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Article

Digitization, Epistemic Proximity, and the Education System: Insights from a Bibliometric Analysis

Ugo Fiore [1,*,†], Adrian Florea [2,†], Claudiu Vasile Kifor [2,†] and Paolo Zanetti [1,†]

1 Department of Management and Quantitative Studies, Parthenope University, 80132 Napoli, Italy; paolo.zanetti@uniparthenope.it
2 Computer Science and Electrical Engineering Department, Lucian Blaga University of Sibiu, 550024 Sibiu, Romania; adrian.florea@ulbsibiu.ro (A.F.); claudiu.kifor@ulbsibiu.ro (C.V.K.)
* Correspondence: ugo.fiore@uniparthenope.it
† These authors contributed equally to this work.

Abstract: Advances in IoT, AI, Cyber-Physical Systems, Computational Intelligence, and Big Data Analytics require organizations and workforce to be able and willing to learn how to interact with digital technology. In organizations, coordination and cooperation between actors with expertise in business and technology is fundamental, but integration is hard without understanding the terminology and problems of the interlocutor. Epistemic proximity becomes prominent, underlining the importance of an education focused on flexibility, willingness to cope with the unknown, and interdisciplinarity. The main goal of this work is to provide a perspective on how the education system is evolving to support organizations in the digitization era through a quantitative analysis of literature. More than 170,000 papers were selected from the Scopus database, matching a wide set of keywords related with innovation, problem solving, and organizational change. Patterns in the co-occurrence of keywords were studied. In addition, similarities and differences in the distribution of relevant themes across disciplinary areas, as well as their evolution since 2000, were analyzed. Academic interest is found to be generally increasing over the years in all disciplines, although considerable fluctuations can be observed. This variation is found to be nonuniform in the macroareas.

Keywords: problem-solving; university; curriculum; innovation; multidisciplinarity

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1. Introduction

Digitization involves a profound transition that redefines the context in which entrepreneurs operate. Information and knowledge are generated, used and discarded at an unprecedented rate and they determine to a large extent the success of business initiatives. Information and communication technologies also curtail the importance of geographic and political boundaries, although several attempts to resist this trend can be observed (Ventre 2016). The shift in importance from tangible objects to intellectual content and services, as well as the continual restructuring of economies to adapt to constant change, impose reconsidering the desiderata for the education system to enable new business models and maintain competitiveness. In an industrial setting, automated and interconnected systems on the factory floor bring change in production processes, supply, quality control, and organization. The Factories of the Future (FoFs) need to ensure their personnel has adequate digital skills. In factories, Artificial Intelligence (AI) will cause complex and time-consuming tasks to be automated, making several jobs obsolete (Kwilinski et al. 2020) but also creating new ones—arguably in equilibrium (Marengo 2019). For example, in 2025 the following jobs are anticipated: robot supervisor, data professional (analyst scientist, engineers), human to machine UX specialists, Smart City technology designers, AI assisted healthcare technicians.

Education is one of the four basic stakeholders of the "Quadruple Helix" innovation model where government, industry, academia and civil participants work together in a synergistic way to create and accelerate structural changes. Public-private partnerships and knowledge alliances foster knowledge transfer and cooperation between industry and academia. Digitalization cannot be fully achieved without increasing the level of employee competence and ability to interact with algorithms and robots. Higher Education Institutions (HEIs) must create new study programs or adapt curricula to generate the competences and new qualifications required by the digital transformation in society and in the FoFs.

Coexistence between innovative and traditional business models, as well as simultaneous presence of digital and legacy production platforms, is also raising unprecedented issues that need to be addressed during the period while new technologies are gradually introduced. With notions like Virtual and Augmented Reality, Artificial Intelligence, and Cyber-Physical Systems massively entering the industrial environment, employees should be expected to have at least a basic understanding of those technologies and, most importantly, have a clear awareness of what their limitations are. This is particularly true as far as security concerns are involved. The observation by Schneier (2000) that "security is a process, not a product" states firmly both the requirement for an adequate mindset on part of the workforce—not only those directly involved with security—and a need to stay continuously alert, keeping an eye on signals that can indicate malfunctions or, worse, attacks.

It is up to HEI, then, to guarantee an adequate supply of skilled graduates that master digital technologies and who are flexible enough to be able to adjust to a constant technological evolution. Additionally, engineering programs can be fitted with courses that will put graduating engineers in the position of understand the interdependencies existing among technical, economic, environmental and social dimensions so that stable, sustainable, and socially acceptable solutions can be found (Matos and Petrov 2016). In essence, the fundamental transformation the education system is undergoing could be best understood by outlining the major directions of evolution. Learning is changing from an individual process with a heteronomous nature to a collective process largely managed in an autonomous way. The forced recourse to distance learning associated with the outbreak of COVID-19 has further stressed the need for learners to self-pace their activity.

Research Gaps

Although scholars have outlined the importance of an evolved training and a more intense interchange among academia and industry for an efficient and frictionless adoption of innovation, extant literature offers little insight into the first theme and does not fully explore the latter. For example, Zawacki-Richter et al. (2019) offered a systematic review on the applications of AI in higher education, emphasizing ethical and pedagogical perspectives, and the capability of AI-enabled learning systems to enable an adaptation of content to individual needs of learners was explored by Kabudi et al. (2021). Both are very interesting themes, but a wider perspective would be valuable. In an attempt to address these research gaps in an integrated way, an analysis of relevant scientific literature has been carried out in this manuscript. In particular, we were interested in literature where higher education was combined with what we feel are the most important notions in the context of organizational evolution in the digitization age, viz. innovation in organizations, problem-solving, and multi-disciplinarity. These three themes reflect, each in its way, an aspect of what can be expected of the education system to support organizations in their efforts to assimilate innovation. To be more precise, for innovation to be incorporated, organizations should adapt to support both the creation and use of knowledge, thereby focusing on research and development and flexibility. Strict disciplinary boundaries are increasingly becoming an obstacle for an effective training of a workforce that should be able to understand, use, and transfer knowledge originated in different fields. This is related to an open-minded attitude, which can be achieved if an approach based on problem-solving is widely adopted in curricular programs. The shift from deep, specialized competence to the capability of embracing innovation requires rethinking academic curricula.

