The nexus between digital skills/competences and work: A bibliometric study

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The nexus between digital skills/competences and work.

A bibliometric study[1]

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Abstract

The widespread use of computers and other new information and communication technologies (ICT) in every realm of society has increased the demand for specific skills and competences for people at any age and stage of life to use and work with ICT effectively. Summarised under the terms "digital skills" and "digital competences" by the European Commission in 2018, these concepts still lack clarity and are characterised by some ambiguity though much research has been devoted to them. Given that these two concepts are of high topicality with regard to current labour market developments, like skills mismatch, the digital divide or the design and implementation of occupational retraining programmes, the main purpose of this paper is to contribute to a more clear-cut understanding of the nexus between digital skills/competences and work. To accomplish this goal, we carry out a bibliometric study consisting of both quantitative and qualitative analysis. Our main findings are that research on the nexus between digital skills/competences and work is evolving and this research field is anchored in many different scientific disciplines and shares thematic overlaps with various other areas such as higher education research. The qualitative part of our analysis reveals that this research field is defined by six building blocks with one motor theme on "digital literacy". Furthermore, employment or employability as well as the effects of changing technologies at the workplace are the most crucial topics addressed in this research field, reflecting the high value attributed to digital skills/competences in determining the employability of the current and future workforce.

1. Introduction

Different waves of computerization have invaded almost every realm of society since the 1940s. Following the first wave associated with mainframe computing, the second wave started in the 1970s, when the first commercially available microprocessor – the Intel 4004 – came up, paving the way for the use of personal computers. Distinct of the third wave was the rise of the Internet that got commercialized in the late 1980s and has been established as the global digital communication infrastructure facility since then. Up to today, all of these information and communication technologies (ICT) have gained widespread ground and their diffusion went along with deep structural and organisational changes in the economy. Yet, the latter are characterised by a high degree of inertia:

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focusing on the labour market, a good example is the development of the skills and competences necessary for people at any age and stage of life in order to use and work with ICT effectively.

To grasp these specific skills and competences in a coherent manner and develop adequate policy measures to promote their development, the concepts of "digital skills" and "digital competences" emerged in the public discourse some years ago. The European Commission (2018, p. 9, emphasis added) defines digital competences and digital skills in the following way:

> *Digital competence* involves the confident and critical use of Information Society Technology (IST) for work, leisure and communication. It is underpinned by *basic skills in ICT*: the use of computers to retrieve, assess, store, produce, present and exchange information, and to communicate and participate in collaborative networks via the Internet. Digital competence requires a sound understanding and knowledge of the nature, role and opportunities of IST in everyday contexts: in personal and social life as well as at work. This includes main computer applications such as word processing, spreadsheets, databases, information storage and management, and an understanding of the opportunities and potential risks of the Internet and communication via electronic media (e-mail, network tools) for work, leisure, information sharing and collaborative networking, learning and research. Individuals should also understand how IST can support creativity and innovation, and be aware of issues around the validity and reliability of information available and of the legal and ethical principles involved in the interactive use of IST.

According to this definition, digital skills are complementary to digital competences – they underpin them. However, there are also alternative definitions that use these two concepts interchangeably and as synonyms as emphasised by Spante et al. (2018). It is our impression that despite not new, these two concepts still lack conceptual clarity and are characterised by some ambiguity. To clarify on these concepts and their meaning, several scientometric and bibliometric studies have explored the use of these two concepts in higher education research; see e.g., Spante et al. (2018) or Fernández-Batanero et al. (2020). However, the relevance of these two concepts is not limited to the education sector and to the education of the future workforce such as to prepare them to use ICT effectively. Quite the contrary, their relevance is much more far-ranging, and we presume that they are also of high topicality concerning current labour market developments, like skills mismatch, the digital divide or the design and implementation of occupational retraining programmes.

Against this background, the main purpose of this paper is to contribute to a more clear-cut understanding of the nexus between digital skills/competences and work.

To the best of our knowledge there are hardly any reviews that address this literature strand, which might have to do with the fact that it cannot be easily delimited. A rare exception is Oberländer et al. (2020), who provide a systematic review on definitions, theories and frameworks of digital competences at work, in particular white-collar office work. Different to them, we decided not to restrict our analysis to single types of work (e.g., office work). What further distinguishes our research from Oberländer et al. (2020) is that the authors merely focus on literature published in the field of psychology, sociology and education research. We find it, however, more promising not to limit our study to specific academic disciplines and single out any specific theories, respectively definitions or frameworks of these two concepts at work. Thus, we address a more diverse literature strand consisting of studies that contextualise these two concepts to the workplace and/or to labour market-related aspects. In this way, we are able to develop a full-fledged picture on the topic at hand.

More specifically, this paper addresses the following research questions:

- *Research question 1*: *What are the basic characteristics of the literature on the nexus between digital skills/competences and work and how does the social and conceptual structure of this research field look?*
- *Research question 2*: *What are the main themes defining this research field?*
- *Research question 3: What dimensions of work and which labour market-related aspects are addressed in this research field and what are its results and findings?*

To answer these research questions, we carry out a bibliometric study and we chose a top-down research design, starting with a very broad perspective on the research topic and going then into detail step-by-step: After reporting on a first set of bibliometric indicators revealing the social and conceptual structure of this research field (research question 1), we carry out co-word analysis as well as thematic mapping in order to answer research question 2. This is then complemented by a content analysis-based literature review aiming at answering research question 3. Our data material are peer-reviewed, open-access articles published in English which we retrieve from Scopus and WOS. For the bibliometric study we use the software programme R and especially the R-package bibliometrix (Aria and Cuccurullo, 2017).

We think that this constitutes a very interesting research topic as it informs the readership about a supposedly very dynamic and versatile knowledge domain that is of relevance not just for policy-making, e.g., in the field of vocational training but for anyone engaged in the scientific discourse and debate about technology-driven changes in the demand for and supply of skills and competences of the workforce.

The proposed research agenda is original as it promises to bring forth new insights into a research field that to our best knowledge has not been systematically reviewed so far. Especially, its originality lies in the comprehensive mixed-method analysis carried out that brings forth both quantitative *and* qualitative evidence on the nexus of digital skills and digital competences and work.

The remainder of this paper is organised as follows: Section 2 describes the collection, selection and preparation process of the document sample underlying our bibliometric study. Section 3 reports the results and findings. Section 4 provides a final discussion and highlights some concluding remarks.

2. Collection, selection and preparation of document sample

In this paper, we used a mixed-methods approach to accomplish our research goal of clarifying on the meaning of digital skills and digital competences as applied and used in the actual working world. As highlighted by Oberländer et al. (2020) among others, there is no consensus on the terminology, frameworks and definitions used for capturing ICT-related skills. Therefore, we decided to summarise them under the umbrella term “digital skills/competences”.

To collect and prepare the data material underlying our bibliometric study, we followed the PRISMA 2020-guidelines (Page et al., 2021) and to search for potentially relevant publications for our bibliometric study, we reverted to two scientific databases, namely Web of Science (core collection), henceforth “WOS”, and Scopus. We retrieved our initial document sample from these two databases using the following search string:

- (“digital competenc*” OR “digital skill*” OR “digital literac*”) AND (“labour” OR “employ*” OR “work” OR “job”)

The search strings were worked out by the first author and then discussed, refined and revised by all authors.

We narrowed the document collection in Scopus to the three tags “title, abstract and keywords” and in WOS these are subsumed under the field “topic”. We think that restricting to these tags is well-justified as the information provided under these tags is given by the authors themselves and it is typically chosen with the intention to convey as much information on the article as possible. See also Spante et al. (2018) for a similar approach.

In order to assure reproducibility of our search strategy and selection process, we specified the following inclusion and exclusion criteria (i)-(iv) detailed in Table 1:

Category	*Inclusion criteria*	*Exclusion criteria*
(i) Document type	peer-reviewed journal articles	other document types (e.g., books, conference papers and proceedings, reviews)
(ii) Language	main text in English	main text is not in English (though Title, Abstract and Keywords may be)
(iii) Accessibility	all open access, Gold, Hybrid Gold, Bronze, Green and accessible from the authors’ institution(s) (full digital access via the Internet)	non-open access or non-accessible
(iv) Thematic relevance	Thematic relevance – focus on the application and use of digital skills and digital competences at work, respectively their nexus to labour market-related aspects	thematic irrelevance

Table 1: Inclusion and exclusion criteria for the data collection process.

Note that in terms of exclusion and inclusion criteria we did not impose any restrictions on methodological grounds, scientific discipline or on time and place of publication.

A more detailed description of the collection, screening and review process in order to prepare the documents for the bibliometric study is illustrated in Figure 1.

