ANALYSING THE FUTURE WORKFORCE PROFILE IN THE LIGHT OF DIGITAL TRANSFORMATION AND INNOVATIVE BUSINESS MODELS IN THE DIGITAL ERA

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ABSTRACT

This study considers the contribution of digital competences in forming the future workforce within the European Union in the context of digital transformation and emerging business models. The research combines bibliometric mapping based on the Web of Science database (visualised using VOSviewer) with data-driven analysis of Eurostat data for 2021, 2023, and 2025. The findings reveal a steady increase in the proportion of individuals with at least basic digital skills (from 56,30% in 2021 to 61,02% in 2025), confirmed by repeated measures ANOVA indicating a statistically significant time effect. Despite overall progress, substantial disparities persist throughout Member States. Western and Northern European countries consistently outperform Eastern and Southern regions, reflecting structural differences in education systems, digital infrastructure, and policy effectiveness. The results highlight that digital competences are strongly associated with labour market adaptability, employability, and the ability to engage with innovative business models. The study contributes to the literature by integrating structural, temporal, and regional perspectives as well as draws attention to the need for targeted policy interventions to reduce the digital divide and support convergence within the EU.

KEY WORDS

digital competences, digital transformation, labour market trends, workforce

CLASSIFICATION

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INTRODUCTION

Without adequate digital skills, European citizens will become functionally illiterate in the economy of the 21st century. Digital technologies are fundamentally transforming daily life, behaviour and the operations of economic actors. The European Union's digital strategy seeks to ensure that this transformation benefits both individuals and businesses, while also contributing to the EU's long-term objective of achieving climate neutrality by 2050. Fostering the digital transformation fulfils a central role in the European Union's political and policy objectives, sets the direction, which it is implementing through a comprehensive digital strategy. The aim of this strategy is for Europe to strengthen its digital sovereignty, proactively shape global technological and regulatory criteria, increase security and create a digital ecosystem which benefits EU Member State citizens, businesses and the public sector. The pillars of the strategy affect multiple areas and include key policy initiatives such as the Digital Markets Act, the Digital Services Act, the European Digital Identity, the European Chips Act, the regulation of artificial intelligence, the European data strategy, and the industrial policy strategy. These initiatives aim to encourage or provide a secure, fair, and effective digital environment, which will likewise contribute to strengthening European security capabilities and space technology developments. As an integral part of this comprehensive framework, the European Commission's Digital Decade 2030 program functions as a central compass for coordinating the EU's digital transformation. The objective-driven purpose of the program is to build a people-centered, sustainable, and prosperous digital future in which both individuals and businesses are empowered. The Digital Decade program sets out specific measures, objectives, milestones and indicators in four areas: digital skills, digital public services (government), digital infrastructure, and businesses. This study concentrates on the dimension of digital skills. Skills development is a key element of the Digital Decade 2030 program, as it is necessary for the EU's digital future that the EU population has the right skills to use digital technologies. The main issue of the study is: What factors influence individuals' digital competences in the context of the EU2030 framework and how does their distribution vary throughout Member States? The aim of the research is to analyze, determine, and identify the current state, improvement trends and patterns in digital skills and literacy, the digital divide, future workforce profile in the digital era and digital participation at Member State level through analyzing Eurostat data published by the Digital Decade program.

Main research questions related to the objective:

RQ1: What types of digital competences characterize the workforce in the digital era?

RQ2: What are the differences in levels of basic digital competence among EU Member States?

As yet, limited attention has been given in the literature to the multi-level interpretation of digital competences in light of EU objectives. This study addresses that gap by examining and evaluating their socio-economic correlates inside a unified structure.

Every year, starting in 2023, the European Commission publishes the State of the Digital Decade report, which looks at the development of the digital economy and the progress of the EU's digital transformation. Digitalisation is a key factor in the economic and social transformation of our times. The new skill set required by the digital economy and innovative business environment affects not only the employability of individuals as well as the development of their career paths, which is critically determined by the extent and quality of the skills and competences they acquire, as the dynamics of technological progress and the ever-changing labour market expectations make it indispensable for individuals to continuously learn and up-skill, and to develop their digital skills, especially in industries significantly affected by digitalisation. Digital transformation is driving fundamental changes in the way we work, learn and participate in society and in our daily lives. Unlocking the potential of digitalisation without the right skills is limited. The European Union is investing €500 million to promote digital development through the Digital Europe Programme, one indicator of which is a beneficial change from a baseline of 56% of adults aged 16-74 with at least basic digital skills in 2019 to a target of at least 70% by 2025 [1, 2].

