*** colleagues could benefit from getting further training, through e.g. life-long learning education offers? Please select ***up to three*** competencies that you find most important. Rank your choices in order of importance by ticking the appropriate box.

between 1 and 3 answered rows

	Rank 1 (top)	Rank 2	Rank 3
Machine learning, deep learning and data science	☐	☐	☐
Robotics and autonomous systems	☐	☐	☐
Numerical analysis, simulation, optimisation, modelling tools	☐	☐	☐
Cloud computing	☐	☐	☐
Generative AI and Large Language Models	☐	☐	☐
High-performance computing (HPC) with CPU and GPU applications	☐	☐	☐
Cyber security	☐	☐	☐
Scientific programming and software development	☐	☐	☐
Data engineering, semantics, interoperability and quality assurance	☐	☐	☐
IoT, sensors technology, Extended Reality	☐	☐	☐
Blockchain technology and applications	☐	☐	☐
Advanced digital tools for research and innovation communication	☐	☐	☐

* 14 To your knowledge, did your company/organization already have difficulties filling positions requiring digital competencies in any of the areas listed above?

3 Training methodologies and link with domain skills

* 16 According to your experience, what types of training activities are commonly used in your organization? Please select all formats that apply.
Minimum 1 selection(s)

- ☐ Informational videos
- ☐ E-learning on dedicated platforms (Learning Management Systems)
- ☐ Classroom-style, on-site in-person training
- ☐ Off-site courses (e.g., at a University)
- ☐ Peer training, mentorship arrangements
- ☐ Virtual training (simulators, extended reality and similar)
- ☐ Hands-on training
- ☐ Other, please specify below

18 What types of ***training facilitation*** do you find suitable for providing your current colleagues with new digital skills as part of a life-long learning training process?

	Highly suitable	Suitable in many cases	Partially suitable	Not suitable in most cases	Not suitable at all
Online educational programs	○	○	○	○	○
Short, standalone online courses	○	○	○	○	○
On-site in-person training	○	○	○	○	○
Off-site courses (e.g., at University)	○	○	○	○	○
Virtual training (extended reality, simulators and similar)	○	○	○	○	○

19 In your view, which of these ***engineering and R&D*** job activities will have the highest benefit from introducing training with increased focus on digital skills? Please rank the top three according to importance.
between 1 and 3 answered rows

	Rank 1 (top)	Rank 2	Rank 3
Wind resource assessment and weather forecasting	☐	☐	☐
Wind farm project development including layout optimization	☐	☐	☐
Asset management (data analytics, diagnostics, performance optimization)	☐	☐	☐
Operations (wind farm control, grids, market & revenue)	☐	☐	☐
Wind turbine design, lifetime and reliability assessment	☐	☐	☐
Design of instrumentation and specialized equipment	☐	☐	☐
Materials and components design	☐	☐	☐
Manufacturing and process engineering	☐	☐	☐

20 In your view, which of these ***technical*** job activities will have the highest benefit from introducing training with increased focus on digital skills? Please rank the top three according to importance.
between 1 and 3 answered rows

	Rank 1 (top)	Rank 2	Rank 3
Wind turbine O&M	☐	☐	☐
Wind turbine installation	☐	☐	☐
Transport & logistics	☐	☐	☐
Health and safety	☐	☐	☐
Production / assembly in factories	☐	☐	☐
Electricians	☐	☐	☐

4 Final comments and follow-up possibilities

21 Do you have any additional comments or insights you would like to share?

For example:
- Are there any knowledge gaps in the industry you would like to make us aware of?
- Have you experienced a lack of learning content within a specific subject?
- Are we missing a type of skill definition?

* 22 Would you consider taking part in follow-up activities such as an in-depth interview?

Yes, please contact me if needed

* 25 How did you learn about the DigiWind survey?

I was personally invited

26 May we contact you in the future? The DigiWind partners would like to continue updating their educational offerings and prepare new ones.

- ☐ I agree that my contacts are kept for marketing purposes and developing new educational offerings.

0%

DigiWind skills survey - learner's perspective

Fields marked with * are mandatory.

*

Welcome to the DigiWind survey!
Please read this introduction carefully as it contains useful guidance as well as information about data handling.

Note that this survey focuses on potential learners and their requirements. A similar survey aimed at employers and trainers is available here:
Link to DigiWind survey for employers and trainers (https://ec.europa.eu/eusurvey/runner/521a7fb5-762c-60d2-dc2e-d9bcadb31cec)

There is evidence that certain gaps exist between the competencies taught at higher education institutions and what is currently needed by the industry. This gap is especially pronounced when it comes to advanced digital skills, as seen in recent surveys (https://oreskills.eu/ (https://oreskills.eu/)).

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Thank you for your willingness to support our work. We expect that completing the survey will take between 10 and 15 minutes.
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LinkedIn page: DigiWind on LinkedIn (https://www.linkedin.com/company/digiwind/)

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*

☐ I hereby consent to my personal data (name, e-mail, age, gender, occupation, affiliation) being used for the purpose of the DigiWind knowledge bank, including analysis of survey results and follow-up inquiries.

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You may withdraw your consent at any time by contacting us at info@digiwind.org

1 Importance and gap of digital skills

1 In your view, how important will these digital competencies be for your career? Please rate each one's performance on a scale from 1 to 5 where 5 is most important.

