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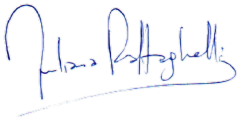

# Centering complexity in "educators' data literacy" to support future practices in faculty development: A systematic review of the literature

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## Abstract

As algorithmic decision-making and data collection become pervasive in higher education, how can educators make sense of the systems that shape life and learning in the 21st century? This paper outlines a systematic literature review that investigated gaps in the current framing of data and faculty development, and explores how these gaps prevent the formulation of potential pathways and principles for fostering educators' data literacy. The analysis of 137 papers through classification by relevant categories and key word mapping shows that there is little attention on higher education teachers. It also makes clear that most approaches to educators' data literacy address management and technical abilities, with less emphasis on critical, ethical and personal approaches to datafication in education. The authors conceptualise this situation as a "complicated" approach to data literacy in the academic profession, as opposed to a complex vision which would bundle management and technical skills together with a critical, systemic approach to professional learning and data.

Keywords: data literacy, educators, faculty development, complexity

## Introduction

Digital technologies and data systems play central roles in contemporary life and in the structural challenges our society faces. The systems we rely on for scholarship and education are increasingly datafied, even as race and gender biases built into algorithmic decision-making become increasingly evident (Noble, 2018). Moreover, surveillance capitalism (Zuboff, 2015) continually translates digital experience into behavioural data for extraction (Erickson, 2018), within learning environments as well as the broader culture. This represents a fundamental shift in the relationship between society and its knowledge platforms.

Critical literacy in these core systems that shape our world is, therefore, increasingly important. In education, where the perspectives of emerging generations are shaped and

honed, critical and systemic explorations of digital and data infrastructures should be a particular priority. However, the growing datafication of education (Perrotta & Williamson, 2018; Williamson, 2018) and the increasing pervasiveness of learning analytics (Siemens, 2013; Wasson, Hansen, & Netteland, 2016) appear to have crept up on many educators, both in K12 and in higher education. In order to grapple with this shift and its implications for academia, educators must develop data literacies in order to be a part of shaping the future of the academy (Author, 2018).

The term "data literacy" was coined out of a tradition of research on numeracy, and later on "statistical literacy" (Gould, 2017). This initial frame was connected to basic mathematical operations, later undertaken within and through digital tools and environments (OECD, 2012). The increasing complexity of information in our contemporary society led to the widespread adoption of statistics to support journalism, public policies, business success and expansion, with the consequent manipulation of this type of information and the need of educating people to read, understand and deal with statistics (Gould, 2017; Huff & Geis, 1954) . More recently, datification in digital environments became tied to a specific set of advanced skills in an interdisciplinary field at the cross-over of informatics and statistics, namely *data science.* However, the educational tradition of developing literacies for all in contemporary society led to open debates framing "data" literacy as a complex set of basic skills including statistical readiness, digital data collecting and processing, and deployment of data as evidence in narrative (Ridsdale et al., 2015). These differing definitions coincide regarding elements of data extraction, management, and processing. A literature review by Maybee & Zilinski (2015) identifies 8 key frameworks for data literacy: a) Awareness: Understanding data and its role in society; b) Access: Understanding how to identify, locate and appropriately use datasets and databases; c) Engagement: Evaluating,

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analyzing, organizing and interpreting existing data for decision-making; d) Management: Planning and managing data, including organization and analysis, security protocols for data storage, sharing data, and data-driven documentation; e) Communication: Synthesizing, visualizing and representing data; f) Ethical Use: Identifying diversified data sources, in particular data from human and social activity, considering the risks and issues implicit in the use of such data; g) Preservation: Being aware of long-term practices of storing, using and reusing data.

The European debate on Digital Competence recently included data literacy in its DigComp 2.1 framework (Carretero, Vuorikari, & Punie, 2017). Their usage, however, was mostly connected to the first phases of digital information literacy (search, retrieve, interpret) and less connected to technical or creative elaboration of data (Author, 2017). Such data literacy models tend to cover fragmented sets of abilities, mostly connected to technical skills and with minimal connection to social media studies (Pangrazio & Selwyn, 2019). This means that power issues, ethics, the politics of personal data traces, and the usage of personal data in profiling, data recirculation, and other controversial practices are seldom factored in.

The types of technical and instrumental approaches featured in fragmented, skills-focused data literacy models tend to reduce an interwoven set of systems to the parts and outcomes that can be observed or measured. Technological innovation is framed in terms of saleable products or processes, rather than systemic or social changes, and the data from networked interactions is increasingly deployed for profit (Erickson, 2018). As a result, the educational focus on data infrastructure is dominated by “learn to code” initiatives and an emphasis on computational thinking, which obscures other elements of the rise of AI, big data, and machine learning from view (Bridle, 2018).

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The authors of this paper were curious whether this tendency towards technical approaches to data literacy extended from models to the broader literature, and to faculty development initiatives and approaches. We hypothesized that few empirical studies would analyse the relationship between professional learning needs and data-driven practices in higher education, and set out to find whether the existing literature on educators' data literacy focused primarily on technical data-handling and on educational data management (Mandinach & Jimerson, 2016). In order to move our inquiry forward, we systematically analyse the literature on educators' data literacy, in order to establish which discourses are absent. We then develop a conceptual scheme that suggests future directions for faculty development, based in the tenets of educational theory, critical data literacy, and the concept of complexity.