The remainder of this manuscript is organized as follows. Innovation and its managements are the subject of Section 2. Problem solving is specifically addressed in Section 3. The research methodology is described in Section 4. Afterwards, Section 5 is dedicated to reporting and discussing the results, and Section 6 concludes the manuscript and outlines directions for future study.

2. Managing Innovation

Especially in the early stages of development of an innovative technology, investing in it is risky and can be associated with failure. However, being early adopters of emerging technology can also bring substantial returns (Leoncini 2017). Technological innovation can be generated internally, acquired from external sources, or both. As projects become more articulated, a single firm is unlikely to have all the knowledge required to find effective solutions. Analogously, the uncertainty often associated with innovation also discourages investments in R&D. These two factors, complexity and uncertainty, should be considered jointly to gain a better understanding of the factors affecting openness to external partners (Bagherzadeh et al. 2019). An empirical study on Chinese firms showed that the decision to "make" novelty increased innovative output but had no effect on sales growth, whereas the decision to "buy" novelty contributed positively to sales but reduced innovative output (Wang et al. 2014). Another study on innovative firms in China found that innovation performance was positively affected by both in-house and contracted R&D (Chen et al. 2016). A study based on the answers of 108 employees from six European countries (Florea 2019) revealed that digital design skills are considered by firms when recruiting new personnel, and training is provided or encouraged for employees. At the worldwide level, HR managers admit that they are struggling in keeping up with the costs of training workers, especially considering that technological innovation generates new jobs that require new skills and working methods (Florea et al. 2017). Practical, face-to-face work is described as preferable with respect to traditional training and online experience. As the future can bring a strong competition between the USA, Asia and Europe both in the labor market and at the educational level, Europe should invest heavily in the digital skills of their own population and in some strategic profiles, to prevent the workforce to migrate. Finally, the study found that companies are only moderate innovators. This finding aligns with an observation by Leoncini (2017), who remarked that the relentless search for innovation that is so preached in manuals is not as frequent in organizational behavior as one might expect.

Heterogeneity of projects implies that the scale at which decisions to activate external collaborations are to be made is that of single projects rather than that of firms. Further, collaborative links need not be unique, as it may be advantageous to set up multiple connections. This in turn raises the issues of how to select partners and of formalizing collaborative endeavors. The characteristics of partners that have resulted in successful alliances vary over the technology life cycle (Stolwijk et al. 2015). Early on, the most fruitful collaborations were those established with technologically similar partners, while later on in the technology life cycle technologically dissimilar partners brought the greatest benefit. In some high-technology and innovation-oriented sectors, finding ways to produce innovative solutions is not even the whole story. Processes to obtain approval by regulatory entities can be stringent, complex, and lengthy (Hall et al. 2016). Such processes create additional costs that, together with other commercialization costs, may limit the competition, because only a few big firms can afford these costs (Stolwijk et al. 2015).

From what has been said above, one might get the impression that technological breakthroughs stem from isolated flashes of brilliance. Empirical evidence suggests, instead, that genesis of innovative ideas is influenced by the context at all levels, including policy makers, organizational form, and scientific communities (Dosi et al. 2020). While generation of novelty does not necessarily occur solely at one geographical scale, implying there is not a single optimal level where innovation policy should be focused at (Marzucchi and Montresor 2013), policy can go to great lengths to support the creation of a fertile environment. Strengthening competences and skills in innovation and creativity management enables employees to establish fruitful interactions with external partners, making effective use of the acquired knowledge (Markovic et al. 2020).

Consequently, the ability to quickly reconfigure, extend, and adapt industrial systems to market needs requires a new set of skills that HEI should include in their curricular programs (Florea 2019). Creativity is the mantra of our times, reflecting the essential role played by the ability to think "outside the box" (Leoncini 2017). Not only does innovation provide firms with a competitive advantage (a "positional advantage"), it also boosts their flexibility to suit changing conditions (an "adaptive advantage"), since it has a long-term positive effect on the survival likelihood of firm when things get worse (Cefis and Marsili 2019). If firms were race cars, then innovation—encompassing product innovation, process innovation, organizational innovation, and marketing innovation—would increase both their speed and manoeuvrability. An innovative mindset present since firm inception has also been seen to create a long-lasting resilience to shocks (Cefis and Marsili 2019). Competitiveness, and ultimately survival, of organizations is increasingly dependent of their ability to generate novelty, at opportune times, and—what is most difficult—consistently over time. This underlines the need for a kind of "innovation engineering", aimed at organizing knowledge and procedures to support the development of new ideas and their transformation into marketable products.

Knowledge shapes organizations, but it is also true that organizations shape the characteristics and distribution flow of knowledge. Not only is knowledge distributed and divided into pieces strongly connected and interdependent, there also is uncertainty as to where relevant knowledge is located (Dosi and Marengo 2015). The ability to learn and solve problems of an organization basically depends on the cognitive capabilities of its members as well as on the organizational architecture and the distribution of decision power within it (Dosi et al. 2018). In many circumstances, processes of cognitive and behavioral adaptation yield more efficient and quicker coordination than is obtainable by means of explicitly articulated decision processes. The most effective organizational set-ups have been found to be those in which the exploration phase (learning) is decentralized while exploitation (the ensuing coordinating rules) is centralized (Dosi and Marengo 2015). In essence, the change in curricular programs should not be focused on technology alone, but should also cover strategies to measure and enhance organizational adaptability.

3. Problem Solving

The adjustment required of the education system by the two classes of skills and competences (technological and organizational) outlined in the previous sections, although significant, still do not constitute the whole picture. Indeed, the education system is to play a key role not only to ensure that skilled workers are available at the right place and time (Goldin and Katz 2009), but also to alleviate the painful fallouts of the fourth industrial revolution on the labour market, providing support to the weaker segments of the workforce. The ability of AI, machine learning, big data analytics and the like to undertake activities characterized by sophisticated skills extends in fact the risk of unemployment to qualified workers and even specialists (Marengo 2019). In the financing sector, for example, the availability of new channels and the increasing digitization create new opportunities, some alternative to traditional intermediaries and some others within their grasp. Ideally, AI-based systems will become tools in the hands of employees (Melnychenko 2020), and human effort will go towards developing personalized services.