	5 (Highly important)	4 (Important)	3 (Neutral)	2 (Less important)	1 (Not important at all)
Advanced digital tools for research and innovation communication	○	○	○	○	○
Machine learning, deep learning and data science	○	○	○	○	○
Cloud computing	○	○	○	○	○
Numerical analysis, simulation, optimisation, modelling tools	○	○	○	○	○
Cyber security	○	○	○	○	○
Generative AI and Large Language Models	○	○	○	○	○
Data engineering, semantics, interoperability and quality assurance	○	○	○	○	○

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	5 (Highly important)	4 (Important)	3 (Neutral)	2 (Less important)	1 (Not important at all)
High-performance computing (HPC) with CPU and GPU applications	○	○	○	○	○
Blockchain technology and applications	○	○	○	○	○
Robotics and autonomous systems	○	○	○	○	○
Scientific programming and software development	○	○	○	○	○
IoT, sensors technology, Extended Reality	○	○	○	○	○

2 Which of these skills do you wish to improve or acquire? Please select ***up to three*** competences that you find most important. Rank your choices in order of importance by ticking the appropriate box.

between 1 and 3 answered rows

	Rank 1 (top)	Rank 2	Rank 3
Advanced digital tools for research and innovation communication	☐	☐	☐
Numerical analysis, simulation, optimisation, modelling tools	☐	☐	☐
Cloud computing	☐	☐	☐
High-performance computing (HPC) with CPU and GPU applications	☐	☐	☐
Robotics and autonomous systems	☐	☐	☐
Scientific programming and software development	☐	☐	☐
Data engineering, semantics, interoperability and quality assurance	☐	☐	☐
Machine learning, deep learning and data science	☐	☐	☐
IoT, sensors technology, Extended Reality	☐	☐	☐
Cyber security	☐	☐	☐
Blockchain technology and applications	☐	☐	☐
Generative AI and Large Language Models	☐	☐	☐

2 Self-assessment of digital experience

* 3 How do you rate your proficiency in digital technologies on a scale from 1 to 5?

- ○ 5 (High) - regularly creating and maintaining complex digital tools and solutions
- ○ 4 - occasional creator of own digital solutions, extensive use of existing solutions
- ○ 3 - proficient user of digital technologies
- ○ 2 - familiar with digital technologies and a basic user
- ○ 1 (Low) - avoiding digital technologies or asking others for help

* 4 Have you previously participated in any form of digital skills training, including self-learning?

- ○ Yes
- ○ No

* 7 Have you ever been in a situation where digital skills were required for a job or a project?

○ Yes ○ No

3 Learning preferences and needs

9 What are your preferred formats for learning new digital skills?

	Highly suitable	Suitable in many cases	Partially suitable	Not suitable in most cases	Not suitable at all
Online educational programs	○	○	○	○	○
Short, standalone online courses (self-paced learning)	○	○	○	○	○
On-site in-person training at a company	○	○	○	○	○
University courses	○	○	○	○	○
Virtual training (extended reality, simulators and similar)	○	○	○	○	○

* 10 What are the main obstacles that you face when trying to learn new digital skills?

Minimum 1 selection(s)

- ☐ Lack of time
- ☐ Prohibitive cost
- ☐ Lack of relevant courses
- ☐ Material is difficult to understand
- ☐ No sufficient study materials and/or support
- ☐ Other, please specify below

* 12 How likely are you to pursue training in advanced digital skills in the next year?

- ○ Very likely
- ○ Somewhat likely
- ○ Unlikely

4 General information about the respondent and organization

* 13 Name

* 14 E-mail

* 15 Age
- < 20 years
- 20 - 25 years
- 26 - 30 years
- 31 - 40 years
- 41 - 50 years
- 51 - 60 years
- 60+ years

* 16 Gender
- Male
- Female
- I prefer not to disclose
- I prefer to self describe

* 18 What is currently your primary occupation?
- Studying (e.g., at a University)
- Seeking employment
- Currently employed
- Other non-employment occupation (e.g. parental leave, retirement)
- Other, please specify below

* 20 What is your highest level of education or what educational programme are you currently in?
- High school / vocational school
- Short higher education (College or Bachelor's degree)
- Long higher education (Master of Science or similar)
- Ph.D.

21 Which branch of scientific disciplines is closest to your competences?
- STEM (Science, Technology, Engineering, Mathematics)
- Natural sciences (e.g. biology, chemistry, physics)
- Social sciences (psychology, sociology, economics, history)
- Multidisciplinary (strong focus in at least two of the above disciplines)

* 22 Are you or have you been employed in a job related to your current education, and for how long?
- Not yet
- 0 - 5 years
- 6 - 10 years
- 11 - 20 years
- > 20 years

* 23 Which country are you located in? Please select from the drop-down list.

* 24 What industry do you work or aim to work in? Choose the category that describes the company/organization best.
- Wind Turbine OEM
- Developer / operator
- Fund manager / investor
- Equipment and component supplier to OEMs and/or developers
- Supplier of high-tech products and services
- Product testing and/or certification
- Contractor - wind farm development and logistics
- Contractor - wind farm service and operation
- Transmission System Operator (TSO) or Distribution System Operator (DSO)
- Regulator
- Provider of training / education services
- Research and Technology Organization (RTO) or University
- Other, please specify below

5 Final comments and follow-up possibilities

27 Could you think of a successful, inspiring (digital) learning experience you have taken part in? Please describe it briefly.

28 Do you have any additional comments or insights you would like to share?

0%

For example:
- What suggestions do you have for educational institutions or training providers to better address the digital skills gap?
- Have you experienced a lack of learning content within a specific subject?
- Any additional thoughts about digital skills development that go beyond the contents of this survey?

* 29 How did you learn about the DigiWind survey?

30 May we contact you in the future? The DigiWind partners would like to continue updating their educational offerings and prepare new ones.

- [ ] I agree that my contacts are kept for marketing purposes and developing new educational offerings.

Submit