LITERATURE REVIEW

FEATURES OF THE DIGITAL ECONOMY

Due to the interdisciplinary nature of the digital economy and its wide range of interpretations, there are no universally accepted, precise definitions or taxonomies. Due to disciplinary specificities and the approaches taken by specific subfields of study, a number of definitions delimit the subject. The digital economy is a key driver of economic growth, inducing changes in lifestyles, economic restructuring and leading to considerable consequences for businesses, jobs and people [3, 4]. The digital economy encompasses the digital representation and availability of goods and services and the associated technology infrastructure that enables value creation, transactions and the flow of data and information. It is defined by OUP [5] as an economic segment that operates mainly through the implementation of digital technology, in particular electronic transactions over the Internet. However, the digital economy is a globally interconnected network of economic and social activities and transactions, a driver of globalisation, enabled by digital technology such as the internet and the business transactions and actions that occur through it. The beginning of the digital economy can be detected from the 1960s-80s, when the new technology that penetrated from the military to the civil and corporate sectors, the internet, was propelled towards exponential growth as a widely available, affordable and accessible tool. Since the millennium, the rapid emergence of advanced information and communication technologies (ICTs), alongside the proliferation of interconnected smart devices (e.g., smartphones, laptops, tablets, and 3D printers), has fundamentally reshaped this landscape. Recent OECD assessments [6] highlight that foundational hardware changes have shifted into a highly integrated, data-driven ecosystem. The widespread use of the Internet of Things (IoT), sensors, and advanced analytics now powers the continued growth of the digital economy.

Tapscott [7] refers to the age of networked intelligence, where beyond smart machines, people can be networked through technology, which predicts an increase in social welfare by joining technology, knowledge and creativity. Lane's [8] research explored the convergence of computing and telecommunications technologies through the internet and digitalisation, and the specificities of information and technology flows that have fundamentally changed commerce and the traditional organisational structure. Margherio and others [9] identify four critical areas, the technological penetration and deployment of the Internet, e-commerce, digital delivery of goods and services (logistics and distribution), and retailing of goods. According to Brynjolfsson and Kahin [3], the digitalisation of information is ongoing and uninterrupted with the help of computers and digital tools in most sectors of the economy.

The rise of the Internet of Things (IoT) in the 2000s became a dramatic catalyst for the digital transition. IoT refers to a multitude of devices that are capable of detecting data and information and communicating with each other over the internet, as the incorporation of components capable of receiving, storing and transmitting data captured in devices allows these devices to interact with each other, while at the same time, we are also smarting up devices that are primarily designed for non-communication purposes (e.g. smart cars, smart refrigerators) [10-12]. In the 2010s, the focus of technology at the forefront remained no longer on "smart" functions, i.e. functions that interact with other devices, communicate and can be remotely controlled, but on machine learning. The IoT provides the right foundation for the continued development of systems that support machine learning through its devices. So, the digital economy is not a static state, but a globally evolving, exponentially unfolding, continuous wave of innovation. Research by the Economist Intelligence Unit [13] indicates that the ranking of the digital economy by country is based on the quality of their ICT infrastructure and the ability of economic actors (consumers, businesses and governments) to adapt to and use these technologies. The level of cooperation and responsibility of government, public and business sectors in building the technical infrastructure and in carrying out educational tasks is of cardinal importance. The combination of IoT and Artificial Intelligence (AI) could be the basis and catalyst for the development of the digital economy in the future, by translating physical reality into online space, i.e. digitising physical reality and making it perceptible and meaningful to AI through the transformation of identified data, which can meaningfully apply and transform information extracted from big data into action [14, 15]. Beyond the general approach of the digital economy, other areas that could shape the future include the further spread and use of new digital business models (digital platforms, cloud services), automation, massive data collection, processing and analysis, algorithm-based decision making and robotisation technologies [6]. "A business model is a descriptive representation of the activities and actions of a business, showing the cause and effect relationship between different choices, partner arrangements, resource requirements, value flows and cash flows, determining specific customer and consumer groups, their needs and determining how and by what activities the business can meet their needs" [16].

"The relevance of the business model lies in the fact that it has a fundamental impact on the success of the firm, as it can be a direct cause of gaining competitive advantage, building revenue streams and attaining sustainable operations" [17]. Emerging from the fast evolving new technologies and forming the backbone of the digital economy are the digital capabilities, actions and sequences of actions, and the set of these through which an individual or organisation can perform digitally in the complex environment in which it operates [18]. Such digital tools or tasks include datafication, digitisation (the transformation of data and information from analogue to digital), virtualisation and generativity (the reprogramming and re-purposing of data and technologies) [19].