## 2. Background

### *2.1. Responses to datafication*

As noted, the strategic professional development of educators' data literacy remains limited, but the literature on datafication in education is growing. Lupton and Williamson (2017) posit that a new governance regime is established through technological surveillance and datafication, with emphasis on practices of 'evidencing, auditing, measuring, and monitoring.' (p. 3). Ball (2012) and Williamson (2016) argue that the digitization of educational governance – through focus on calculation, database architectures, analytic packages, and data dashboards – has subjectified a new kind of quantified teacher. As Buchanan and MacPherson (2019) note, 'much of the current datafication requires an unthinking engagement from teachers' (p. 4). Rather than an empowered subjectification or an opportunity for developing key contemporary systems

literacies, Williamson asserts that these effects on educators' professional identities are not an accident, but part of an education system increasingly under technocratic control.

> Although venture philanthropies have long sought to interfere in public education through charter schools, the new Silicon Valley venture philanthropists are seeking more overtly computational models of education reform which utilize the technical expertise of Silicon Valley itself to design new software systems and technological fixes for insertion into the institutions of education (Williamson, 2017, p. 226)

There are forms of resistance to the current state of affairs. For Milan & Van der Velden (2016), data activism represents an emergent means of countering datafication. They frame data activism as a set of emerging practices which interrogate datafication and its socio-political consequences. These practices can take varying shapes: 'While our notion of data activism presupposes the possibility for contention and rebellion, we understand data activism as a series of nuanced phenomena that position themselves in a continuum between contestation and recognition' (p.61). Their framing creates a continuum from positive engagement with data and or "pro-active" data activism, to "reactive" data activism or tactics of resistance to data collection. However, this approach only describes existing practices. Neither reactive nor pro-active responses to the changes that big data represents to higher education are fully adequate lenses through which to evaluate a pervasive and destabilizing phenomenon.

Instead, data activism needs to go beyond reactive and pro-active perspectives, and must re-frame and critique our societal relationship to data entirely. In this regard, education as discipline can offer a key way forward, since epistemologically education is a science supporting social awareness and transformation (Freire, 2000; Margiotta, 2006) Education is a design science, with 'designerly ways of thinking' (Goodyear & Dimitriadis, 2013) that encompass loops of experimentation, reflection and change.

Moreover, education is also the disciplinary home of critical pedagogy. Critical pedagogy's focus on the evaluation of structure, power, and transformational capacity means that the field offers a valuable lens through which to frame questions of educators' data literacy and the systemic shifts we currently face (Manca, Atenas, Ciociola, & Nascimbeni, 2017; Markham, 2018; Tygel & Kirsch, 2016). In the following section, we attempt to tie this evolving debate on data literacies to the specific challenge of faculty development for increasingly datafied contexts of practice.

### *2.2. A framework to rethink data epistemologies for faculty development*

*Faculty development* generally refers to professional learning within higher education. Traditionally, studies on faculty development focus primarily on the effectiveness of professional development programs (Centra, 1978; Simon & Pleschová, 2013), and the skills and literacies needed to do scholarship in digital spaces (Meyer, 2014). However, many faculty development studies have been criticized for a lack of theoretical or conceptual framework on professional learning and its relationship to practice (Webster-Wright, 2009). A few exceptions cite adult learning theories such as transformative learning by Mezirow, andragogy by Knowles, or reflective practice by Argyris & Schon (Amundsen & Wilson, 2012; Meyer & Murrell, 2014), nonetheless, the literature is uneven. Some studies focus on skills acquisition or student achievements as proof of effectiveness (Bahar-Ozvaris, Aslan, Sahin-Hodoglugil, & Sayek, 2004; Cole et al., 2004). Others focus on the process of active professional learning as part of changing practices, but also emphasize modification of the professional and organizational context, treating academics as social and situated learners (Boud, 1999; Cox, 2004). However, Bali and Caines (2018) do specifically call for a transformative and heutagogical (Blaschke, 2012) approach to digital faculty development via connected learning, offering models for engaging educators in the

development of networked practice. In alignment with this, we propose faculty development grounded in professional and connected learning, and aimed at developing the literacies needed to deal with data cultures in higher education. We posit that faculty development for data literacy should foreground policies on data use, shape institutional approaches, open dialogue with students, and generate models that are relevant for all stakeholders of the educational process, not solely for those focused on performance management or surveillance interests.

In higher education, the emerging use of learning analytics has raised interest in training faculty to adopt analytics (Persico & Pozzi, 2015; Wasson et al., 2016), in order to signal innovation and objectivity. Against this context, faculty development in data literacy may be likely to be situated within a context of accountability culture and evidence-based policy, or framed as an efficiency for supporting school performance and school management, as has been the case in teacher education and K12 data literacy research (Dunlap & Piro, 2016; Hoogland et al., 2016; Mandinach & Jimerson, 2016). In the latest report by the Joint Research Center for the EU Commission, the lack of mainstreamed practice in adopting learning analytics and developing institutional policies that centre learning analytics as instruments within HE (Vuorikari et al., 2016) was strongly emphasized. At the same time, the literature has pointed out how seldom learning analytics technologies align with pedagogical conceptions and theories, stemming mainly from developers' priorities rather than educational processes (Prinsloo, 2017; Slade, 2016). DeRosa (2017) notes that the rise of learning analytics in educational systems was originally focused on understanding digital data in order to create meaningful interventions, but – with the emergence of predictive analytics – has shifted from hindsight to foresight. Institutional policies addressing the use of Learning Analytics are still developing and more consideration has been shown to be needed in

areas of pedagogy-based approach and establishment of communications channels among stakeholders (Tsai & Gasevic, 2017). In any case, the need for skills and knowledge to engage ethically and pedagogically with learning analytics in relation to institutional data traces should be considered a specific strand of data literacy (Wasson et al., 2016)