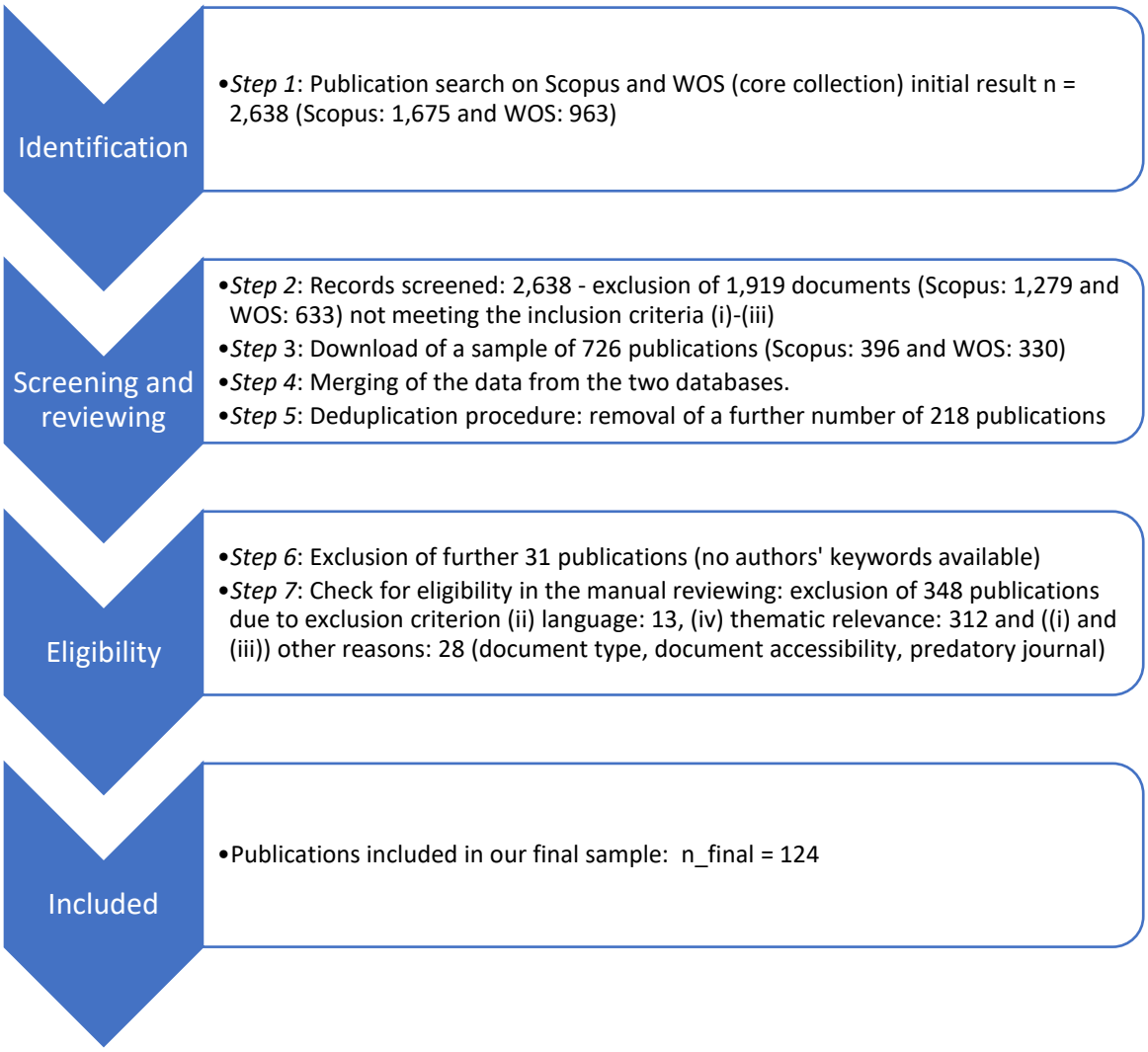

Figure 1: Material selection process – main steps. Own illustration.

Step 1 – Identification: Our initial search on Scopus and WOS led to a sample of 2,638 papers.

Steps 2-5 – Screening and reviewing:

In the first round of screening, we applied the inclusion and exclusion criteria (i)-(iii) in the two databases. By means of this step, 1,919 paper were excluded and we then downloaded the sample of altogether 726 documents from the two databases (Scopus: 396, WOS: 330) on May 19, 2021. Note that no iterative search was conducted.

Then, the data was merged and the deduplication process was started both manually and automatically, using Microsoft Excel and Citavi as a supporting software. As the unique identifier for the deduplication procedure we used the DOI. Note that in Scopus seven publications had no DOI but instead of the DOI were designated the attribute "final" or "article". Since these were hidden duplicates *within* the Scopus dataset, these were immediately excluded. Furthermore, in the dataset downloaded from WOS, 47 publications did not have a DOI such that we had to check for their uniqueness manually and used the "Title" and "Authors" as alternative identifiers for the duplicates. Through this manual procedure we found another seven duplicates. The automatic deduplication procedure according to the DOI revealed a further number of 204 duplicates which were removed from the merged sample such that altogether, the deduplication procedure resulted in a number of 508 unique entries of the merged dataset.

Steps 6-7 – Eligibility: From this set of 508 publications satisfying our inclusion criteria, a further number of 38 articles did not include author keywords, such that we amended them manually through internet search. For a set of seven articles, keywords could be amended by this procedure, whereas 31 articles for which no keywords could be found were excluded as these do not qualify for parts of the bibliometric analysis, i.e., the co-word analysis and the content analysis-based literature review. The remaining 477 articles were screened manually and this procedure led to the exclusion of a further number of 348 articles:[2] These proved to be non-eligible due to (ii) language (i.e., not in English) (13) or (iv) topic irrelevance (312) or for other reasons (i) and (iii) (i.e., document is published in a predatory journal[3] or is not peer-reviewed, wrong document type or non-accessibility (28)). The remaining 124 articles in our final document sample were reviewed by the corresponding author in order to make sure that they are certainly relevant for the bibliometric study. The basis for categorizing a single document into either "relevant" or "irrelevant" at this stage were the "Title", "Abstract" and "Conclusion/Discussion".[4,5]

For the co-word analysis, the thematic mapping and the content analysis-based literature review, we had to carry out a data cleaning and standardisation procedure. This was applied to the authors' keywords as these are the basis for this part of the analysis. Initially, 501 authors' keywords were linked to the 124 documents. With regard to the data cleaning and standardisation procedure, our goal was to revise as few as possible but as much as required in order to ensure high quality and an unbiased set of keywords: Note that plural forms of keywords were standardised to the corresponding singular form[6] as well as American English to British English. Moreover, synonyms were merged (e.g., "flipped classroom approach" and "inverted classroom approach") and misspellings were corrected. Whenever existing, specific technical terms were summarised under an umbrella term, e.g., tMOOCs, sMOOCs under "MOOCs", academic teacher, professor, university staff, scientists under "academics", e-learning, digital learning and distance learning under "technology-mediated learning" or use of ICT, Internet use under "technology integration". To avoid any misinterpretation of authors' keywords in the standardisation and cleaning procedure, we again cross-read the definitions and use of these specific technical terms in the publications themselves. We also removed method-related terms (like ANOVA, Bayesian statistics, cluster analysis, qualitative analysis, semi-structured interviews etc.) and excluded countries as keywords. This standardisation and cleaning procedure resulted in a final set of 300 keywords.

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[2] Numbers in brackets indicate the articles excluded due to the exclusion criteria numbered according to Table 1.

[3] Predatory journals were filtered according to the Open Access Journal List as well as the List of Suspicious Journals and Publishers of the Yale Library.

[4] Note that in the first round of screening a few articles could not be assigned as either thematically relevant or irrelevant. Therefore, these were reviewed by all authors again and in a second round, each paper could be assigned as either relevant or irrelevant with regard to its topic.

[5] To delineate our document sample in terms of its focus on the working world, respectively labour market-related aspects, we took the following further steps: We decided to include papers where the focus was on teachers' development of digital competences but excluded those where the focus is on future teachers' (students') development of digital competences. We did so as the former are already in the labour force and thus there is an explicit link to work, whereas this is not the case for the latter. Also note, that professional training, on-the-job training as well as employees' education is accounted for in our sample whereas the education of students at universities or pupils'/children's acquisition of digital skills/competences in schools or other education institutions is not captured.

[6] There is one exception, where we used the plural form as this is more common, namely all terms including "skill" and "competence".

3. Results and findings

3.1. Basic characteristics of the document sample

We first of all report some basic bibliometric indicators of our document sample: Figure 2 reveals the yearly distribution of publication activities in this research field. It can be seen that after 2014 there is a sharp increase in annual scientific production of articles focusing on the nexus between digital skills and digital competences and work, which follows almost an exponential trend. Hence, from this time onwards, the number of publications in this research field accelerated. Note that the drop in publication activities in 2021 is owed to the fact that the sample includes only published material published before our search date on May, 19th 2021. However, since the material included in the sample with the publication year 2021 covers less than half of the year and already 20 articles were published in these 5 months (which is almost the number of articles published in total in 2019), it can be expected that the positive trend of the preceding years is going to continue.