DIGITAL COMPETENCES FOR WORKERS: BASIC EXPECTATIONS IN THE DIGITAL ECONOMY AND THE MODERN LABOUR MARKET

The dynamic development of the digital economy and the exponential growth rate of the role of technology in everyday life have fundamentally reshaped the expectations of workers in the labour market. Society has shifted from an economy based on commodities and manual labour to an economy based on knowledge and highly skilled human capital [20-22]. Concepts such as digital competence and digital literacy have become key to the effective performance of workers, and the importance of acquiring these skills and competences, and of training programmes and courses in this area, has increased. According to Eshet [23], digital skills are the specific abilities of an individual to perform tasks and jobs such as producing, living and learning in a digital environment. The acquisition of digital skills allows for greater choice and job security, as well as more opportunities for workers who are working, looking for a job or changing jobs [24]. Innovative processes and alternative work arrangements created by digitalisation provide a broad perspective for expanding employment opportunities [25]. Workers need to have digital skills to participate in digital work processes and to be able to work more efficiently and effectively [26]. Boros [27] conducted a Scopus-based keyword analysis (2021-2023) concentrating on future jobs, skills, and competences in economic and business journals. Their findings highlight the importance of soft skills – especially communication – and suggest enhancing creative, less automatable abilities, as well as technical knowledge and systems thinking. A systematic literature review on digital skills for 21st century workers [28] identifies and examines 7 core competences/Technical skills, Information digital skills, Communication digital skills, Collaboration digital skills, Critical thinking digital skills, Creative digital skills, Problem-solving digital skills / that are necessary in modern labour markets in the information age. Technical skills refer to the recognition and use of the mechanisms and patterns of operation of tools, software, applications and systems. Information digital skills refer to the process of searching for, processing and evaluating information, but also include the filtering or identification of credible and relevant information as well as harmful and fake news information. Information management skills also refer to the ability to maintain, sort, select, retrieve, retain and use information, as workers need to be able to manage documents, files, emails and other digital forms using digital tools as part of their work activities [29]. Employees must be proficient in digital communication [30]. Digital communication, an essential tool for connecting in virtual space and working on a collaborative project or in a group, has become easy, cheap, instantaneous and distance-independent through digitalisation. Effective communication in the digital space has become more valued, and it is now essential to exchange and interact with clear, accurate and effective information through digital mail applications, social networking sites and messaging apps. The ability to collaborate in the digital environment is a new dimension of teamwork. It is vital that workers are able to express themselves beyond the physical environment and are able to collaborate with colleagues regardless of distance [31], through the messaging, file and voice sharing applications created by the digital economy. Digital skills in critical thinking and problem solving support the analysis and solution of complex tasks, and the identification and filtering of the large amounts of fake news and disinformation generated in the digital space is critical [32]. Being informed by credible, verified and trusted sources is essential for forming our worldviews and opinions, as it is only through such information that we can credibly and effectively answer questions and solve problems, while ensuring that our decisions be informed and objective. Creative digital skills, enable the development of innovative approaches to maximise the opportunities offered by technology (e.g. platforms) [33]. The integrated application of these skills enables workers to collaborate, cooperate, create, edit and share digital content effectively in the dynamic and rapidly changing environment of the digital economy.

MATERIAL AND METHODS

To adequately measure and monitor digital progress across the Member States, the European Commission historically utilized the Digital Economy and Society Index (DESI). Although the standalone DESI framework has recently been integrated into the wider ‘State of the Digital Decade’ report to directly track the EU’s 2030 targets, its methodology and historical data remain foundational in understanding Europe’s digital performance among key dimensions: human capital, connectivity, the application of digital technology, and digital public services. Within this framework, the human capital dimension is especially important. As demonstrated by recent cluster analyses of DESI indicators, human capital acts as the central factor in digital development and is strongly correlated with the successful deployment of digital technologies in business [34]. Furthermore, Zoroja [34] highlights that despite general improvements across the EU, structural disparities continue: while Nordic countries maintain leadership, Eastern and Southern European nations show limited organic convergence, stressing the absolute necessity of focused policy interventions, now monitored via the Digital Decade framework, to close the digital divide.

To support the conceptual foundations of the research, a bibliometric background analysis was conducted using VOSviewer software. The analysis was based on the Web of Science multidisciplinary scientific database, which was searched using the following keywords: ‘digital literacy’, ‘digital skills’, ‘business model’, ‘digital transformation’ and ‘labour market’.

The bibliometric query targeted the 'Title', 'Abstract', and 'Author Keywords' fields. To maintain scientific validity and corpus homogeneity, inclusion criteria were restricted to English-language, peer-reviewed journal articles and review papers published from 2014 to 2024. To capture the long-term evolutionary dynamics as well as conceptual foundations of digitalization, the dataset was supplemented with a purposive search. Select seminal documents identified through external searches, including those published outside the primary timeframe, were incorporated to provide historical perspective. Exclusion criteria omitted book chapters, conference proceedings, editorial materials, and non-English publications. This planned search protocol resulted in a final dataset of 1344 documents. The search results were used to create a co-occurrence network, which allowed the identification of links, clusters and scientific focal points between relevant subject areas. It is important to note that the bibliometric network is not the same as the bibliography presented in this article. The analysis aimed primarily at structurally mapping the relevant scientific discussion, identifying thematic trends, keywords and research directions, Figure 1. In contrast, the theoretical and methodological literature used in the article is based on a conscious selection that takes into account the scientific relevance and topicality of the sources, as well as the specific research questions and objectives of the research. The scientific clusters identified on the basis of the bibliometric network have contributed to a systematic presentation of the skills, educational dimensions and economic and social implications of digital transformation in the research background. The relationship structures thus identified confirmed the basic hypotheses of the research and helped to inform the choice of topics and the conceptual framework. In addition, the analysis has also shown that digital competences are interdisciplinary in nature, located at the intersection of many disciplines and central to discourses of education, labour market, technology and social inequalities. The network around digital skills identifies three main clusters: blue, green and red. The blue cluster focuses on the labour market and economic aspects of digital skills, highlighting the economic and industrial relevance of digital skills, especially in the context of efficiency, innovation and competitiveness. The green cluster interprets digital skills within the education sector, looking at the development of digital skills in the context of education. The focus is on pedagogical methods and the use of digital tools, as well as the competences needed