As observed in the overall field of data literacy, the literacies required for educators to thrive in datafied professional contexts seem to demand broader epistemological frameworks than a technical, instrumentalist focus on performance mangagement, effiencies, or evidence can offer. As Fenwick and Edwards (2016) have suggested, the dominant technically-focused framing reconfigures professional practice and responsibility without adequately addressing the implications this holds for professional education. Therefore, as a complement to the tools that critical pedagogy and professional learning-based approaches to faculty development bring to the table, we also draw on Snowden and Boone's (2007) Cynefin Framework as a way of distinguishing complicated from complex approaches to the investigation of data. An anti-technocratic approach demands a conceptual framework that can identify how technical vs. systemic approaches operate, and apply these distinctions to the analyses at hand.

"Cynefin" translates from the Welsh as "habitat," broadly, but focuses on ecological, relational understandings of environment and domain, and emphasizes that knowledge and sense-making emerge in specific ways from particular and situated cultural communities. As a framework, Cynefin identifies five domains for decision-making, each representing a different type of ecosystem for problem-solving based on variant cause-effects patterns. As Snowden (2007) puts it,

> Four of these—simple, complicated, complex, and chaotic—require

> leaders to diagnose situations and to act in contextually appropriate ways. The fifth—disorder—applies when it is unclear which of the other four contexts is predominant. (para 5)

For our purposes, the key distinction the Cynefin framework offers is between the complicated domain and the complex. In English, the two words are often used interchangeably, and the distinction is not always clear. But Cynefin – which operates as a sense-making tool for understanding which kind of environment or problem one is dealing with – draws a valuable distinguishing line between the two. In a society grappling with drastic systemic change, the capacity to identify which domain a particular challenge – or response – originates from can help establish whether proposed solutions actually address the problems at hand.

In Cynefin, contexts designated as complicated tend to be the domain of experts, can contain multiple right answers or paths toward right answers, and have clear – if not always visible – relationships between cause and effect. They are characterized by a "sense, analyse, and respond" approach to problem-solving, because while expertise is required to investigate several options, good practices, if not the singular and established best practices of the simple or obvious domain, can be established. This is what Snowden calls the realm of "known unknowns," or situations where it's clear – at least to experts - what needs to be figured out and some of the established paths to achieving that end.

In the complex domain, however, patterns are not as replicable: this is the realm of "unknown unknowns," in constant and systemic flux. Complexity is an emergent domain wherein the predictability that expertise is based on is no longer a reliable construct, in which a "probe, sense, respond" approach to problem-solving is demanded because solutions cannot be known in advance.

Dichiaro che nel presente articolo ho ideato e implementato la ricerca, e i seguenti paragrafi possono essere attribuiti al mio lavoro di elaborazione dati e scrittura:

How can the concept of complexity ground a new approach to data literacy be applied to faculty development to drive meaningful institutional change surrounding datafication?

As we see it, dominant instrumental models and technical framings of data and its use represent what the Cynefin model would identify as a complicated approach to the problem of developing educators' data literacies. These models approach faculty professional learning in relation to data literacies as a field with knowable right answers that can be arrived at via correct application of expertise. A complex approach, instead, would be grounded in the recognition of the interwoven socio-technical nature of the undertaking. A complex approach rejects a purely technical perspective, which does not acknowledge the professional cultures and institutional cultures in which faculty development takes place, nor the individual learning needs that faculty and staff members bring to professional learning contexts.

A starting point in developing this complex, critical approach is an exploration of the many existing practices and meanings assigned to the intersection of data literacy and faculty development, but also the identification of gaps in existing data literacy research. Our systematic review of existing literature is a first step on that path.

## 3. Methodology

### *3.1- Study design and Sampling*

Our systematic approach was based on the PRISMA workflow (Moher, Liberati, Tetzlaff, Altman, & PRISMA Group, 2009). This type of approach to reviewing entails a process of appraising, summarizing and outlining the literature, while dealing with otherwise unmanageable quantities of documents. Moreover, the process also attempts to control for researcher bias in data collection and analysis (Petticrew & Roberts, 2006)

Following this approach, four scientific databases (SCOPUS, ISI Web of Science, ERIC, DOAJ) that index peer-reviewed research were scanned (see Fig 1). In terms of access policies and quality of resources, the first two databases index prestigious journals, but that are prevalently of restricted access. To balance this situation, the authors considered also ERIC and DOAJ which address Open Access and provide links to full access resources. As for the material indexed, these databases were selected due to their coverage of a) peer-reviewed empirical research; b) social research; c) educational research. Within each database, we adopted the query "Data Literacy" AND "Teachers" AND "Faculty Development" without time or disciplinary constraints.