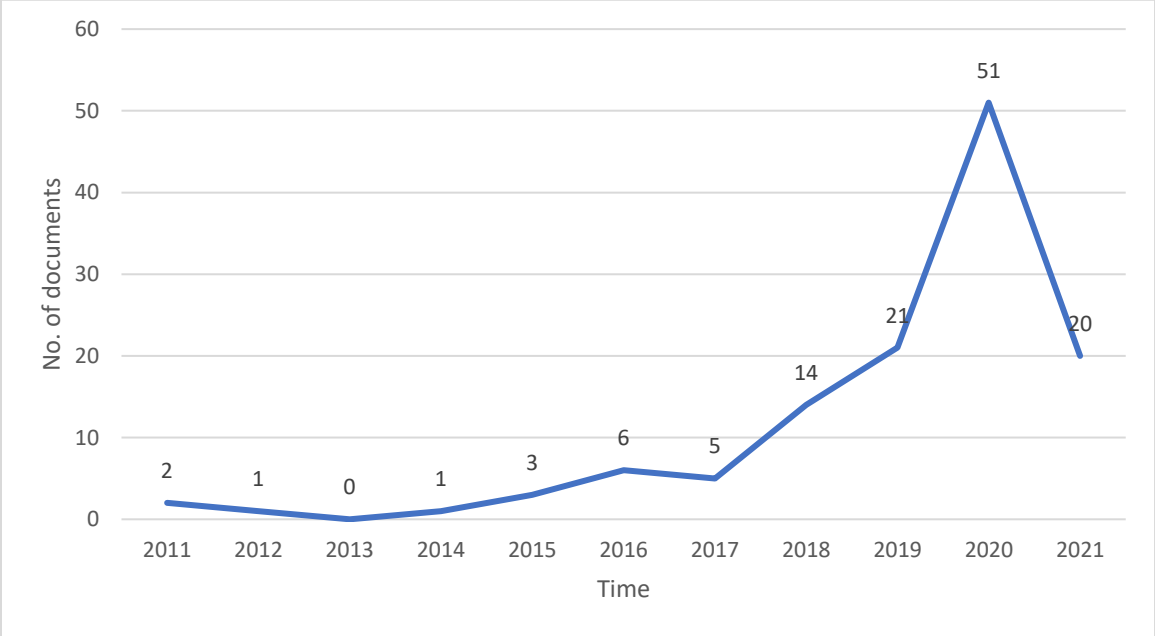


Figure 2: Yearly distribution of publication activities of articles satisfying our inclusion criteria.

Altogether the 124 documents of the sample were published in 100 peer-reviewed journals. Such a high number of peer-reviewed journals underlying the relevant document sample points towards a highly dynamic research field. Taking in a next step a closer look at the most relevant sources of publication as illustrated in Figure 3, these are *Sustainability* (7 articles), followed by *Education and Information Technologies* (5 articles) and *Economics*, *the Nordic Journal of Digital Literacy* and *the Universal Journal of Educational Research* (3 articles in each of them). The top-ranking position of *Sustainability* is a particularly interesting finding, since this is a cross-disciplinary journal explicitly targeting research with a thematical focus on environmental, cultural, economic and social sustainability issues or a mixture thereof. This gives a first hint that research in this field is of an interdisciplinary nature. With regard to the second most prominent publication source, that is *Education and Information Technologies*, this primarily covers research focusing on the relationship between ICT and education, indicating that despite its focus on work-related aspects, the document sample underlying our bibliometric analysis also clearly relates to educational research. Finally, the three journals being ranked third in our sample have very diverse research foci and address different audiences, ranging from academia up to policymakers from different disciplines and fields.

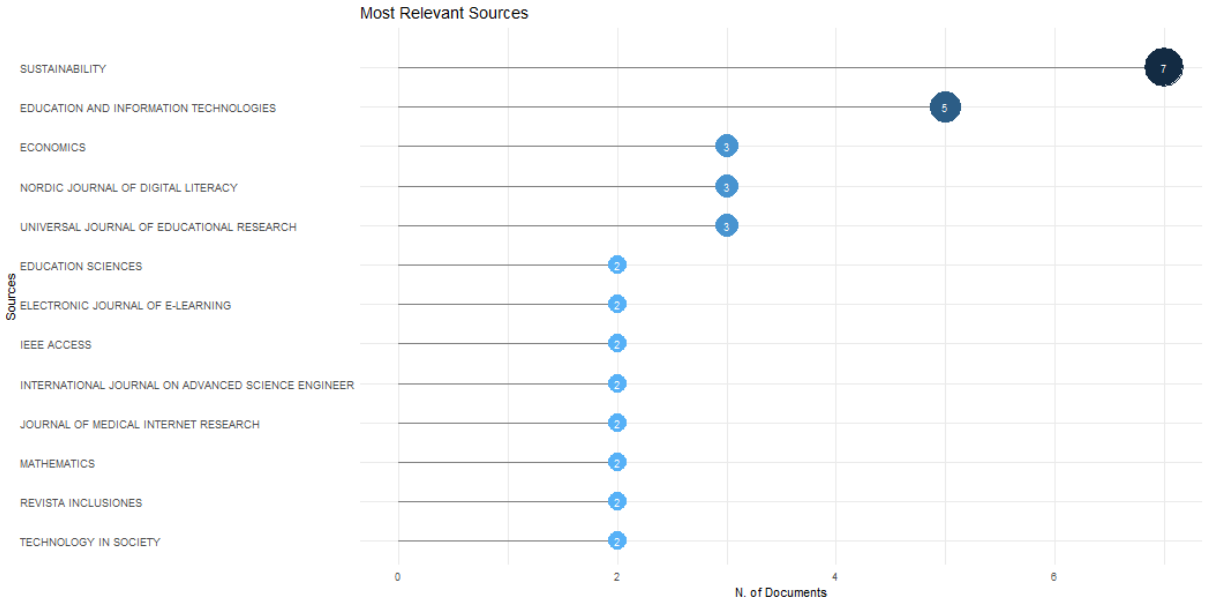
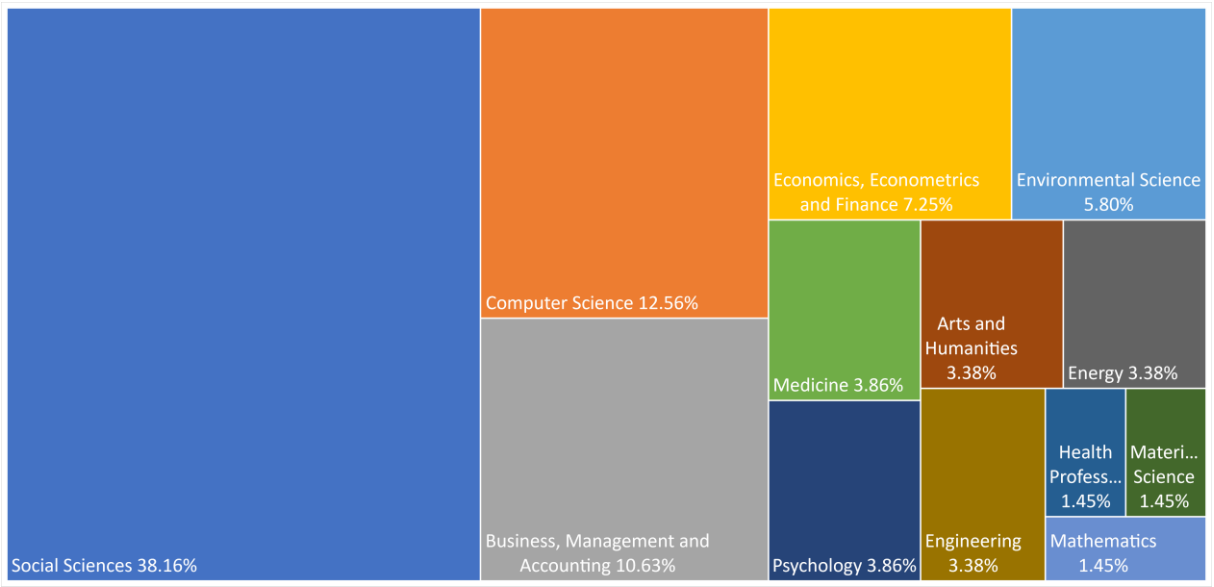


Figure 3: Most relevant publication sources. Note that the graphical illustration includes just those 15 peer-reviewed journals in which at least two articles were published.

To get a first impression on the conceptual structure of this research field, we look at the different subject areas associated with the 100 peer-reviewed journals in which articles included in our document sample are published. We consider this as a useful initial step for delimiting this research field. Subject areas as illustrated in Figure 4 are defined according to the classification used by SCOPUS[7] and they are assigned by SCOPUS to the journals and not to the articles themselves.

On average 1.62 subject areas are mentioned on the 124 documents included in our document sample, and about the half of documents are associated with at least two subject areas which we consider as a proxy of the interdisciplinarity of this knowledge domain.