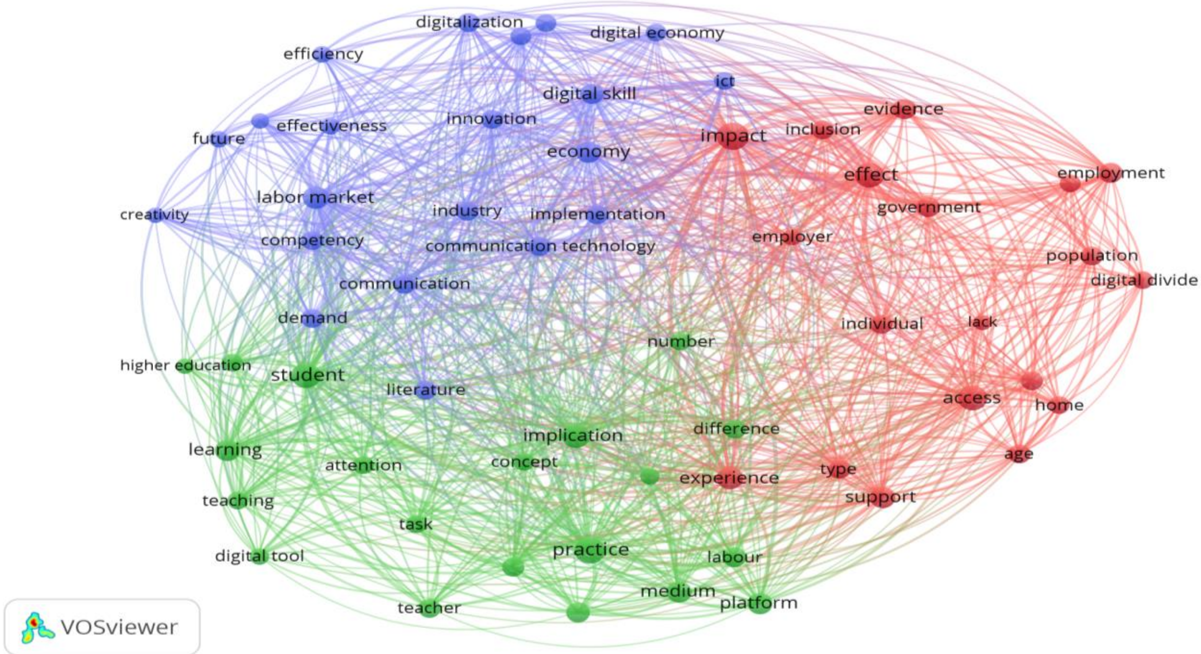

Figure 1. The interdisciplinary framework of digital skills – a keyword network analysis.

to prepare for the future labour market. The red cluster looks at digital skills from a societal perspective and focuses on the problems of access to digital skills in society. It highlights the digital divide, age differences, and the importance of the role of government and institutions in building an inclusive digital society. The notion of digital skills acts as an interdisciplinary bridge between the three clusters, as digital skills are presented in the literature as a complex and networked phenomenon.

The objective of this article is to examine progress towards the milestones established in the European Commission's Digital Decade 2030 programme. The analysis adopts Eurostat's harmonized database, "Individuals' level of digital skills (from 2021 onwards)" (code: isoc_sk_dskl_i21__custom_21227537), which provides comparable indicators across European Union Member States and enables both cross-country and longitudinal analysis.

Data from 2021, 2023, and the most recent 2025 dataset are analyzed for identifying temporal trends and structural changes in digital competences across the EU. The dataset captures the distribution of individuals across multiple skill levels and reflects differences associated with social and economic factors such as education, labour market status, and regional development. In accordance with the Digital Decade policy framework, the distribution and inequalities of digital skills are examined through secondary analysis of Eurostat data. Data preparation, transformation, and preliminary statistical analysis were conducted using Microsoft Excel, while specialized statistical procedures were performed using SPSS.

The original Eurostat classification divides individuals into eight groups, Table 1. Category "A" represents individuals with above basic digital skills, while categories "B", "C", "D", and "E" represent progressively lower skill levels. Category "F" includes individuals with no digital skills, and category "G" includes those whose skills could not be assessed due to a lack of recent internet use. According to Eurostat methodology, categories "A" and "B" are combined to form the indicator "individuals with basic or above basic digital skills" (A+B), which serves as a key benchmark in EU policy monitoring.

Table 1. Aggregation of Eurostat digital skill categories into analytical groups.