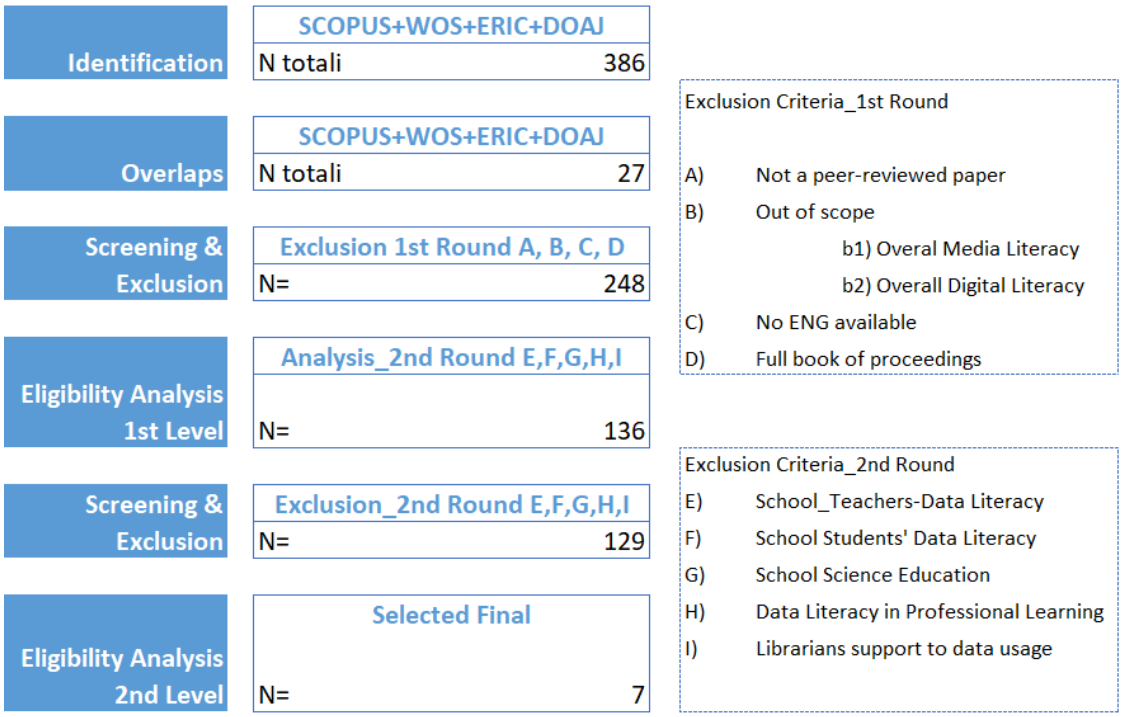


Figure 1 - PRISMA Workflow – Selection of Articles

This search yielded 386 papers. From these, 92 were overlaps and, once eliminated, 294 papers were considered for the screening phase. In this phase, two researchers read the abstract and excluded the papers that were not relevant for the analysis envisaged. The

exclusion criteria (see Fig. 1) were elaborated considering the transparency and replicability of the procedure, as well as the focus of the research on data literacy. From this first screening phase, 157 papers were eliminated and 137 were considered for the next phase of analysis. Two researchers read the full text of the articles and classified them according to a set of categories which were discussed and deemed relevant to depict the landscape of faculty development on data literacy.

*3.2. Data Analysis*

As for the analysis, the papers were coded and classified into different categories, as defined by the two authors on the basis of the background and research hypothesis. The categories attempted to capture the emerging discourses in the literature on data literacy and faculty development, according to the conceptual scheme devised. The scheme was presented and discussed within one group of four researchers (coming from the consolidated Edul@b research group, two senior researchers and two PhD students engaged in the session) for validation, and adjusted.

| | | |
|---|---|---|
| Research Topic | Connected to the overarching disciplinary field where the research can be placed, and based on the keywords given by the authors. | Teachers' professional learning |
| | | Faculty Development |
| | | Science Education |
| | | Research Training/Development |
| | | Media Education |

| | | |
|---|---|---|
| | | Civic Education |
| | | Teaching |
| | | Learning |
| | | Arts Education |
| Educational Level | Characterization of the educational level taking into consideration the lifelong learning spectrum | Early Education and Care |
| | | K12 |
| | | Teacher Education |
| | | Professional Learning |
| | | Adult Learning |
| | | Higher Education |
| Data Literacy Definition | The conceptual and empirical definitions given to the construct of Data Literacy. The concept relates the way the phenomenon is characterized overall, beyond the specific type of practices. Therefore, it relates to the ontological level. The categories have been elaborated over the work of Pangrazio&Selwyn, 2019. and Tygel&Kirsch, 2016. We provide here a synthetical definition: | Data Safety/Data Management |
| | | Data Science |
| | | Data in Education |
| | | Data Hacking |

| | | |
|---|---|---|
| | Data Safety/Management: data handling to produce evidence. It can be both applied to the research or to educational management, and it encompass data curation to support research or evaluative claims.<br><br>Data Science: the technical practices of data production/extraction, elaboration, visualization and communication through more or less statistical and computer science skills. It is connected also to the usage of data as educational resource.<br><br>Data in Education: the usage of pedagogical data-driven decisions, particularly the usage of learning analytics.<br><br>Data Hacking: all citizen forms of engagement with open government data or open research data in order to learn, improve own life conditions, or generate new social practices. The term “hacking” has been adopted in connection to the activist approach where data is browsed, extracted and integrated into narratives that challenge the system or empower the users.<br><br>Critical Approach to Data: a vision of personal, social, or technical/research data where the users go beyond data handling (technical abilities) and embedding into social life, but they reflect over the cultural, semiotic and political nature of data in its context of production.<br><br>Unclear Theoretical approach: when the article does not fall in any of the categories above. | Critical Approach to Data<br><br>Unclear theoretical positioning |
| Data Epistemologies | The type of epistemological positioning relating data (according to &van der Velden, 2016 and authors’ elaboration). | Re-Active<br><br>Pro-Active<br><br>Complex |

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| | | |
|---|---|---|
| | Reactive: datafication is seen in a dystopic way, where the people take action to defend privacy and avoid personal data collection or tracking. It is a defensive positioning.<br><br>Proactive: datafication is seen as utopia, and people make every effort to capture data value. The focus of activity deals with data handling, collection, extraction, visualization, communication and integration into technical and technological innovation.<br><br>Complex: datafication is considered as layered system, where reactive and proactive epistemologies are embedded, but there is an effort of social and cultural contextualization that leads to actors- understanding of all possible scenarios and to search and decide own best way. | |

Table 1 – Interpretive categories used to analyse articles

The whole table as codebook for our classification, as well as the dataset, can be consulted as Open Data (Author, 2019)

After consolidating the categories, the authors analysed 13 papers (10% of the overall, first phase dataset of 137 papers) and the inter-rater agreement was calculated.