[7] Note that for those documents in our sample taken from WOS, we looked up the journals in SCOPUS to identify the relevant subject areas.

Figure 4: Subject areas of the bibliometric sample. Own illustration. Note that the classification of subject areas is used by SCOPUS. Note also that the subject areas are not assigned to single papers but to the journals in which the papers are published.

As can be seen from Figure 3, the most relevant subject area that marks research in this knowledge domain are the Social Sciences, with a relative frequency of 38.16% of all mentions on the documents included in our sample. This is followed by Computer Science (12.56%) as well as Business, Management and Accounting (10.63%). There is a bulk of subject areas, including Psychology, Medicine, Engineering, Energy as well as Arts and Humanities which are almost equally ranked (3-4%). Furthermore, Health Professions, Materials Sciences and Mathematics each account for 1.45% of mentions. Finally, the remaining six subject areas – i.e., Agricultural and Biological Science, Earth and Planetary Sciences, Multidisciplinary, Neuroscience, Nursing as well as Pharmacology, Toxicology and Pharmaceutics – are niche fields and are thus only scarcely mentioned, attaining a relative frequency of mentions of 1% or less.

These findings support our initial impression that research on the link between the application and use of the two concepts "digital skills" and "digital competences" and work is interdisciplinary: it touches a broad field of subject areas and articles with that specific research focus fall into a wide array of scientific disciplines.

3.2. Social structure of the document sample

Having reported some basic bibliometric characteristics of the document sample, we continue by reporting findings related to the social structure of research in this field.

Shifting the focus to the authors of the 124 articles included in the sample, these involved a number of 341 authors and 367 author appearances. There were only 15 single-authored documents, whereas the rest were co-authorships. On average, 2.75 authors contributed to an article and in Figure 5 you can see the most productive authors in this research field as measured by the author-weighted mentions on a document.

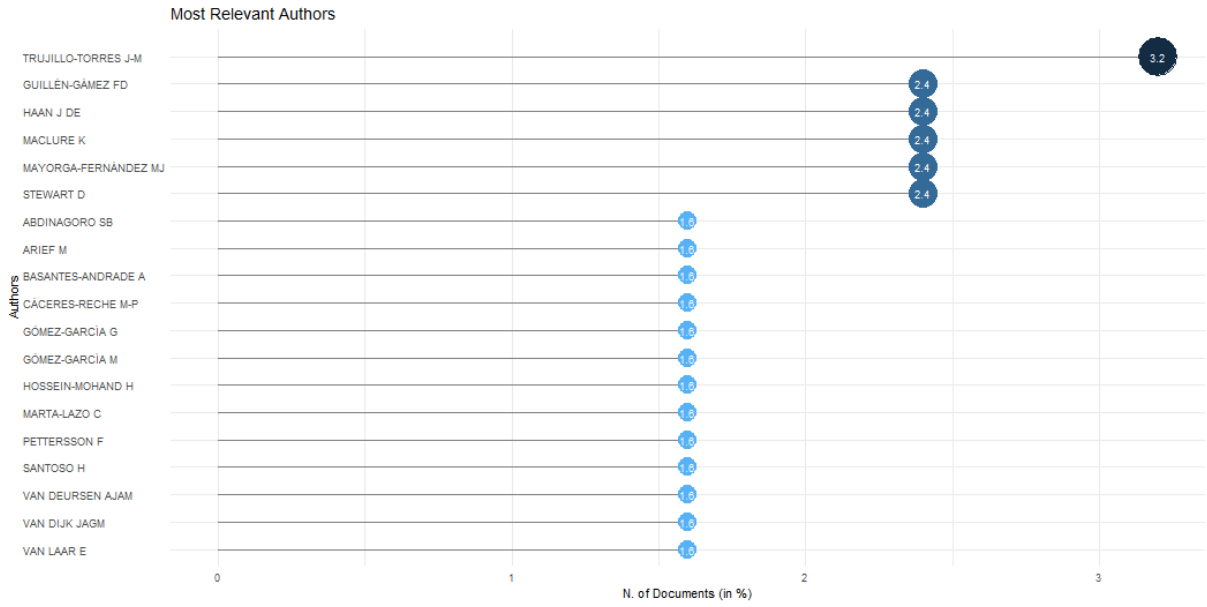


Figure 5: Most relevant authors. Note that the graphical illustration includes just those 19 authors who contributed to at least two published articles included in our document sample during the investigation period 2011-2021.

There is one outstandingly productive author (Trujillo-Torres JM) who contributed to 3.2% of articles which corresponds to an absolute number of 4 articles. A range of further authors, ranked second, each contributed to 2.4% of articles (3 in absolute numbers). Alike to the most important sources of publication, the finding that there is a high percentage (almost 95%) of authors who have just started publishing in this research field and who have not contributed to more than a single paper suggests that research in this area is still evolving. In other words, there is a low degree of persistence in authorships of the documents included in our sample.

While there is a low degree of persistence in authorships, a different picture emerges along the institutional dimension, where some institutions appear quite frequently on the single documents: Among the 188 institutions to which the 341 authors are affiliated, 18.6% (35 institutions in absolute numbers) are at least mentioned twice. The highest ranking position – as shown in Figure 6 – is filled by the University of Granada, to which not only the most productive author (Trujillo-Torres JM) but also his colleagues (Cáceres-Reche M-P and Gómez-García G), who are also ranked among most productive authors, are affiliated. Referring to our document sample, especially the University of Granada hosts a comparatively productive and leading research group in this field of research.

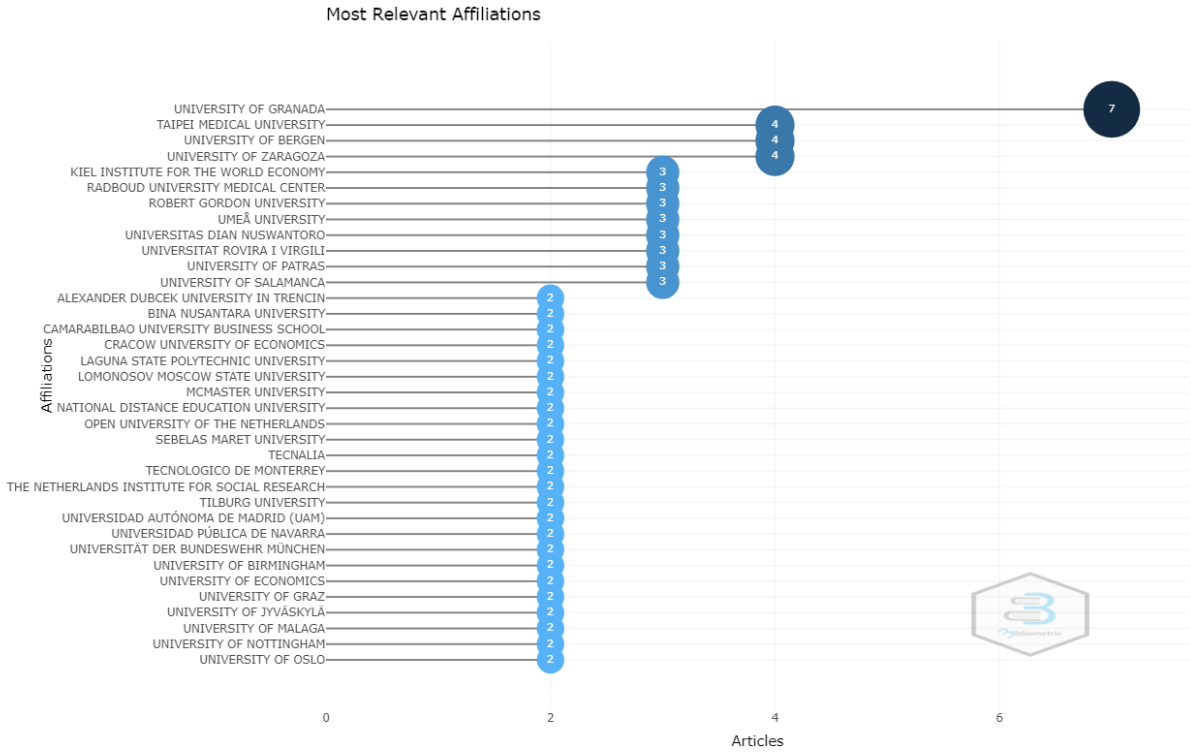


Figure 6: Most relevant affiliations. Note that the graphical illustration includes just those 35 institutions that appeared at least twice in our document sample.

Turning to the next bibliometric indicator of the social structure of research in this field, Figure 7 maps the distribution of publications across geography: This is counted by the number of mentions of a country in authors' affiliations and with almost 75% of all mentions, Europe is the most productive region across the world, followed by Asia (13%) and North America (4.6%). On a country level, we observe a rather uneven distribution of scientific production and resulting from this, a high degree of concentration: While there are a few highly productive countries, like Spain on the top of the ranking with 50 mentions, followed by the United Kingdom (25) and the Netherlands (14), there are some countries which are only mentioned once or not represented at all in the authors' affiliations in the 124 articles included in the document sample.