In this context, problem solving capabilities escalate to assume a prominent role. Problem-solving seldom reflects in the separate solution of a set of unrelated problems. Most of the time, it requires the coordinated solution of a multiplicity of interdependent problems, and the global solution is not necessarily the juxtaposition of individually optimal ones. It then requires strong coordination between team members (Marengo et al. 2000), which in turn relies upon good communication. By studying post-acquisition innovative performance in relation to R&D investments prior to acquisition for a set of acquisitions, Cefis et al. (2020) found that acquiring firms that had nurtured their problem-solving skills and mindset are better able to identify, assimilate, and apply relevant knowledge from the acquired firm. In particular, HEI need to confront with a transformation from a knowledge-importing economy to a knowledge-generating economy. Initiatives to promote autonomy, encourage the attitude to question existing methods and to explore fresh ways, and in particular the ability and willingness to commit to lifelong learning, are vital. The epistemological and theoretical framework for this includes learning models such as humanistic psychology, with its emphasis on the fact that the uniqueness of a human being cannot be neglected, and Piaget's constructivism, where experience is viewed as the primary mechanism whereby people create knowledge and meaning. In this context, the efforts of learners to solve new problems and variants of existing ones is a formidable source of valuable information, thus learners take the twin role of consumers and producers of knowledge. An economy of thought can be thus realized, activating a self-sustained virtuous process. This requires the construction and continuous maintenance of databases of problems and solutions, interlinked between them so that users can efficiently navigate through them and discover new intriguing connections and patterns (Corsaro et al. 2009).

Business games are a powerful tool where players learn by experience rather than solely listening to lectures or reading texts (Mettler and Pinto 2015). Learning shifts from reading and memorizing to acquiring the ability to find, evaluate, adapt, and use information. Guided discovery results in a deeper understanding and longer retention. The recreational aspect arsing from the enjoyment experienced by players also has a positive effect on learning. Learning transcends traditional objectives, including skills at the cognitive level (context awareness and memory), the behavioral level (leadership and trustworthiness), and social level (team working and communication) (Lavis et al. 2003). Modern learning practices that seek to overcome the limitations of the traditional lecture provide opportunities to experiment new paradigms while at the same time making learners familiarize with, and acquire the skills needed for, the collaboration with peers from around the world. In particular, with Massive Open Online Courses (MOOCs) massive groups of participants can be assembled, much larger than those permitted by the practical restrictions of traditional education. The spontaneous emergence of subgroups should also be accurately studied, as it influences learning effectiveness (Cameron and Adsit 2018). Online learning platforms generate huge and quickly growing volumes of data, also having the characteristics of veracity, variability and value. They thus fully adhere to the definition of Big Data (Gandomi and Haider 2015). Extracting value from such data and transforming it into applicable knowledge–and ultimately into tangible benefits–is an essential challenge for organizations operating MOOCs and also for HEI in general.

The increased importance of Intellectual Capital strongly emphasizes employees' motivation and job satisfaction. Firstly, dissatisfied workers often leave an organization, taking with them their integrated, immediately applicable knowledge. In essence, what is taken away from the organization is a valuable asset which took time and effort to be build (Nicolaescu et al. 2020). Secondly, the constant and fast evolution of technology and of the skills needed to effectively use it accentuates the importance of learning. Knowledge-centered organizations, where learning is encouraged and supported, can be attractive for employees and increase their level of satisfaction (Janz and Prasarnphanich 2009).

At the same time, when many innovative techniques being tried, the ability to effectively validate new solutions becomes fundamental. Therefore, being able to plan, design, and perform controlled experiments, as well as interpreting their results, is crucial to the creation of reliable procedures and methods. Fostering teamwork culture is an aspect that should also be strongly incentivized. A convenient paradigm for collaborative learning, fitting perfectly with the notion of "collective intelligence" (Lévy and Bononno 1997), is cooperative learning theory, where learning is defined as a social process in which a group of individuals cooperate to accomplish a shared goal while maximizing their own and others' learning.

Radical changes in technology sometimes involve the development of systems particularly complex and articulated. Developing such systems is a knowledge-intensive process where the involvement of highly specialized individuals is decisive to success. Team members at all levels should integrate their knowledge, sharing it to formulate globally coherent strategies and solutions (Janz and Prasarnphanich 2009). When several specialists from different organizations are assembled together in a team, sharing and integrating knowledge among individuals can not be assumed to be seamless, especially in high-pressure situations (Bistaraki 2017). Previous acquaintance and cooperation is a factor which has been found to be essential in ensuring a calm collaboration and a productive exchange of information. People who had worked together the year before coped with emergency in a more composed and productive way as compared with teams whose member never met before (Bistaraki 2017).

The accelerated and facilitated interaction among economic actors enabled by information and communication technologies has accentuated the need to surpass organizational boundaries and adopt a systemic perspective for product development, embracing the notion of business ecosystems, communities of interdependent entities that create value together (Zhao et al. 2019). In particular, Innovation Ecosystems facilitate the creation, nurturing, and multiplication of synergies between local actors with diverse affiliation and background. In this case, the detailed structure of the network of intra-organizational and inter-organizational relationships is in itself an important subject to be studied. Recent findings have shown that the self-emerging structure has interesting properties of modularity with sub-structures focused on specific areas.

For a long time, the process through which innovation is realized was described through the so-called linear model. In this model, firms spend their efforts into refinement and practical application of research developed by higher education institutions (Carayannis and Campbell 2010). The latter used predominantly public funding, while the former was mainly based on private investments. Underlying the linear model is the notion that new ideas are generated in universities as basic research and are successively transformed into commercially lucrative products or services by the firms interested in bringing them to the market. The linear model has been termed Mode 1 by Gibbons (1994), who emphasized the role of peer review for quality control and the strict adherence to boundaries between scientific disciplines. Being only focused on disciplinary excellence, Mode 1 is not interested in the practical aspects arising when knowledge is actually applied to solve real-world problems.