The Cohen's kappa obtained was 0.67, which can be interpreted as "Substantial Agreement" (0.6 to 0.8). Therefore, the codification of the remaining 136 papers was undertaken, adopting the criteria discussed within the research group.

The data collected through the database (cf. Table 1) was processed by adopting two techniques:

A- Descriptive univariate and bivariate statistics for the first set of papers analysed (137), focusing the overall discourses and research on data literacy. This technique was adopted to better describe and summarize the numerous variables studied in the

literature, according to the classification in Table 1. The software Tableau was used to produce visualizations.

B- A keywords map was created. Bibliometric maps are a form of representation of scientific networks (van Eck & Waltman, 2014), used in Scientometrics as a mean for "mapping science" or understanding connections between researchers and their work. Bibliometric maps are based on three main elements: statistical analysis of written publications (often including text and data mining); methods of visualization (distance-based; graph-based; timeline-based) and digital tools supporting analysis and visualization. Bibliometric maps are usually based on graphs consisting of nodes and edges; while the nodes may represent publications, journals, researchers or keywords, the edges represent forms of relationship between the nodes. In the keywords map, the terms co-occurrence gives information about the distribution of topics. Not only do the forms of visualization explore a current, static relationship, but they also highlight groups (clusters) that are "closer" within the relationship. We deemed this type of analysis relevant to search for convergences with the prior analysis based on researchers' codification, where there is a risk of bias due to the researchers' judgement (in spite of the intersubjective raters' agreement). The software VosViewer was adopted to produce this type of visualization.

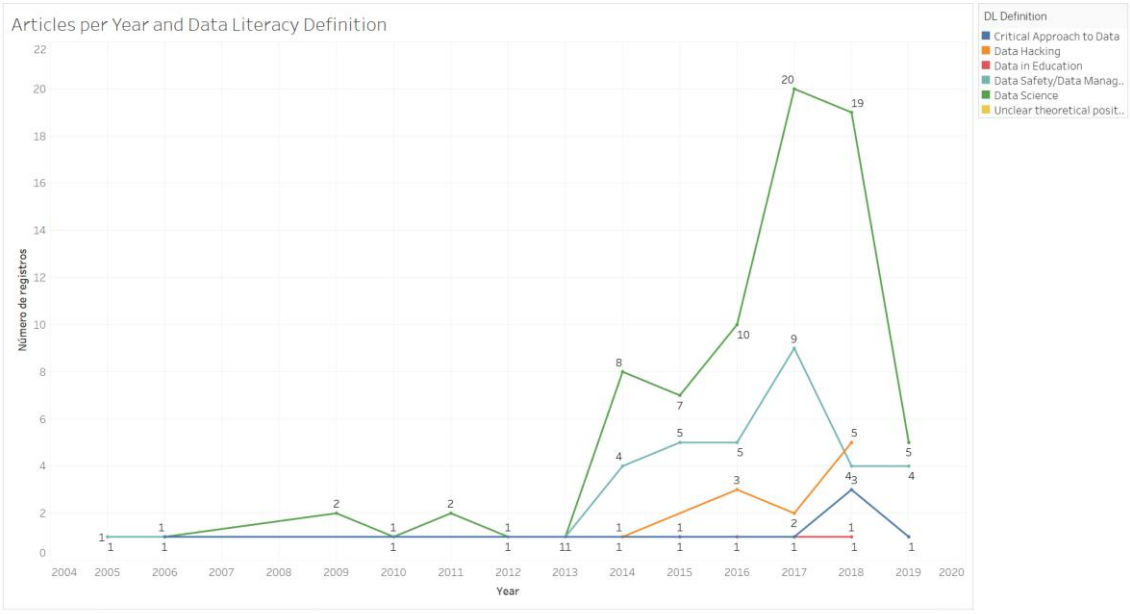
### *4. Results*

In this section, the results are presented according to the main categories of analysis explained in the previous section, combining the elements in order to gain a better understanding of the findings.

The first issue considered was the types of data literacy definitions, across a time span. Fig. 2 describes the research activity along a timeline. Firstly, it shows growing interest on the topic, with a peak of articles after 2017 in the two main categories (data science

and data management), showing the increasing concern and interest of the educational research community on the topic.