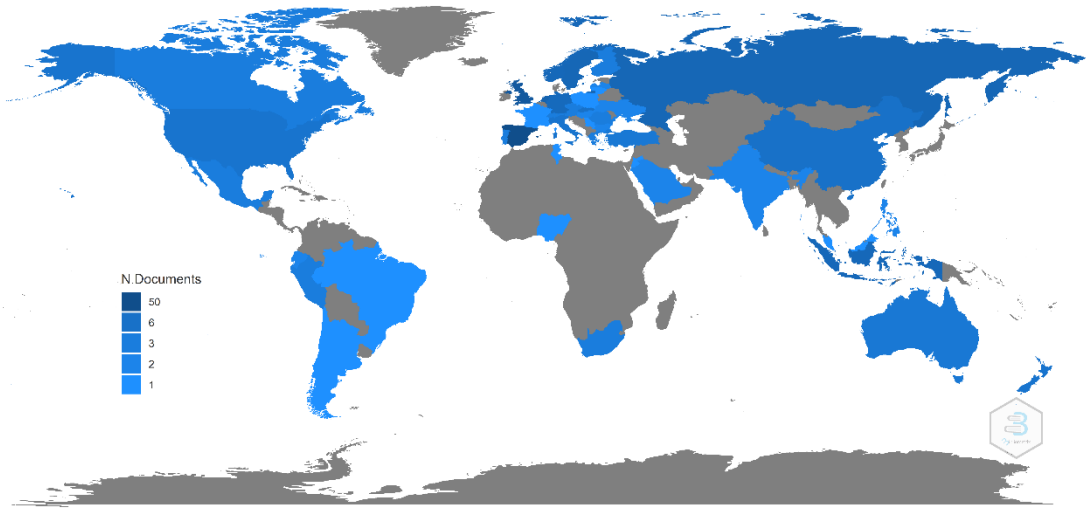


Figure 7: Country scientific production. Note that the colour intensity is proportional to the number of publications on which countries are mentioned in the authors' affiliation.

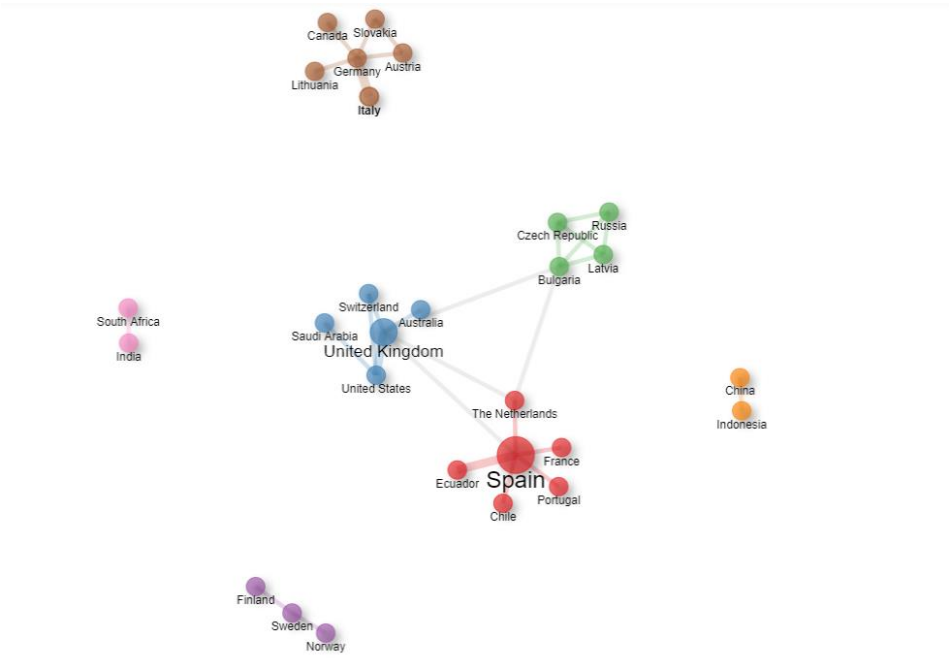


Figure 8: Country collaboration network. Note that we removed isolated nodes from the network and we used the Fruchterman-Reingold network layout and as a clustering algorithm we applied the Louvain method. Note also that, (1) the size of vertices is proportional to their degree centrality (2) self-loops have been left out for better visibility (3) the thickness of edges reflects the intensity of cross-country co-authorships. Data is normalised based on the association measure.

Looking at the social structure of this research field from yet another angle, in a next step we illustrate the collaboration network at the country level, as can be seen from Figure 8. What immediately gets evident from Figure 8 is that the network structure is not cohesive. There is a low density in cross-country collaboration and on the whole, international joint publication activities are sparse and not well-established in this research field.

Taking a closer look at the collaboration patterns between countries, it can be seen from the network structure that non-isolated nodes group into seven distinct communities and joint publication activities thus tend to cluster. In each of those seven clusters, cross-country collaboration proves to be comparatively strong, compared to collaboration with countries belonging to a different cluster. Most notably, only three clusters are connected to each other, including basically European countries, whereas the remaining four clusters are isolated subgraphs. The existence of such isolated but internally cohesive clusters may be due to various reasons: In the case of the cluster of Scandinavian countries (Finland, Sweden and Norway) this most probably reflects geographical proximity as well as low internal language barriers. Despite of all articles included in our document sample being published in English, low internal language barriers equally reveal themselves in intense collaboration between authors affiliated to Spanish speaking countries, like Spain, Ecuador and Chile. As can be further seen from Figure 8, this also holds true for the case of close collaboration patterns between the United States and the United Kingdom.

In terms of countries' status in the network as measured by normalised degree centrality[8], the following can be observed: The top-3 ranking positions are occupied by Spain (1), United Kingdom (0.705) and Germany (0.361). For the rest of countries, there is a sharp decline in degree centrality and hence, only a few countries dominate joint publication activities (see Table 4, Appendix). Noteworthy, the high degree centrality positions of Spain, United Kingdom and Germany are determined by co-authorships between domestic authors (more than 70%) again reflecting the unimportant role of cross-country joint publication activities.

3.3. Conceptual structure – co-word analysis and thematic mapping

Digging yet deeper into the conceptual structure of this research field, we apply the technique of "thematic mapping" as developed in Cobo et al. (2011). Thematic mapping builds on co-word analysis (Callon et al. (1991)), the latter serving as a content analysis technique for specifying the main building blocks, i.e., themes of this research field.

From a methodological viewpoint, in our case thematic mapping involves carrying out the following two steps, explained in more detail in Cobo et al. (2011, pp. 148-152): (1) identifying the building blocks, i.e., detecting the main themes treated by the research field by means of co-word analysis and (2) mapping the knowledge domain using a thematic network[9] and applying a clustering technique.

Altogether, the basis for the co-word analysis are 300 authors' keywords identified in our bibliometric sample. With regard to the occurrence of authors' keywords in the document sample and their frequency distribution there appears to be a natural cut-off: 222 authors' keywords occur only once in

[8] Note that for this metric the position of a node in the network is determined by the number of nodes it is incident to. Self-loops are double-counted for this metric. Note also that for standardised degree centrality, the individual centrality score of a node is divided by $N-1$, where N is the number of nodes in the network. Moreover, centrality scores are normalised along the $0-1$ interval, where 1 is adopted by the highest ranked node.

[9] Note that the goal of constructing a thematic network is to map the conceptual structure of bibliometric material, i.e., to identify "themes". Based on the concept of a weighted, undirected graph, nodes in the thematic network correspond to e.g., authors' keywords. Weighted edges connecting any pair of nodes reflect the frequency of their co-occurrence and it is assumed that this also sheds light on their conceptual relatedness. By applying a clustering algorithm to the thematic network, keywords can be grouped into themes, each characterised by two centrality indicators ("Callon density" and "Callon centrality").

the sample, whereas 78 at least twice. Therefore, the thematic mapping is based on those 78 keywords only. Figure 9 illustrates the thematic mapping, and the themes identified "can be understood as conglomerates of textual information or semantic/conceptual groups of different themes addressed by the research field" (Aparicio et al. (2019) p. 108).