Mode 2, a model conceived to overcome the limitations of Mode 1, abandons disciplinarity as a major concern and focuses on application, which often—if not always—necessitates combination of knowledge not necessarily developed in the same disciplinary sector not at the same time (Gibbons 1994). Since success in Mode 2 is measured by the extent of practical application, Mode 2 underscores the the importance of collaboration between knowledge producers separated by geography, affiliation, and time. Quality control is then operated by the community of practitioners that, through actual adoption, attests convenience and efficiency of knowledge. In our opinion, disciplinary barriers are still pervasive and they have profound effects, actively hindering the progress of science and the diffusion of innovative ideas and methods. Even the emerging community of data scientists can be seen as partitioned into two tribes, statisticians and machine learning specialists. Despite the fact that, most often than not, they cope with the same problems, they frequently are unable to share useful, relevant knowledge. One of the reasons is that the two communities speak different languages, and they sometimes refer to the same notion with different words (Wasserman 2013).

4. Methodology

Achieving consensus about a set of search keywords that describe comprehensively the objective of our study is hardly viable, as there likely are as many different opinions in this regard as there are scholars. Therefore, we are proposing our own choice of keywords, with no pretense of it being the unique valid interpretation. We believe, however, it captures some aspects worth studying and provides interesting insights. In contrast to many quantitative literature surveys (Paul and Criado (2020) write "40–50 to 500 or more relevant papers"), we have extended our analysis to a corpus of more than 170,000 papers. Note also that the analysis is carried out on all the keywords that are recorded in the metadata for the selected papers, reducing the selection bias (Paul and Criado 2020, Section 3.2).

In this study, Scopus was retained as the primary database, since it offers the broadest coverage of scientific literature in many fields (Paul and Criado 2020, ibid.). Selecting eligible literature to fit with the specified research objectives was done based on the followin Scopus keywords: PUBYEAR > 1999 AND PUBYEAR < 2021 AND TITLE-ABS-KEY ((university OR "higher education") AND (problem-solving OR curricul* OR r&d OR innovation OR "organizational ambidexterity" OR *disciplinary)).

Results were then analyzed based on publication year, subject area and macro-area. The subject areas and macro-areas are reported in Table 1.

Focusing specifically on some particular keywords, the following analysis is concentrated on the rate of occurrences of that keyword over the years in works belonging to the four macro areas detailed in Table 2. For each set of keywords investigated, the number of papers where the keywords were present in year 2000 has been set equal to 100, and subsequent years have been scaled accordingly.

Table 1. Scopus subject areas.

Code	Subject Area
AGRI	Agricultural and Biological Sciences
ARTS	Arts and Humanities
BIOC	Biochemistry, Genetics, and Molecular Biology
BUSI	Business, Management, and Accounting
CENG	Chemical Engineering
CHEM	Chemistry
COMP	Computer Science
DECI	Decision Sciences
DENT	Dentistry
EART	Earth and Planetary Sciences
ECON	Economics, Econometrics and Finance
ENER	Energy
ENGI	Engineering
HEAL	Health Professions
IMMU	Immunology and Microbiology
MATE	Materials Science
MATH	Mathematics
MEDI	Medicine
MULT	Multidisciplinary
NEUR	Neuroscience
NURS	Nursing
PHAR	Pharmacology, Toxicology and Pharmaceutics
PHYS	Physics and Astronomy
PSYC	Psychology
SOCI	Social Sciences
VETE	Veterinary

Table 2. Macro-areas and Subject areas in Scopus.

Macro-Area	Subject Area Codes
Health Sciences	DENT, HEAL, MEDI, MULT, NURS, VETE
Life Sciences	AGRI, BIOC, IMMU, NEUR, PHAR
Physical Sciences	CENG, CHEM, COMP, EART, ENER, ENGI, MATE, MATH, PHYS
Social Sciences	ARTS, BUSI, DECI, ECON, PSYC, SOCI

5. Results

In total, metadata about 177,130 unique papers were collected. The subdivision of paper per disciplinary area is reported in Table 3. Note that a single paper may be attributed to multiple areas.

Figure 1 reports the evolution of the paper count over time. The plot shows a distinguished upward trend that became more pronounced from around 2016 and a peak in 2019. A 5-year forecast was done by fitting a linear trend model (adjusted R^2 = 0.8713).

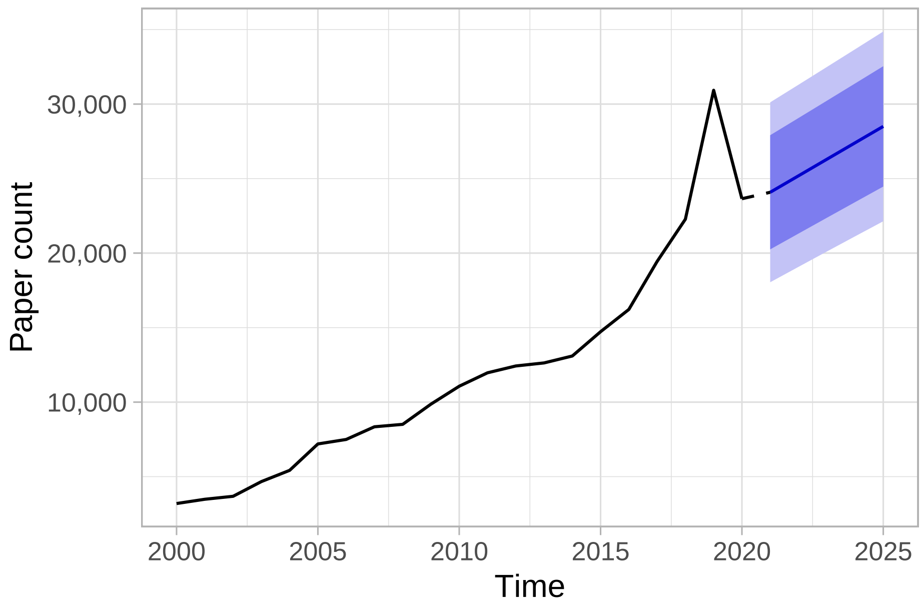

Figure 1. Total number of papers matching the search keywords in the Scopus database in the years 2000–2020, along with a forecast for the next 5 years obtained by a linear model. Shaded areas are the 80% and 95% confidence intervals.