Mark	Eurostat categorization	own categorization
A	Individuals with above basic overall digital skills	advanced
B	Individuals with basic overall digital skills	
C	Individuals with low overall digital skills	average
D	Individuals with narrow overall digital skills	
E	Individuals with limited overall digital skills	weak
F	Individuals with no overall digital skills	
G	Digital skills could not be assessed because the individual has not used the internet in the last 3 months	not used
A + B	Individuals with basic or above basic overall digital skills	in advanced

To enhance interpretability and statistical robustness, the original categorical structure was aggregated. The eight initial categories were grouped into four broader analytical categories (advanced, average, weak, and not used) based on conceptual similarity, theoretical relevance, and methodological considerations. This transformation, known as category collapsing, is a well-established practice in quantitative analysis of complex categorical variables. Its primary purpose is to improve interpretability, reduce noise, and enable more reliable statistical comparisons.

To statistically validate this transformation and explore the underlying data structure, a Principal Component Analysis (PCA) with Varimax rotation, Table 2, was conducted using the 2025 dataset. The Kaiser-Meyer-Olkin (KMO) measure (0,713) indicated acceptable sampling adequacy, and Bartlett's Test of Sphericity ($\chi^2 = 180{,}762$; df = 15; $p < 0{,}001$) confirmed that the correlation matrix was suitable for dimensionality reduction, Table 3.

The PCA extracted two components with eigenvalues greater than 1, jointly explaining 89,036% of the total variance, Table 4. This high explained variance indicates a strong latent structure and confirms that the original categories are highly interrelated. The rotated component matrix demonstrates that the first component captures a general digital competence gradient, distinguishing higher from lower skill levels, while the second component isolates the "basic" skill category as an intermediate level. All communalities exceeded 0,70, indicating that the extracted components adequately represent the original variables.

A clear distinction must be maintained between the latent statistical dimensions identified by the PCA and the analytical categorization applied in this study. The PCA serves as an exploratory statistical technique to uncover underlying relationships among variables and does not define classification boundaries.

Accordingly, the study retains the theoretically grounded aggregation of categories, combining "basic" and "above basic" into an "advanced" category. This decision is based on conceptual and policy considerations, aligning with Eurostat methodology and the European Commission's Digital Decade 2030 indicators, where this aggregation serves as a core benchmark. This approach ensures that the analysis remains statistically supported and policy-relevant, while maintaining cross-country comparability. The final structure of the recoded variable is presented in Table 1.

Table 2. Rotated component matrix (varimax rotation). Extraction Method: PCA. Rotation method: varimax with Kaiser normalization. Rotation converged in 3 iterations.

	Component	
	1	2
Var_A_AboveBasic	–0,980	
Var_D_Narrow	0,912	
Var_C_Low	0,854	
Var_E_Limited	0,840	0,483
Var_F_NoSkills	0,690	0,635
Var_B_Basic		–0,944

Table 3. KMO measure and Bartlett's test of sphericity.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0,713
Bartlett's Test of Sphericity	**Approx. Chi-Square**	180,762
	df	15
	Sig.	< 0,001

Table 4. Total variance explained by PCA.

Com-ponent	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumu-lative %	Total	% of Variance	Cumu-lative %	Total	% of Variance	Cumu-lative %
1	4,177	69,614	69,614	4,177	69,614	69,614	3,706	61,769	61,769
2	1,165	19,422	89,036	1,165	19,422	89,036	1,636	27,267	89,036
3	0,481	8,023	97,060						
4	0,081	1,354	98,413						
5	0,059	0,975	99,388						
6	0,037	0,612	100,000						

RESULTS AND DISCUSSION

This study examines the temporal evolution of digital competences and cross-country differences among European Union Member States within the framework of the Digital Decade 2030 programme. The analysis focuses on the proportion of individuals possessing at least basic digital skills (A+B category), a key indicator for monitoring digital readiness at the EU level.

The most recent data show that the EU average reached 61,02% in 2025, an increase from 56,30% in 2021 and 57,61% in 2023, Table 5. This trend demonstrates a steady and cumulative improvement in digital competences, Table 6.

Table 5. Descriptive statistics of digital competences (EU Member States, 2021-2025).

Year	*N*	Minimum	Maximum	Mean	Std. Deviation
2021	27	27,82	79,18	56,30	12,11
2023	27	27,73	82,70	57,61	12,65
2025	27	31,84	83,61	61,02	12,85

Table 6. Temporal evolution of individuals with at least basic digital skills (A+B) across EU Member States, 2021-2025. All data represent percentages (%).

Country	2021	2023	2025	Change 2021-2025
Austria AT	63,33	64,68	69,77	10,17
Belgium BE	54,23	59,39	61,22	12,89
Bulgaria BG	31,18	35,52	38,26	22,71
Croatia HR	63,37	58,95	63,38	0,02
Cyprus CY	50,21	49,46	55,75	11,03
Czechia CZ	59,69	69,11	70,45	18,03
Denmark DK	68,65	69,62	81,45	18,65
Estonia EE	56,37	62,61	62,52	10,91
Finland FI	79,18	81,99	80,98	2,27
France FR	61,96	59,67	65,74	6,10
Germany DE	48,92	52,22	59,55	21,73
Greece GR	52,48	52,40	50,96	–2,90
Hungary HU	49,09	58,89	57,32	16,77
Ireland IE	70,49	72,91	82,82	17,49
Italy IT	45,60	45,75	54,27	19,01
Latvia LV	50,80	45,34	48,43	–4,67
Lithuania LT	48,84	52,91	53,80	10,16
Luxembourg LU	63,79	60,14	62,40	–2,18
Malta MT	61,23	63,02	66,80	9,10
Netherlands NL	78,94	82,70	83,61	5,92
Poland PL	42,93	44,30	50,42	17,45
Portugal PT	55,31	55,97	59,15	6,94
Romania RO	27,82	27,73	31,84	14,45
Slovakia SK	55,18	51,31	53,56	–2,94
Slovenia SI	49,67	46,70	46,50	–6,38
Spain ES	64,16	66,18	66,50	3,65
Sweden SE	66,60	66,44	69,99	5,09