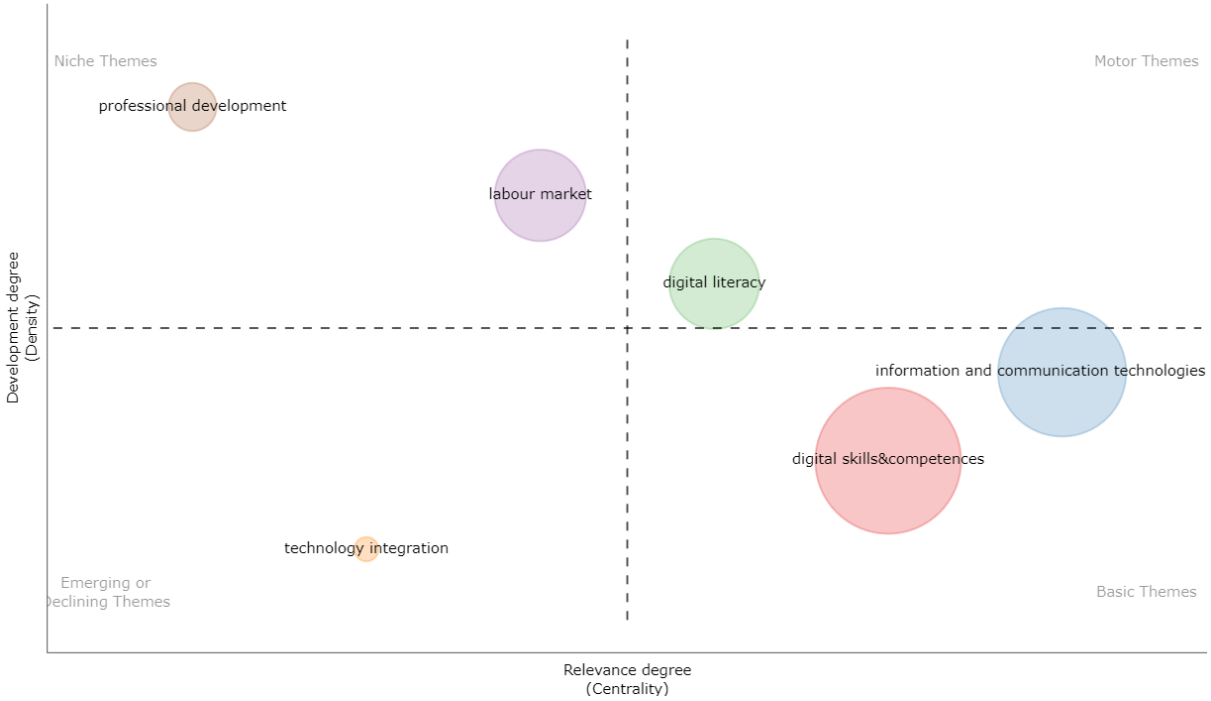


Figure 9: Thematic mapping. Own illustration. Note that for the thematic mapping, we chose the following parameters: The minimum cluster frequency was set at 30 (per thousand documents). In terms of the number of words occurring in the label of each cluster, this was generated based on unigrams and hence, the keyword with the highest co-occurrence frequency was decisive for labelling a cluster.

Figure 9 reveals six building blocks with the biggest cluster – in terms of the cumulative frequency of keywords – on "digital skills&competences" and the smallest one on "technology integration". There is only one building block, dubbed "digital literacy", that qualifies as a motor theme and that can be classified as well-developed and decisive for structuring the whole research field, according to the criteria identified by Cobo et al. (2011), that is a high Callon density and a high Callon centrality. On the other hand, the cluster "digital skills&competences" as well as the second largest cluster on "information and communication technologies" are transversal, basic themes. This means that both account for topics that are very important for the whole research field, i.e., have strong external ties and a high Callon centrality; but they are not well-developed and have only weak internal ties (a low Callon density). The fourth building block "labour market" together with the cluster on "professional development" are niche themes, which means that these are relatively unimportant for the research field as such but due to strong internal ties cover highly specialised themes. Finally, the cluster on "technology integration" is the only one that qualifies as an emerging (or declining) topic characterised by both weak external and internal ties and this building block is thus of only limited importance for the whole research field.

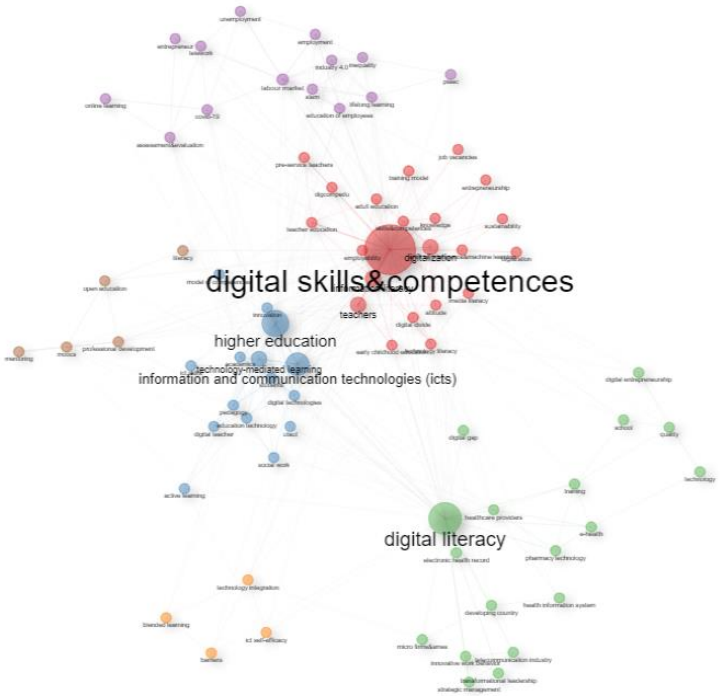


Figure 10: Co-occurrence network. Own illustration. Note that for the thematic mapping, we chose the following parameters: The minimum cluster frequency was set at 30 (per thousand documents). In terms of the number of words occurring in the label of each cluster, this was generated based on unigrams and hence, the keyword with the highest co-occurrence frequency was decisive for labelling a cluster. Note also that we decided to use the Louvain algorithm as a clustering technique.

As can be seen from Figure 10 that illustrates the co-occurrence network on which the thematic mapping is based, for the building block “digital skills&competences”, other prominent keywords are “digitalization” and “teachers”, while for building block “information and communication technologies”, “higher education” and "technology-mediated learning” are central nodes. In the building block “digital literacy”, the keywords “healthcare providers” and “e-health” rank 2nd and 3rd in terms of occurrence, indicating that documents associated with that cluster share a research focus on the health sector. Looking at the keywords that determine the building block "technology integration”, gives the impression that this is a emerging rather than a declining theme as it includes also novel concepts such as “blended learning” or “ICT self-efficacy” that may become a niche theme for the whole research field in the future. Distinct keywords for professional development are further “MOOCs” (massive open online courses), “mentoring” and “open education” reflecting well the high degree of specialisation of this theme. Not least, for building block “labour market” that is of particular interest in our research context, “assessment&evaluation“, education of employees”, “inequality”, “lifelong learning” and “Covid-19” are the most central nodes.

3.4. Content analysis-based literature review

3.4.1. Preparatory steps

In this section we complement our previous findings through another qualitative analysis. A content analysis-based literature review enables us to specify the link between the concepts “digital skills” and “digital competences” and work.

To identify the papers used for the content analysis-based literature review, we took the following steps: On the one hand, the authors individually screened the document sample, looking for those papers that have a predominant research focus on work and more generally, on labour-market related aspects. After discussing on the individual outcomes and doing some revisions, 33 papers were filtered by this manual screening procedure. On the other hand, we took the papers associated with the theme "labour market" from the thematic mapping as a basis, as these are expected to provide most detailed information on the use of these two concepts in work. In this regard, 18 papers were filtered. We then compared the two sets of manually and automatically filtered documents and took the intersection between them as the starting point for the content based-literature review. Moreover, two articles were excluded ex post as these did not focus on the link between digital skills and digital competences and work. Hence, the basis for the review are 7 articles.

We used a deductive approach to elaborate the coding scheme and select the relevant categories for our analysis. In a first instance, the categories and dimensions based on which the seven articles are evaluated are defined (see also e.g., Mayring (2014)). After an initial screening we refined the categories and the final coding scheme is shown in Table 2. Note that for the single sub-categories of "digital skills & competences" we relied on the definition of the DigComp framework[10] and to identify the relevant policy dimensions, we relied on the four key domains specified in the European employment guidelines[11].

Category	Description and details	Code
(1) Research focus	What is the topic addressed and covered by the research of this paper?	1
(2) Research aim/purpose	What is the main objective of the paper?	2
(3) Conceptual emphasis on "digital skills&competences"	Yes (dig.skills&comp as primary focus)	3a
	No (dig.skills&comp as a supporting concept to other discussions)	3b
(4) Research approach	Quantitative	4a
	Qualitative	4b
	Mixed	4c
	Theoretical/conceptual	4d
(5) Research design/method	Case study	5a
	Interviews	5b
	Survey/questionnaire	5c
	Literature review	5d
	Modelling/Simulation/Experiment	5e
(6) Level of analysis	Micro	6a
	Meso	6b
	Macro	6c
(7) Digital skills&competences context	Information and data literacy	7a
	Communication and collaboration	7b
	Digital content creation	7c
	Safety	7d
	Problem solving	7e
	No specific	7f

[10] See https://joint-research-centre.ec.europa.eu/digcomp/digital-competence-framework_en for details.
[11] See https://ec.europa.eu/social/main.jsp?catId=101&intPageId=3427 for details.