Secondly, fig. 2 highlights that articles addressing data literacy practices and research through the lens of data science are prevalent (78/137). Data science definitions of data literacy are focused on technical abilities like extracting data, making statistical analysis, creating visualizations, interpreting and reporting appropriately (see for example: De Amicis et al., 2019; English & Watson, 2018; Slayter & Higgins, 2018). Data safety/data management followed the data science category with as nearly half the number of articles (35). The prevailing discussion focused on School Management and teachers' data literacy to produce evidence for better educational quality, learning assessment and educational evaluation (e.g.: Dunlap & Piro, 2016; Ebbeler, Poortman, Schildkamp, & Pieters, 2016; Mandinach & Gummer, 2016) Much less numerous were papers dealing with data in education (5 articles taking into consideration the use of data to support learners' self-regulation and pedagogical understanding, e.g., Wasson et al., 2016) data hacking (11 articles focusing data literacy as form of citizen empowerment to deal with Open Data, e.g. Carroll et al., 2018) and critical approaches to data (7 adopting a broader approach to data literacy where learners' understanding and awareness of data-structures is included in data manipulation, analysis, or simple usage, e.g. Atenas, Havemann, & Priego, 2015). As we see, there is a range from technical, instrumental emphases on data literacy towards approaches that envisage learners' empowerment and appropriation of data. The emerging picture, however, shows overwhelming focus on specific skills rather than a more holistic idea of data literacy.




| Articles x | Year | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Data Literacy Definition | 2005 | 2006 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | Total general |
| Critical Approach to Data | | 1 | | | | | | | 1 | | 1 | 3 | 1 | 7 |
| Data Hacking | | | | | | | | 1 | | 3 | 2 | 5 | | 11 |
| Data in Education | | | | | | | | 1 | 1 | 1 | 1 | 1 | | 5 |
| Data Safety/Data Management | 1 | | | 1 | | 1 | 1 | 4 | 5 | 5 | 9 | 4 | 4 | 35 |
| Data Science | 1 | 1 | 2 | 1 | 2 | 1 | 1 | 8 | 7 | 10 | 20 | 19 | 5 | 78 |
| Unclear theoretical positioning | | | | | | | | | | | | 1 | | 1 |
| Total general | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 14 | 14 | 19 | 33 | 33 | 10 | 137 |

Fig. 2 - Number of Articles per Category “Data Literacy Definition” over time.

Our further exploration of the literature focused on the overall epistemological approach to data, both in research topic and educational level. Fig. 3 displays this analysis, highlighting how the majority of papers came from the topic of Teachers’ Professional Development (33/136), followed by research dealing with learning processes (Learning, 27) and research dealing with Research Training/Development (25). The presence of specific papers devoted to the research topic of Science Education (14) is also relevant. Very little attention is paid, as expected, to the research topic of Faculty Development (8 articles). As for educational level, we observe that most papers can be located at the Higher Education level (48/136) and Teachers’ Education (32). However, research focusing on HE practices and processes encompasses the research topics above, namely, most articles coming from research data management and training, learning, science

education, some articles dealing with initial teachers' education, and finally, faculty development.

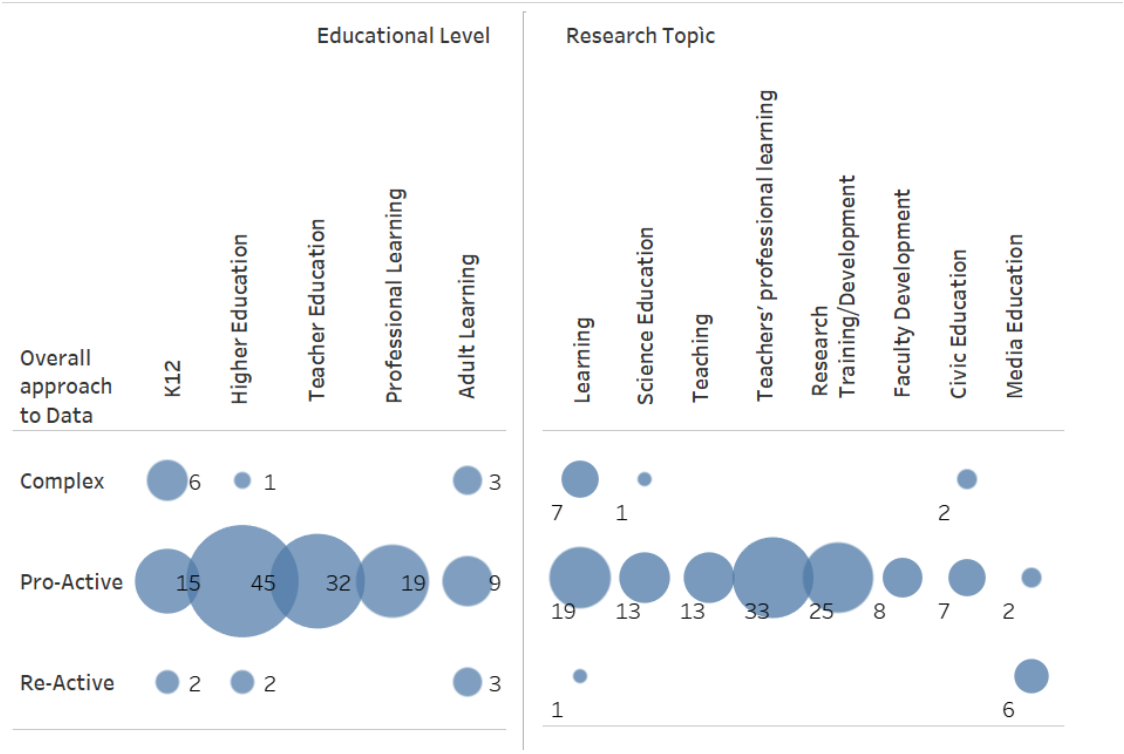



Fig. 3- Overall approach to data, according to the Research Topic and the Educational Level

Finally, the keywords map rounds out the picture. As explained, this technique is based on the analysis of terms co-occurrences in a corpus of text composed of all 137 articles. The clusterization of more frequent terms shows their associations, represented in different colours in the picture. The most frequent terms are represented using bigger nodes. Four clusters emerged, as presented in figure 4. For the detail of words' frequencies and the relevance score in each cluster, please see Appendix 2.