However, the standard deviation (approximately 12-13%) indicates that disparities between countries remain substantial, reflecting a structurally uneven development process. This stable dispersion suggests that the entire distribution of digital skills is shifting upwards, rather than exhibiting strong "catch-up" convergence (beta-convergence), in which lagging countries grow fast enough to close the gap with the leaders.

While aggregate progress is evident, convergence across Member States remains incomplete.

Cross-country comparisons reveal significant heterogeneity. The highest-performing countries, including the Netherlands (83,61%), Ireland (82,82%), Denmark (81,45%), and Finland (80,98%), consistently maintain high levels of digital competence. These nations demonstrate characteristics of digitally mature economies, where digital skills are deeply integrated into both the labour market and daily life. Their success is driven by proactive e-government policies, lifelong learning initiatives, and early integration of digital literacy into primary education. In contrast, Romania (31,84%) and Bulgaria (38,26%) remain well below the EU average, underscoring persistent structural disadvantages related to education systems, digital infrastructure, and socio-economic conditions. The nearly threefold gap between the highest and lowest values illustrates the enduring nature of the digital divide, posing a significant challenge to the uniform deployment of digital business models across the single market. Regional patterns offer additional insights into structural differentiation. Western and Northern European countries lead the rankings, supported by robust institutional frameworks, advanced educational systems, and well-developed digital ecosystems. These countries benefit from sustained investments in human capital and digital infrastructure, resulting in higher levels of digital competence.

Central and Eastern European countries, by contrast, display more heterogeneous trajectories. The Visegrád countries exemplify this variation: Czechia (70,45%) approaches Western European levels and serves as a regional frontrunner, whereas Hungary (57,32%), Poland (50,42%), and Slovakia (53,56%) remain below the EU average. This divergence indicates that, even within similar historical and economic contexts, national policy choices and institutional capacities are critical in shaping digital skill development.

Temporal changes were analysed using a repeated measures ANOVA. Mauchly’s test of sphericity was not significant (p = 0,295), confirming that the assumption of sphericity was met and enabling reliable interpretation of the results (Table 7.).

Table 7. Mauchly’s test of sphericity for repeated measures ANOVA (2021-2025). Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix. Design: Intercept, within subjects design: year.

Measure: MEASURE_1							
Within Subjects Effect	Mauchly’s W	Approx. Chi-Square	df	Sig.	Epsilon*		
					Greenhouse--Geisser	Huynh--Feldt	Lower--bound
Year	0,907	2,440	2	0,295	0,915	0,981	0,500

*may be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the tests of Within Subjects Effects table.

The ANOVA results reveal a significant effect of time ($F(2,52) = 20{,}713$; $p < 0{,}001$; $\eta^2 = 0{,}443$), indicating a statistically significant increase in digital competences over time, Table 8. The large effect size demonstrates that the observed change is both statistically and substantively meaningful, reflecting systematic improvement rather than random variation. Crucially, the partial eta squared indicates that over 44% of the variance in digital skill levels can be directly attributed to the passage of time and the accompanying socio-economic developments. To further verify the robustness of the findings, multivariate test statistics:

Pillai's Trace (0,584) and Wilks' Lambda (0,416) were also examined (Table 9), both of which confirmed a significant time effect ($p < 0,001$). This indicates that the results are stable and consistent across different statistical criteria. The linear trend is particularly pronounced ($F(1,26) = 30,261$; $p < 0,001$; $\eta^2 = 0,538$), whereas the quadratic component is not significant ($p = 0,072$), indicating a steady and continuous upward trajectory without structural breaks, Table 10. This pattern suggests that digital competence development follows a cumulative path, likely driven by gradual improvements in education, digital access, and policy interventions.

Table 8. Repeated measures ANOVA results for digital competences. Tests of Within-Subjects Effects, 2021-2025.

Measure: MEASURE_1							
Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial η^2
Year	Sphericity Assumed	320,105	2	160,053	20,713	< 0,001	0,443
	Greenhouse-Geisser	320,105	1,830	174,935	20,713	< 0,001	0,443
	Huynh-Feldt	320,105	1,961	163,207	20,713	< 0,001	0,443
	Lower-bound	320,105	1,000	320,105	20,713	< 0,001	0,443
Error	Sphericity Assumed	401,810	52	7,727			
	Greenhouse-Geisser	401,810	47,576	8,446			
	Huynh-Feldt	401,810	50,995	7,879			
	Lower-bound	401,810	26,000	15,454			

Table 9. Multivariate test results for temporal changes in digital competences (2021-2025). Design: Intercept, Within Subjects Design: Year.