(8) Major conclusion	What are the key results of the paper with regard to the nexus between digital skills and digital competences and work, respectively labour market-related aspects?	8
(9) Policy dimension	Boosting demand for labour	9a
	Enhanced labour and skills supply	9b
	Better functioning of the labour markets	9c
	Fairness, combating poverty and promoting equal opportunities for all	9d
	no policy relevance	9e

Table 2: Coding criteria for reviewing the document sample n = 7. Note that for categories 5, 7 and 9 multiple assignments are permitted.

We then compared, discussed and revised our text coding results in an online meeting. The outcome of this process is presented in Table 3. Note that categories 1, 2 and 8 involved a textual assessment. For the sake of better readability, we decided to exclude them from Table 3. Instead, results from these three categories are only summarised in the discussion below.

3.4.2. Summary of results

(1) Research focus and (2) research aim/purpose: Carlisle et al. (2021), Ertl et al. (2020) as well as Zilian and Zilian (2020) focus on the digital divide: In light of the digitalisation and virtualisation of work, Carlisle et al. (2021) for a set of European countries aim at evaluating the existing as well as identifying the future proficiency levels of digital skills/competences in tourism and in hospitality companies such as to present measures for digital skills/competences development. Their study is part of a larger European survey that plans to establish a blueprint strategy for digital and sustainability skills and competences development in the EU.

Different to that, Ertl et al. (2020) investigate the socio-demographic factors affecting the digital divide. Within the scope of an intersectional and hierarchical analysis, they aim to uncover differences across Germany in digital problem solving skills for three different groups of persons: (i) with computer use at work and home, (ii) without computer use at work but at home, (iii) out of the labour force.

Finally, Zilian and Zilian (2020) set the research focus on Austria and address the questions: *"What impact do socio-economic background and gender have on digital competencies in the Austrian workforce?*" and *"In Austria, has digital inequality in terms of ICT use and derived digital skill levels decreased between 2012 (or 2015 depending on data availability) and 2019?".* Answering these research questions, the authors aim to uncover, the extent and development of digital inequality in the Austria workforce.

Considering digital skills competences as an important factor of employability, van Laar et al. (2019) address the sequential and conditional nature of 21st century skills. Concentrating in their research on

the creative industries in the Netherlands, they investigate the relatedness of different types of digital skills/competences with the aim of extending existing empirical knowledge on that topic.

Setting the primary research focus not only on employability but also on the adaptability of the workforce to use new digital technologies, Jandrić and Ranđelović (2018) answer the research question of how well the European workforce is prepared for the digital transformation. The main objective of their analysis is to evaluate the workforce skill adaptability in 30 European countries, distinguishing thereby between various types of digital and other skills and competences.

Krasnopjorovs (2020) and Piatkowski (2020) adopt a more general perspective on the labour market: While the latter studies the labour market effects of the digital transformation and whether as well as how these effects differ between European countries, the former focuses on the magnitude and structure of labour market reserves in the Baltic countries. Particular attention in Piatkowski (2020) is drawn on the current labour market situation with the aim to diagnose expectations towards current and future employees as to their required level of digital skills/competences. With a specific focus on digital skills/competences as well as lifelong learning, the objective of the study by Krasnopjorovs (2020) is threefold: First, the author seeks to quantify the labour market reserves, second, to identify population groups that need a particular attention by policymakers and third, to set out ideas for labour market policy of how to activate those labour market reserves.

(*3) Conceptual emphasis on digital skills and digital competences*: It is only in four cases that the primary focus is on digital skills and digital competences, whereas for the remaining three papers, viz. Jandrić and Ranđelović (2018), Krasnopjorovs (2020) and Piatkowski (2020) the primary focus is not on these two concepts alone.

(4) Research approach: Except for two articles (Carlisle et al. (2021) and Piatkowski (2020)) that have a mixed-method research approach, a quantitative research approach is chosen for the analysis: empirical data analysis based on statistical tools (descriptive statistics, regression analysis, principal component analysis, other econometric tools) and model-based empirical analysis.

(5) Research method: Interestingly, except for van Laar et al. (2019) all articles included a case study. In Carlisle et al. (2021) this case study was complemented by interviews and a survey/questionnaire and also van Laar et al. (2019) used a survey/questionnaire to accomplish their research goal. Interestingly, Piatkowski (2020) is the only paper that included a literature review to answer their research questions which is accompanied by an agglomeration-method based analysis. Also, van Laar et al. (2019) as well as Zilian and Zilian (2020) satisfy the sub-category "modelling/simulation/experiment", using a structural and path model, respectively econometric modelling to achieve their research goal.

(6) Level of analysis: None of the seven papers had a focus on the meso-level. Four papers are focused on the micro-level (Ertl et al (2020), Carlisle et al. (2021), van Laar et al. (2019), Zilian and Zilian (2020)) while the remaining three papers had a macro-level focus. On the micro-level the core units of analysis were either organisations or persons (professionals or private persons). Different to that, countries – mainly the EU member states – were the central units that were addressed from a macro-level perspective.

(7) Digital skills/competences context: in most papers, multiple types of digital skills/competences are investigated, either explicitly and/or implicitly. Most frequently, these are (1) information and data literacy, (2) communication and collaboration as well as (3) problem solving. The dimensions (4) digital content creation and (5) safety are under investigation in two cases, respectively one. And both in Kransopjorovs (2020) as well as Piatkowski (2020), no specific type of digital skills/competences are in

the foreground of the analysis but digital skills/competences are addressed rather as a general concept.

(8) Major conclusion: With regard to the major conclusions drawn in the single papers, we first of all summarise those focusing on the digital divide, i.e., Carlisle et al. (2021), Ertl et al. (2020) and Zilian and Zilian (2020):

For the case of Austria, Zilian and Zilian (2020) conclude that existing patterns of social inequality manifest in the distribution of digital skills and digital competences They use the test results of the assessment of the skill domain "problem-solving in technology-rich environments" (PSTRE) provided by the PIAAC survey to approximate for digital competences. More specifically, the authors identify a negative relationship between female gender and the PSTRE score as well as a positive impact of parental socio-economic background on the PSTRE score.

For Germany, Ertl et al. demonstrate that socio-demographic factors on digital skills (i.e., PSTRE scores) vary significantly regarding the three subsamples under consideration. In particular, they show that education and age have the most pronounced effect on the PSTRE score of employed people who use computers at home and at work. However, for the subsample of employed people using computers at home but not at work, migration background and age are important determinants of the digital divide whereas education plays a subordinate role. Overall, this subsample of employed people using computers in the private but not in the professional context is characterised by lower education, lower age and lower income.

According to Carlisle et al. (2021) the digital skills gaps between today's and future digital skills are most pronounced in advanced digital skills/competences (such as, the use of AI and robotics as well as in augmented and virtual reality skills) but at the same time, they are not perceived as particularly important for employability in the tourism and hospitality industry. Instead, they identify online marketing, communication skills, and social media skills among others, as the most important (current and future) digital skills enhancing the employability in tourism and hospitality companies.

In terms of workforce employability, van Laar et al. (2019) emphasise that 21st century digital skills are strongly interrelated– they build on each other sequentially – implying that "a person who lacks one type is also likely to lack another" (p. 3478). Hence, any initiative to improve digital skills must take into account their interdependence and sequential nature, rather than aiming to improve specific digital skills.

Extending the focus to the workforce adaptability, the cluster analysis performed by Jandrić and Ranđelović (2018), reveals three distinct clusters: The leading performance in terms of the workforce adaptability is achieved by a set of Nordic and Western European countries. On the other hand, countries like Greece, Bulgaria or Romania have only a very limited degree of adaptability; especially the latter result raises concerns of structural problems in the respective countries' labour market. Countries that are found in the third cluster are e.g., Austria, Belgium or France. Jandrić and Ranđelović (2018) conclude that digital skills/competences are fundamental variables influencing the workforce adaptability.

Approaching the nexus between digital skills and digital competences and work from a more general perspective, the major conclusion drawn by Krasnopjorovs (2020) for the case of Lithuania and Latvia is that insufficient digital skills are a potential factor contributing to the comparatively high unemployment rates of men aged 45-59 without tertiary education. Yet, there is no real testing of this hypothesis in the paper.

For another cohort (employees aged 25-34) across all EU member states, Piatkowski (2020) assesses that more than 75% of them possess basic or advanced digital literacy skills. Apart from Estonia, these are mostly the old EU member states, whereas in the "new" EU member states (those that joined the EU in 2004 or later) it is necessary and recommended to increase investment in developing STEM and digital skills. Altogether, digital skills are assumed to be important to adapt to labour market changes (together with lifelong learning).