In Figure 2, a pictorial representation is given of the relative importance of the search terms according to their frequency in the retrieved papers from the Scopus database.

Table 3. Papers per subject areas and macro-areas.

Macro-Area/Subject Area Code	Paper Count
DENT	1093
HEAL	3744
MEDI	28,450
MULT	1327
NURS	5710
VETE	607
Health Sciences	40,931
AGRI	4175
BIOC	4590
IMMU	518
NEUR	1124
PHAR	2476
Life Sciences	12,883
CENG	1835
CHEM	2038
COMP	22,788
EART	5623
ENER	2893
ENGI	30,822
MATE	2847
MATH	7490
PHYS	3975
Physical Sciences	80,311
ARTS	13,685
BUSI	15,036
DECI	3568
ECON	6247
PSYC	5510
SOCI	65,198
Social Sciences	109,244

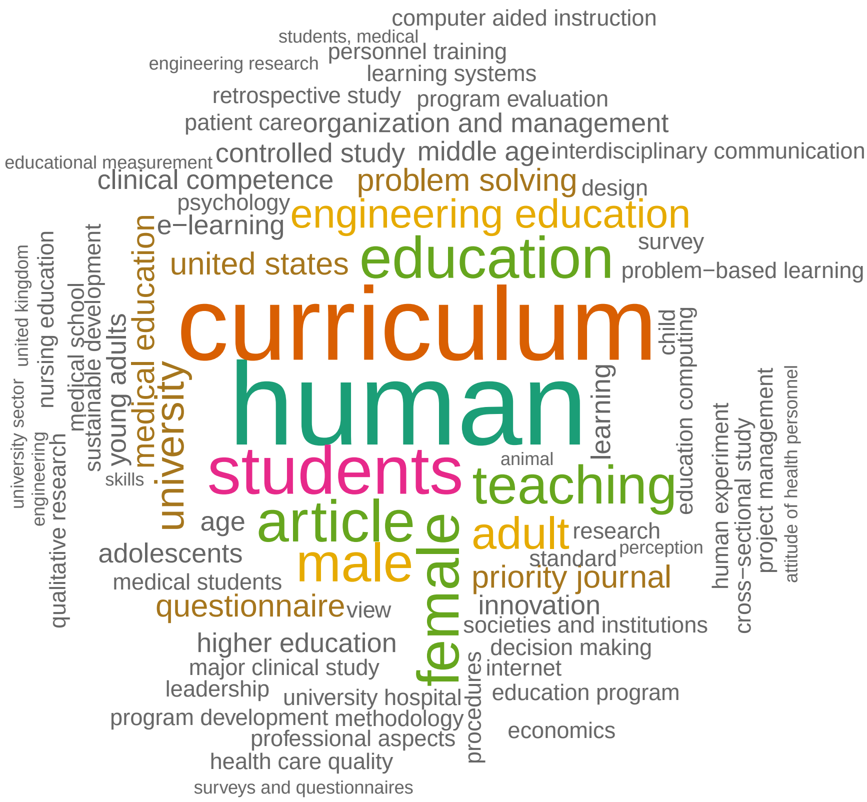

Figure 2. A synthetic illustration of the most represented keywords and their frequency in the Scopus database in the years 2000–2020.

The distribution of all the selected papers per macroarea is provided in Figure 3.

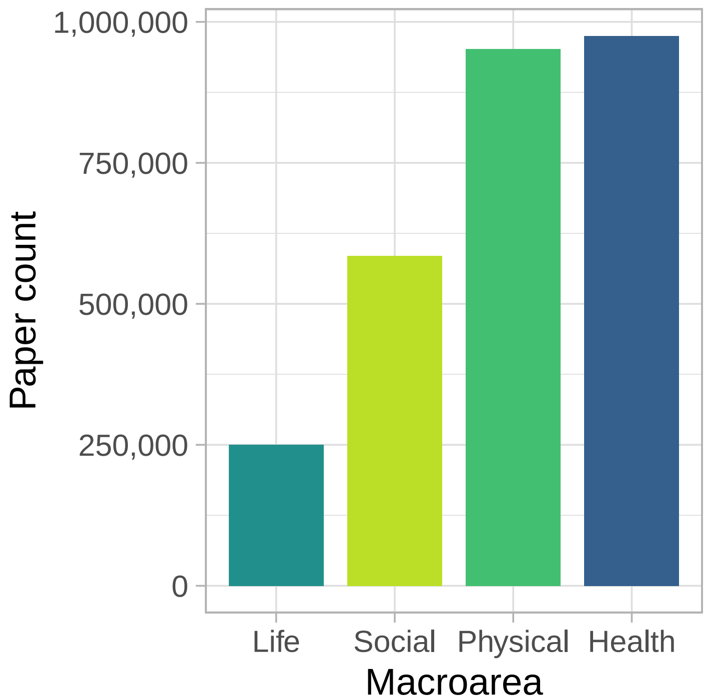

Figure 3. Count of papers matching the search keywords in the Scopus database in the years 2000–2020, per macroarea.

The following Figure 4, obtained with the VOSviewer software[1] shows a pictorial representation of the most represented index keywords in the papers selected. The size of vertices is proportional to the number of occurrences of each keyword and edges are drawn between two vertices if the keywords associated to them occurred together more than a pre-determined number of times. Four clusters, drawn in different colors, are visible in the chart. Interestingly, the rightmost cluster groups keywords roughly related to education in general, especially coupled with aspects such as problem solving, innovation, and technology. Additionally central in this cluster is the keyword "students". In the other three clusters, keywords related to the health sector seem to be prevalent. However, looking more closely, the yellow cluster to the left groups keywords specifically related to medical studies (e.g., "controlled studies" and "retrospective study", an essential distinction), while the blue cluster mainly references topics in medical education (e.g., "medical education" and "medical student") and the green cluster focuses on managerial aspects in healthcare and elsewhere (e.g., "organization and management" and "health care quality"). Although the total number of papers in medicine and health sciences in general was not particularly large, the prevalence of medicine-related terms could be due to a denser concentration of the involved keywords in the papers belonging to social and physical sciences, where the average number of citations attracted by a keyword was apparently larger.