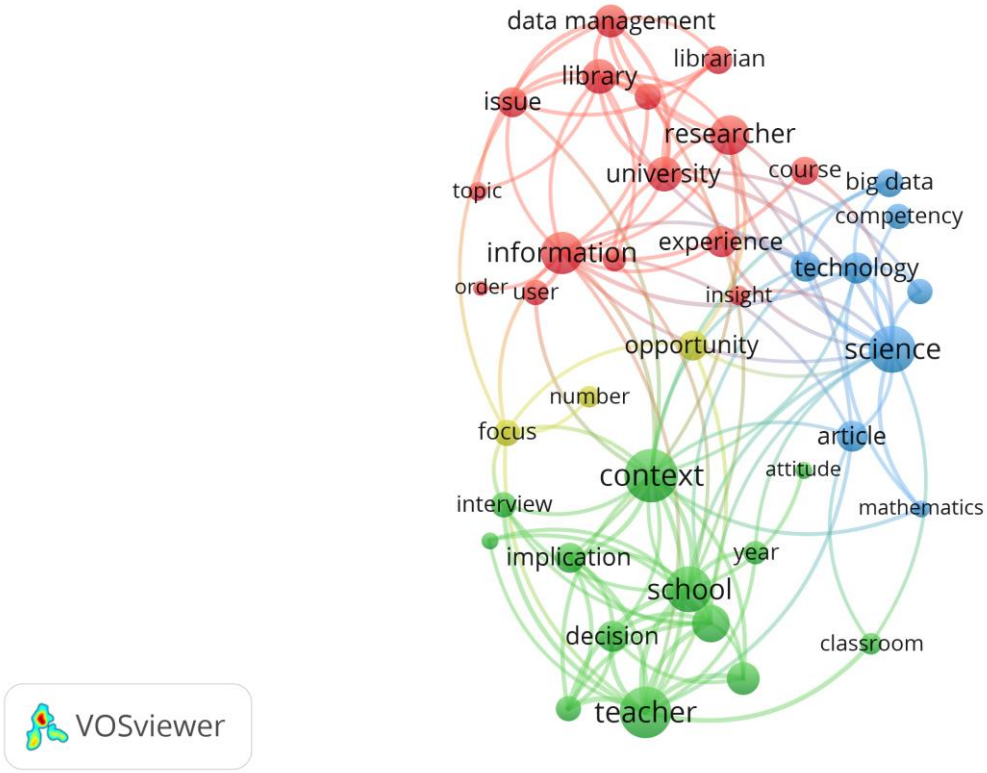



Fig.4- Keywords' map and clusters representation

The first cluster, where the most frequent word was "context", was composed of words clearly relating decision making in school management. This clusterization proved to be consistent with the Data Literacy definition of "Data Management". In fact, the frequent words co-occurring related to the teacher/educator as actor, her implication/intervention at school/classroom, and its professional attitude to the evidence as pillar of educational practice.

The second cluster showed the term "Information" as central node, which conveys the meaning of data management in research. Most important actors here are the librarians, and the library support to researchers, with most practices to be placed in Higher Education. Moreover, as it emerged in our analysis of papers, also researchers' and students' initial training in data management techniques fallen into the definition of data

literacy as research data management. Some of the clustered words (Course, Order, Part, Researcher, Topic, University, User) address this approach to data.

The third cluster presented the term “Science” as most frequent and all the words clustered convey the approach of data science, mostly within STEM education (Ability, Article, Big Data, Competency, Field, Mathematics, Science, Technology). This result was also consistent with our classification of Data Literacy definition as “data science”, encompassing all technical skills required to handled complex datasets and produce dynamic representations.

The last, fourth cluster is certainly the most intriguing, for it is represented by only three terms, with “Opportunity” at the center. In this regard, all the above mentioned definitions of data literacy (data management, data science) including also “data hacking”, could embedded this idea of big and open data as opportunity to transform the human activity.

The definition of data literacy as “data in education” and the “critical approach to data” seems to be misrepresented or not represented at all. This is due to the low number of papers addressing these two definitions, considering the quantitative approach to the analysis of the text and the following representation.

However, the over-representation of the first three definitions of data literacy (management, science, hacking) is telling in any case, and consistent with our prior picture. In our landscape of data-practice, this second analysis is going into the direction of most discourses, research and practices addressing the concern of technical skills to deal with data.

## *5. Discussion*

This investigation explores how contemporary trends toward technical, computational, and evidence-based approaches to education and data tend to narrow focus on data

literacy to its instrumental components, a phenomenon fostered and supported by parallel narratives on machine learning and AI. Our empirical research identifies the following findings.

The majority of the data literacy definitions adopted within the corpus of the 137 articles analysed lean towards an instrumental framing. They highlight a deep focus on the development of technical skills such as data extraction, statistical analysis, visualization, and appropriate interpretation and reporting, framing knowledge in technical and measurable ways. Many papers emphasize the context of science education and research skills development, as related to data management. Another prevailing trend underscores school management and teachers' data literacy as a means to produce evidence. Articles that reflected an evidence-driven approach to data literacy and management also tended to make implicit or overt claims about educational evaluation and better educational quality and learning assessment. The emphasis on data in learning, primarily as content triggering advanced technical skills development, and on science education and K-12 teachers' professional learning was significant compared to emphasis on faculty development. This demonstrates the lack of acknowledgement of the emerging debates on data and ethics, minorities, privacy, agency and empowerment in the context of a datafied society and education.