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial η^2
Year	Pillai's Trace	0,584	17,558*	2,000	25,000	< 0,001	0,584
	Wilks' Lambda	0,416	17,558*	2,000	25,000	< 0,001	0,584
	Hotelling's Trace	1,405	17,558*	2,000	25,000	< 0,001	0,584
	Roy's Largest Root	1,405	17,558*	2,000	25,000	< 0,001	0,584

*exact statistic

Table 10. Polynomial contrasts for temporal trends in digital competences. Tests of Within-Subjects Contrasts (2021-2025).

Measure: MEASURE_1							
Source	Year	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial η^2
Year	Linear	300,664	1	300,664	30,261	< 0,001	0,538
	Quadratic	19,441	1	19,441	3,523	0,072	0,119
Error	Linear	258,331	26	9,936			
	Quadratic	143,479	26	5,518			

Although the steady linear growth identified by statistical models is promising, it reveals a challenging scenario when compared to the European Commission's Digital Decade objective of 80% adult digital literacy by 2030. Projections based on the current linear growth rate indicate that the EU average is unlikely to reach the 80% target by the end of the decade without the implementation of significant policy interventions.

Despite the overall positive trend, significant heterogeneity persists. Countries with lower baseline levels often experience faster relative growth, reflecting convergence dynamics identified in development economics. However, this convergence is partial and uneven. Some countries exhibit stagnation or temporary decline, indicating that progress is not assured and may be affected by external shocks, policy discontinuities, or structural constraints.

Another important implication is that the observed increase in average values does not necessarily indicate uniform improvements across all population groups. The A+B indicator captures a threshold level of competence but does not reflect the depth or quality of digital skills. Therefore, while the increase is encouraging, it should be interpreted cautiously regarding long-term competitiveness and labour market adaptability.

The findings align with the results of the Principal Component Analysis presented earlier. The first principal component, representing a general competence gradient, closely matches the distribution of the "advanced" indicator. This confirms that the A+B category is both policy-relevant and statistically grounded, capturing the underlying structure of digital competences.

Overall, the results demonstrate that digital competences in the European Union are improving over time (Figure 2) yet the process remains uneven and structurally differentiated. Persistent disparities underscore the ongoing need to address the digital divide, both between and within countries.

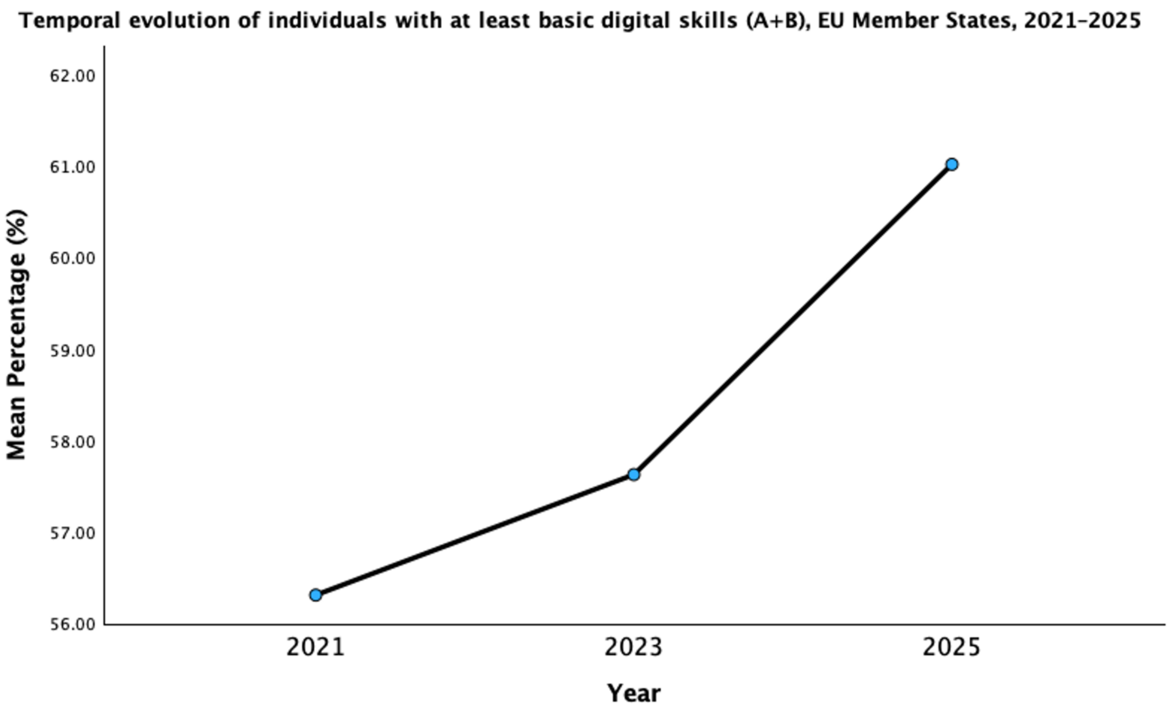

Figure 2. Temporal evolution of digital competences (A+B), 2021-2025.