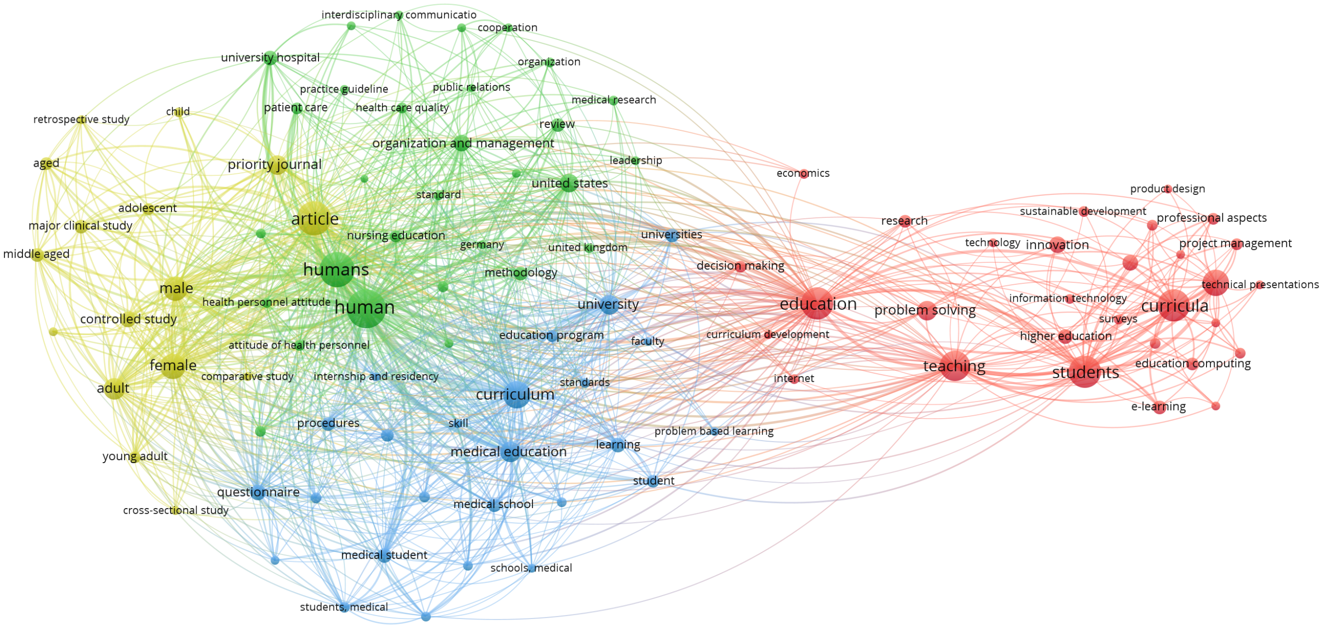

Figure 4. Map of research trends based on co-occurrence of keywords in the selected publications from the Scopus database in the years 2000–2020.

The overall partition of papers referencing the keyword "curriculum" across macroareas is reported in Figure 5.

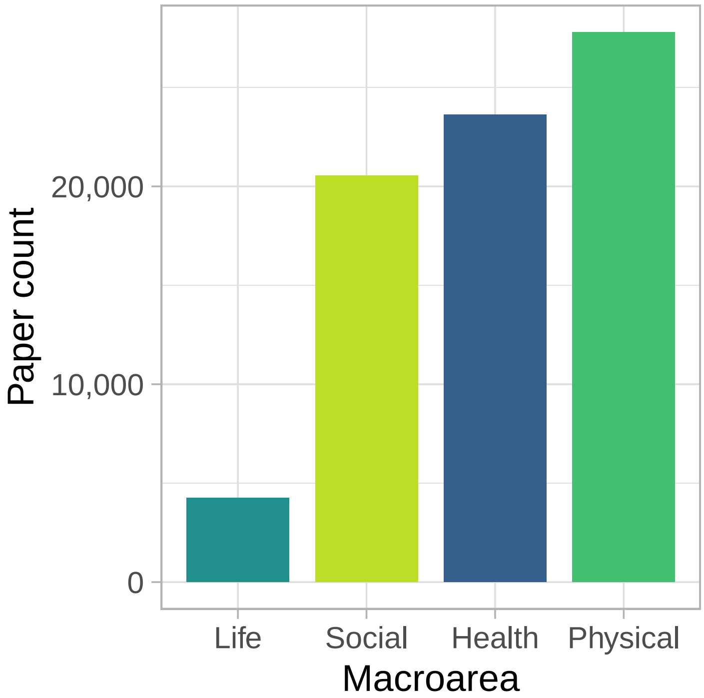

Figure 5. Count of curriculum-related papers in the Scopus database in the years 2000–2020, per macroarea.

The variation over time of curriculum-related papers by disciplinary area is depicted in Figure 6. First, a growth trend was noticeable in all of the macro areas, along with a substantial drop in 2020, very probably due to the pandemic. By observing the chart, it should be remarked that in a 20-year perspective the impact of the pandemic was certainly sizeable and unprecedented, but not destructive. A good share of research activity continued, due to the technological readiness in the academic world. The line associated with life sciences had a remarkably higher growth rate than the other curves. It should be noted that the initial value for life sciences was substantially lower than for other areas. This also explains the wider oscillations with respect to the other curves. In this light, the spike of physical sciences in 2005 became even more significant. The number of involved papers jumped to 1327 in that year, a 48% increment from 2004. No particular reason could be found for this increment, save the observation that "engineering education" was among the keywords that showed the largest rise (from 592 to 827) from 2004 to 2005 in the physical sciences papers. Finally, from 2008 onward, the curves relative to health sciences and social sciences show some similarity.