(9) Policy dimensions: Interestingly, there is not a single paper that does not contain policy implications. Most frequently it is the policy dimension "enhanced labour and skills supply" that is addressed in the seven articles, namely in six out of seven cases, whereas there is no paper with a primary focus on the policy dimension "boost labour demand". Beyond that, in three papers policy aspects of "fairness, combating poverty and promoting equal opportunities for all" take centre stage. This reflects that the increasing use and deployment of digital technologies at work goes hand in hand with the high topicality of gaps regarding digital skills competences. Finally, for a single case (Jandrić and Ranđelović (2018)) the policy-related aspects addressed concern the "functioning of the labour market".

	Category																							
Reviewed Article Authors (Year)	Concep-tual emphasis		Research approach				Research design/method					Level of analysis			Digital skills and digital competences context						Policy dimension				
	3a	3b	4a	4b	4c	4d	5a	5b	5c	5d	5e	6a	6b	6c	7a	7b	7c	7d	7e	7f	9a	9b	9c	9d	9e
Carlisle et al. (2021)	☒				☒		☒	☒	☒			☒			☒	☒	☒	☒	☒			☒			
Ertl et al. (2020)	☒		☒				☒				☒	☒			☒	☒			☒					☒	
Jandrić and Ranđelović (2018)		☒	☒				☒				☒			☒	☒	☒			☒			☒	☒		
Krasnopjorovs (2020)		☒	☒				☒							☒						☒		☒		☒	
Piatkowski (2020)		☒			☒		☒			☒	☒			☒						☒		☒			
van Laar et al. (2019)	☒		☒						☒		☒	☒			☒	☒	☒		☒			☒			
Zilian and Zilian (2020)	☒		☒				☒				☒	☒			☒	☒			☒			☒		☒	

Table 3: Summarised findings of categories 3-7 and 9 of the content analysis-based literature review

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4. Discussion and concluding remarks

The primary research objective of this study was to contribute to a more clear-cut understanding of the nexus between digital skills/competences and work. To accomplish this goal, we carried out a bibliometric study and collected both quantitative and qualitative evidence on the topic at hand.

Discussing results and findings as well as drawing conclusions from this study, in the following we reflect on each of the research questions 1-3.

Research question 1: With regard to the first research question – "What are the basic characteristics of the literature on the nexus between digital skills/competences and work and how does the social and conceptual structure of this research field look?" we would like to stress the following: We observe a rapidly evolving research field after 2014 and it turns out that the nexus between digital skills/competences and work is researched in the literature from a fairly interdisciplinary perspective. Particularly, three findings of our study highlight this: (i) the 124 documents were published in 100 different peer-reviewed journals. (ii) the journal in which the largest number of articles appeared is interdisciplinary (*Sustainability*) and (iii) half of the documents are associated with at least two subject areas. Its interdisciplinary nature makes it however difficult to delimit the research field as such. Regarding the social structure, we find a low degree of persistence in authorships but on the institutional side we identified the University of Granada as a comparatively productive research place that hosts the leading research group in our sample. On average 2.75 authors contributed to an article, with some productive authors and a high percentage of authors that contributed only to one article. This indicates that research in this area is still evolving. For the distribution of publications across geography, we identify Europe as the most productive region. Additionally, we observe a low density in cross-country collaboration and international joint publication activities do play a minor role in this research field.

Research question 2: For the second research question of "*What are the main themes defining this research field?*" six building blocks were uncovered. The biggest cluster is "digital competences&skills" which is also a basic theme, i.e. very important for the whole research field with strong external ties but not well-developed with only weak internal ties. Another basic theme is "information and communication technologies" which points to the importance of conceptualizing digital skills/competences at work vis-à-vis the tools which they are required for. The only building block that qualifies as a motor theme and hence is classified as well-developed and decisive for structuring the whole research field, is "digital literacy". Since digital literacy is a concept also used to describe the ability to use digital technologies at work and in other social spheres, this indicates the application-oriented focus on the nexus between digital skills/competences and work of this building block. The remaining three building blocks are either niche themes, which are relatively unimportant for defining the research field as such but due to strong internal ties cover highly specialized themes, ("labour market", "professional development") or emerging/declining themes ("technology integration"), characterised by both weak external and internal ties and being thus of only limited importance for the whole research field.

Research question 3: Concerning the research question of *"What dimensions of work and which labour market-related aspects are addressed in this research field and what are its results and findings?"* the following findings are particularly noteworthy: Employment or employability as well as the effects of changing technologies at the workplace are the most crucial topics to which all papers can be directly or indirectly related. This reflects the high value attributed to digital skills/competences in determining the employability of today's and the future workforce. The level of digital skills/competences among different groups is central to three papers (Carlisle et al. 2021, Ertl et al. 2020, Zilian and Zilian 2020).

In Carlisle et al. (2021) the focus is on a specific industry, whereas the other authors adopt a wider perspective using case studies to identify overall patterns of digital inequality in the workplace and other social spheres (Ertl et al. (2020), Zilian and Zilian (2020)). While the issue of the digital divide is indirectly related to employability, two other papers of the sample (van Laar et al. (2019) and Jandrić and Ranđelović (2018)) address employability more directly: Van Laar et al. (2019) place the focus on digital skills, while the adaptability of the workforce to novel digital technologies is central to the paper of Jandrić and Ranđelović (2018). Finally, Krasnopjorovs (2020) and Piatkowski (2020) refer to digital skills/competences from a macro-level perspective and approach this issue through taking a more general account of the labour market. Still, their research clearly relates to employment, employability and/or effects of (changing) technologies on employment.

Noteworthy, each and every paper either explicitly or implicitly refers to at least one policy dimension, underpinning the high policy relevance of the nexus between digital skills/competences and work. We find that the dimension of "enhanced labour and skills supply" is addressed in six out of seven papers, highlighting the increasing labour market need to develop the necessary digital skills/competences and shape the ability of the workforce to use digital technologies effectively as well as taking adequate measure to reach this goal. Furthermore, three papers address the dimension "fairness, combating poverty and promoting equal opportunities for all". This shows that in research on the nexus between digital skills/competences and work, the gaps potentially fuelled by the increasing use of ICT in the workforce and among people of different socio-economic and -demographic background are already taken account of. Hence, these aspects are of high topicality in this research field and the challenges arising through these malfunctions in the workplace and more generally in the labour market are a central issue. Against this background, one paper (Jandrić and Ranđelović (2018)) addresses specifically the policy dimension "functioning of the labour market" pointing to the importance of the development of digital skills/competences for boosting the workforce adaptability and thus the employability.

Our findings and results have brought about qualitative and quantitative evidence on the nexus between digital skills/competences and work. It was shown that this is a research field that perceives of an evolving nature and is anchored in many different scientific disciplines and shares thematic overlaps with various other areas such as higher education research. This is not least reflected in the fact that this research field is marked by only a single motor theme and at the same time two basic themes constitute for its major building blocks. However, we consider it as most likely that this research field will establish itself and become more easily delimitable due to its high topicality.

There are two main limitations of this bibliometric study both related to the document collection and identification process: On the one hand, we think it is recommendable for future research to widen the document search to peer-reviewed publications that are not open access publications as this might raise the quality of papers included in the analysis. On the other hand, clearer results may come forth through narrowing the bibliometric study to a single scientific discipline e.g., the most popular one in this research field, viz, the Social Sciences. Apart from elaborating on these issues, potential future research could be done in the following two directions that seem to be particularly worthwhile: For gaining additional insights into the nexus between digital skills/competences and work, narrowing the research focus to the core topics identified in the content-analysis based literature review, that is employability and adaptability of the workforce, seems particularly promising. Second, shedding light on the transformative power of ICT at the workplace from a micro-level perspective is another interesting aspect that we think deserves further research.

Appendix

Node	Cluster	Degree Centrality (normalized)
Argentina*	18	0.033
Australia	2	0.115
Austria	6	0.098
Brazil*	19	0.033
Bulgaria	3	0.148
Canada	6	0.082
Chile	1	0.049
China	5	0.049
Czech Republic	3	0.115
Ecuador	1	0.098
Finland	4	0.082
France	1	0.049
Germany	6	0.361
Greece*	9	0.066
Hungary*	14	0.033
India	13	0.082
Indonesia	5	0.18
Italy	6	0.131
Jordan*	20	0.033
Latvia	3	0.115
Lithuania	6	0.049
Malaysia*	21	0.033
Mexico*	10	0.066
New Zealand*	7	0.066
Nigeria*	22	0.033
Norway	4	0.213
Pakistan*	15	0.033
Peru*	11	0.033
Philippines*	16	0.033
Poland*	23	0.033
Portugal	1	0.082
Romania*	12	0.098
Russia	3	0.246
Saudi Arabia	2	0.082
Serbia*	24	0.033
Singapore*	25	0.033
Slovakia	6	0.131
South Africa	13	0.115
Spain	1	1
Sweden	4	0.23
Switzerland	2	0.098
The Netherlands	1	0.279

Tunisia*	26	0.033
Turkey*	8	0.066
Ukraine*	17	0.066
United Kingdom	2	0.705
United States	2	0.197

Table 4: Centrality metrics of the country collaboration network. Note that countries marked with an asterisk are isolated nodes in the network.

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