From a structural perspective, the results suggest that digital competence development is path-dependent and shaped by long-term institutional factors. Countries with strong educational systems and proactive digital policies tend to sustain their advantage, whereas lagging countries experience cumulative disadvantages.

From a policy perspective, achieving the Digital Decade targets requires improving average performance and addressing structural inequalities by supporting lagging regions through targeted interventions. Without these measures, the current trajectory may result in further polarization rather than convergence, concentrating the benefits of innovative business models in a few technologically elite Member States while leaving others behind.

CONCLUSIONS

This study presents a comprehensive assessment of the temporal evolution and structural characteristics of digital competences among European Union Member States within the context of the Digital Decade 2030 programme. By examining the proportion of individuals with at least basic digital skills (A+B category), the analysis provides a policy-relevant and empirically substantiated perspective on digital readiness in the EU.

The results demonstrate that digital competences have improved over time, as indicated by the increase in the EU average from 56,30% in 2021 to 61,02% in 2025. Repeated measures ANOVA confirms that this upward trend is statistically significant and associated with a substantial effect size, indicating that the observed progress reflects a systematic and cumulative development process. The strong and significant linear trend further suggests that digital competence development follows a stable and continuous trajectory, with no evidence of structural breaks during the examined period. However, the findings indicate that progress is not evenly distributed across Member States. Persistent cross-country disparities continue to characterize the European digital landscape. The gap between the highest-performing countries (such as the Netherlands, Ireland, Denmark, and Finland) and the lowest-performing countries (such as Romania and Bulgaria) underscores the enduring nature of the digital divide. This divergence reflects differences in economic development as well as structural inequalities related to education systems, digital infrastructure, and institutional capacity. The analysis also reveals important regional patterns. Western and Northern European countries consistently outperform other regions, benefiting from long-term investments in human capital and well-established digital ecosystems. In contrast, Central and Eastern European countries exhibit more heterogeneous trajectories. The case of the Visegrád countries illustrates that even within relatively homogeneous historical and economic contexts, national policy choices and institutional effectiveness play a decisive role in shaping digital outcomes. While Czechia approaches Western European levels, other countries in the region continue to lag behind, indicating incomplete convergence. From a theoretical perspective, the results support the interpretation of digital competence development as a path-dependent process. Countries with favorable initial conditions tend to maintain and strengthen their advantage, while those starting from lower baselines encounter structural barriers that impede convergence. Although some catching-up dynamics are evident, particularly in lower-performing countries, these remain partial and uneven, and do not eliminate overall disparities. A key limitation of the analysis is that the A+B indicator captures only a threshold level of digital competence and does not reflect qualitative differences in skills. Consequently, while the increase in average values indicates positive progress, it does not necessarily signify improvements in higher-order or advanced digital capabilities. This limitation has significant implications for labor market adaptability and long-term competitiveness, as the depth and complexity of digital skills are increasingly critical in a knowledge-based economy. The findings are consistent with the results of the Principal Component Analysis, which confirmed the existence of a strong underlying competence structure. This consistency supports the validity of the applied categorization and demonstrates that the "advanced" indicator effectively captures the latent dimension of digital competences. From a policy perspective, the results indicate that achieving the targets of the Digital Decade 2030 programme requires a dual approach. Continued efforts are necessary to raise the overall level of digital competences across the EU, while targeted interventions must address persistent structural inequalities. Policy measures should prioritize investments in digital education, infrastructure development, and inclusive access, particularly in lagging regions. Without such targeted actions, the current trajectory may reinforce polarization rather than promote convergence. In conclusion, although the European Union has achieved measurable progress in improving digital competences, the persistence of structural disparities indicates that digital transformation remains uneven. Addressing these inequalities is essential for ensuring inclusive growth, enhancing economic competitiveness, and achieving the strategic objectives of the Digital Decade.

LIMITATIONS AND SUGGESTIONS

Several limitations should be acknowledged when interpreting these results. The analysis relies on secondary data from Eurostat, which restricts the study to the indicators provided. While these data are standardized and comparable across the European Union, detailed socio-economic, cultural, and educational variables could not be directly included. This limitation reduces the capacity to investigate causal relationships, especially within specific demographic groups. Future research should prioritize targeted data collection at the Member State level, particularly through the expansion of survey modules addressing digital skills. Such efforts would facilitate more precise longitudinal analyses and yield a deeper understanding of regional and social disparities. Additionally, supporting the measurement and development of digital competences at the primary education level is recommended, given that digital inequalities often arise early. Future studies should also integrate quantitative approaches with qualitative methods, such as interviews and focus groups, to obtain deeper insights into the social determinants of digital skill gaps and individual experiences. In light of the rapid digital transformation, ongoing research, continuous data analysis, and systematic monitoring of temporal trends are essential to inform evidence-based policymaking and to enhance understanding of the evolving dynamics of digital competences.

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