Papers referencing the keyword "Problem solving" are distributed as shown in Figure 7. The chart relative to the evolution over time of the mentions of keyword "Problem solving" by macro area (Figure 8) show much higher variation. First, multiple crossings could be seen among the curves. All macroareas with the sole exception of social sciences displayed considerable fluctuations, despite the initial value for social sciences being not very small. Indeed it was halfway between the initial values of health and life sciences, on the one hand, and physical sciences on the other. Although the oscillations were strong for both of the latter two, growth was more marked for health sciences. Moreover, the curve for physical sciences increased initially, it had a plateau from 2004 to 2007, it decreased rapidly in the following two years and it started rising again only after 2013. Again, a similar behavior could be detected between two curves, involving health and physical sciences.

The final chart (Figure 9), devoted to the keyword "Innovation", has been drawn with only two lines, because the values for health and life sciences were too small over the whole time period. The similarity in this case concerned the only two macroareas shown (physical and social sciences) and it was more evident that in the previous figures.

Both curves rose very quickly until 2010. After that, a sharp decline could be observed, followed by a rebound, initially for social sciences and the next year for the physical sciences. Additionally, in 2018, a sudden fall occurred for both curves. Once again, the curve for social sciences had anticipated the trend, having stayed almost stable in 2017.

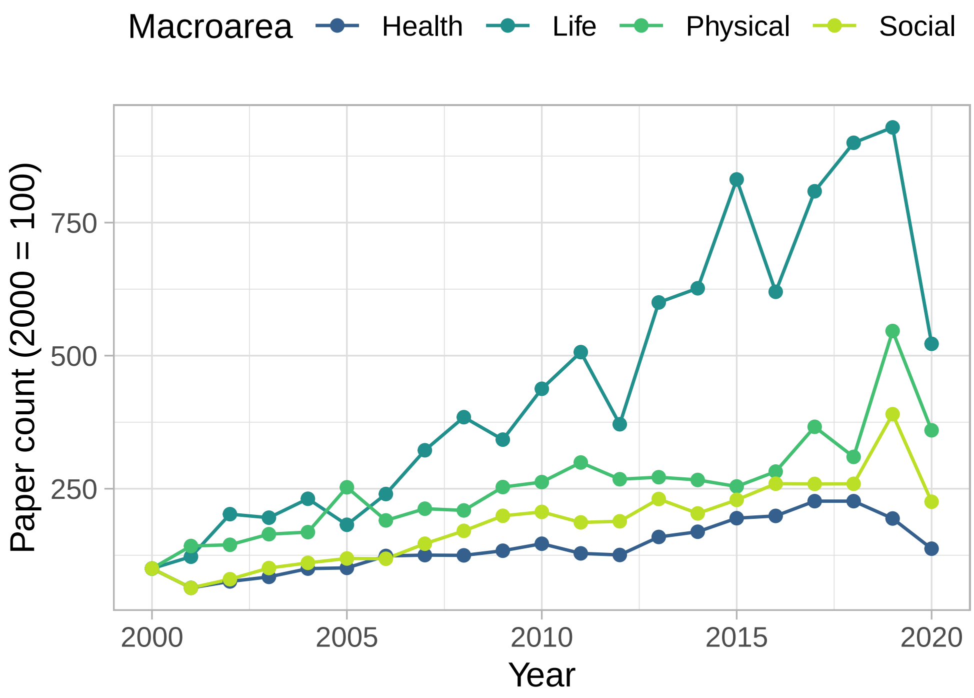

Figure 6. Evolution over time of the relative trend of papers referencing the keyword "Curriculum/a" by macro area (2000 = 100).

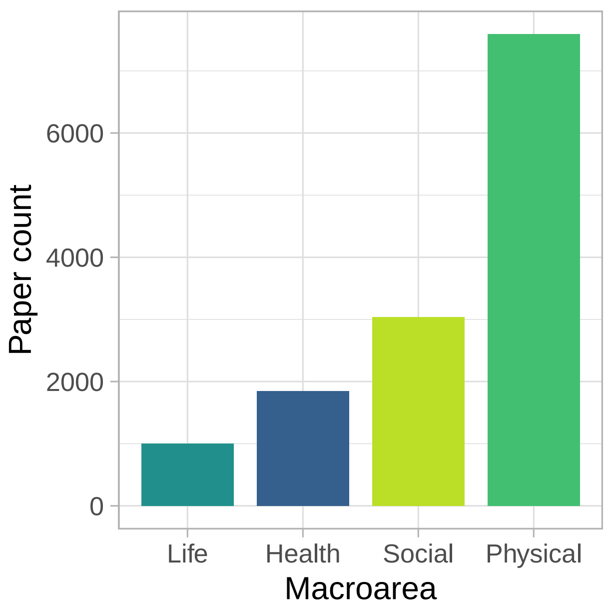

Figure 7. Count of papers referencing the keyword "Problem solving" by macro area.

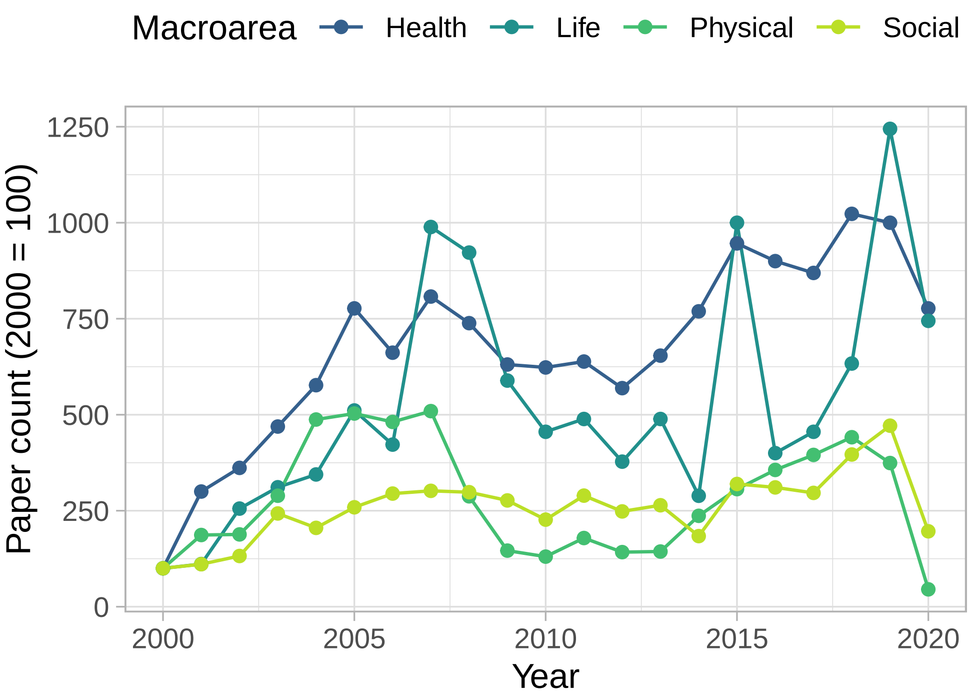

Figure 8. Evolution over time of the relative trend of papers referencing the keyword "Problem solving" by macro area (2000 = 100).

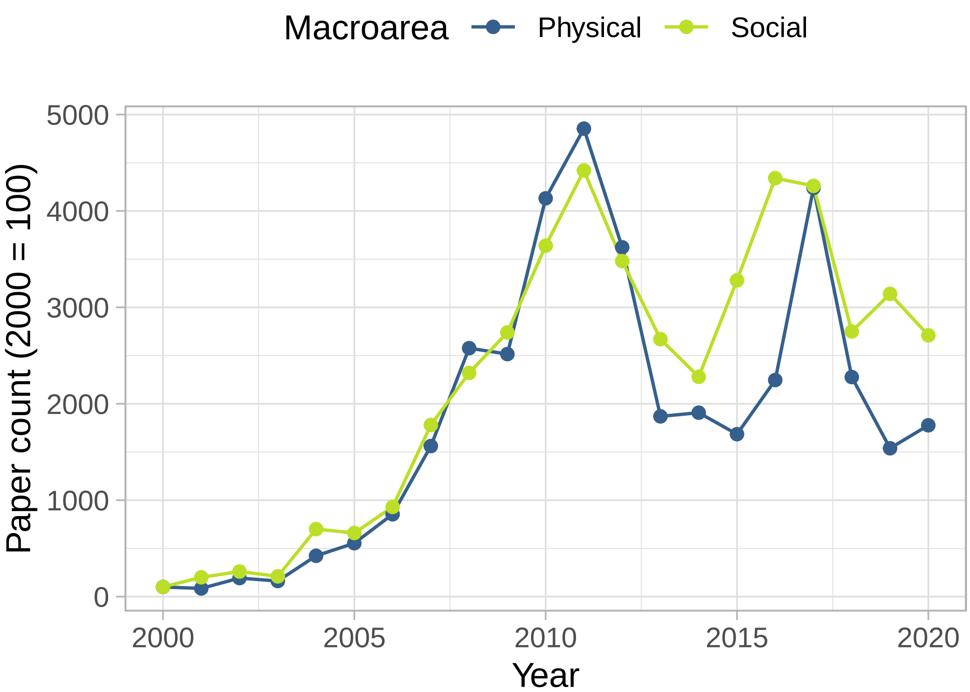

Figure 9. Evolution over time of the relative trend of papers referencing the keyword "Innovation" by macro area (2000 = 100).

6. Conclusions

Technological innovations are provoking a deep metamorphosis in the education system, that should equip graduates with the skills needed to adapt rapidly to digital technology and use it productively, as well as create the conditions for an easier and more frequent interaction in the context of knowledge transfer and, more broadly, in innovation-driven relationships. In essence, it could be said that the role of spatial proximity in IS is being redefined, incorporating the notion of an epistemic proximity grounded on technological literacy and attitude towards change. By analyzing the scientific literature from 2000 onward, this work attempts to draw a map in the major research directions, outlining their evolution over time and how they are distributed among major disciplinary areas. In general, interest around these issues has grown, although there have been slowdowns followed, in recent years, by a rebound. The same behavior has not always been observed in all macro areas. In particular, life sciences tend to show both a large increase and a wide variation.

The pattern of flow of published works within disciplinary areas offers insights into how innovations propagate, identify disciplinary areas that react faster, and helps isolate interesting trends in the scientific literature that usually anticipate the evolution of the market. Those in charge of managing the education system need to be quick in adapting learning strategies, methods, and techniques, in order to respond, and possibly proactively anticipate the needs of the broader community. While being able to devise strategies to support firms in dealing with the rapid change associated with digital innovation is a key factor in contemporary education, this is still uncharted territory for several HEI.

The principal limitations of this analysis are related with the selection of keywords. This choice tacitly introduces a limitation in the scope and validity of a bibliometric study, because some keyword with a high significance could always be left out. As they were wide, the keywords chosen in this work resulted in a substantial number of manuscripts to work with, improving the validity and coherence of results.

Directions for Future Work

Our study will continue to analyze other keywords specific to the current period introduced by the COVID-19 pandemic. Among these we mention "future of work", "remote work", "teleworking", "upskilling", and "reskilling". In addition, besides the analysis of the specialized literature, it would be interesting to extend our activity to the analysis of video materials dedicated to learning platforms, MOOC courses or webinars, lectures presented at workshops dedicated to the gap between academic offer and industrial skill requests. Directions to enhance this study also include a finer-grained analysis based on clustering keywords at the semantic level, also emphasizing and isolating the most recent trends. It should be also noted that, because disciplinary areas are different, the ways in which measures to enhance epistemic proximity are operationalized and deployed may vary substantially and tailoring may be required. Thus, an analysis focused on the specificity of some particular research areas should be a welcome contribution. The global pandemic has visibly impacted scientific production on our selected topics. It would be interesting to study the way paper counts will start to recover when the emergency will be over. Finally, an investigation of the citation counts and the citing relationships would offer interesting insights.

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Notes

[1] https://www.vosviewer.com/ (accessed on 11 June 2021)

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