In our findings, we discovered that the discourse of the majority of the papers in the corpus is concerned with datafication as a series of proliferating technical practices, differing across disciplines, but framed in terms of knowledge and actions: a mastery of known unknowns. There is prevalence of what the Cynefin framework would call a complicated epistemological approach to datafication, with little attention to faculty's professional practices in that realm.

The synthetic set of categories dealing with what we called "data epistemologies" shed further light on data practices and data literacy approaches to professional learning. As noted above, a scarce number of papers envisioned data literacy through a complex lens, with a prevailing trend of papers reflecting a pro-active or mastery-focused perspective. In fact, most papers asserted a need for innovation to embrace the power of data, and reflected acceptance of the premises of computational thinking. And as our keywords map displays, the overall picture from the corpus revealed convergent patterns of information on the prevalence of data discourses and epistemologies.

In place of this dominant approach, we propose an alternative conceptual framework for data literacy which introduces a “complicated/complex” distinction. This distinction, based in the Cynefin framework, iss a mean to distinguish technical and instrumental approaches from critical and socio-technical approaches to understanding datafication and its consequences in educational practice. The Cynefin framework enables us to examine the ways in which datafication discourses operate. Through what Cynefin would call a complicated lens, data are seen to support more effective decision-making by turning unknown factors into knowns. For example, the advertisement for MIT’s 2019 online Professional Education program in Machine Learning (https://professional.mit.edu/programs/digital-plus-programs/course-offerings/machine-learning-data-decisions) claims that machine learning uses data to help optimize choice and turn ‘what is unknown into what is known.’

In Cynefin terms, the complex domain is the territory of unknown unknowns, whereas the complicated domain is marked by the presence of knowable unknowns, making it far more certain and measurable. The tagline for the MIT course, “Machine Learning Diminishes Uncertainty: Harness its Power,” emphasizes the appeal of being able to superimpose order and potential for right answers on the uncertainty of contemporary

life. However, while there are many fields and problems in which known unknowns are genuinely foundational, there are many others in which problems are emergent, and the unknowns can't yet be predicted. Datafication can therefore operate as a reductive lens that restricts what is seen as relevant to factors are knowable, leaving complex realities out of decision-making entirely.

Our assertion is that the strong emphasis on how to navigate datafication effectively, without examination of the assumptions and norms that data practices represent and reinforce within the academy, is a problematic default approach for higher education. It serves to remove the pedagogical and ethical complexities of data from the view of decision makers and stakeholders. It also fails to support the development of complex literacies regarding data, analytics, and higher education systems, and thus cannot be an appropriate foundation for the academy's response to the emerging unknowns of surveillance, datafication, and machine learning systems currently faced.

Neither can this instrumental perspective on data and efficiencies serve as a meaningful or adequate foundation for faculty data literacy development. The narrowness of technical or complicated approaches that reduce unknowns to knowns has the potential to impact educators' capacity to understand and shape what counts as knowledge within this emergent era of datafication. Education - and particularly media education and digital literacy approaches - attempts to generate spaces of collective reflection which can spread awareness and generate creative and agentic practices for dealing with unknowns. Institutions of education are the most likely societal sites for any formal development of complex data literacies, but the instrumental and technical approach to data systems within education serves to obstruct that development. The same can also be said of faculty development practice: if approached from a complex, critical professional learning focus, as supported by Bali & Caines (2019), data literacy faculty

development could generate creative, agentic responses and critical awareness among educators. However, our findings on data literacy approaches generally and in faculty development specifically suggest that this approach is not currently in broad use, which has the potential to affect students' development as future intellectuals in this important area.

### *6. Further research and conclusions*

This research clearly establishes a gap in higher education's response to datafication, particularly in the areas of faculty development and professional learning. We acknowledge that our efforts to make this gap evident and to advocate for a complex epistemological approach to addressing it rely primarily on quantified methods. This was an intentional choice on our part. A formal schematic and systematic review of data literacy faculty development needs to form the foundation for any argument for change, if we hope to convince those who are invested in a more complicated rather than complex view of the field. From here, however, a more critical and complexity-focused research approach will ground our ongoing investigations. Next steps that this research demands include qualitative interviews and thick description aimed at exploring the actual data literacies of higher education professionals and the tensions and contradictions that datafication creates in daily practice. After that, further research into systematic yet agentic approaches to faculty development and professional learning in the area of data literacy need to be undertaken.

These next steps are important, because if training in the technicalities of innovation remains the norm for data-focused faculty development initiatives, then the power relations that privilege complicated rather than complex epistemologies will not be addressed. Moreover, voices and disciplines that value complex positions are likely to be increasingly marginalized in discussions of innovation, futures, accountability,

efficiencies, and other conversations in which data is deployed in lieu of policy or professional learning approaches.

If professionals in academia want to see higher education grapple with data and the often reductive and instrumental nature of the ways data is used in our organizational systems, we need to advocate for more critical and complex data literacy and professional learning efforts. A complex, critical pedagogy approach to designing faculty development for data literacy would include frameworks for competence, contexts for knowledge claims, resources, institutional strategies and policies, case studies, coaching and personal scholarly practices as they relate to data systems. It would also include critical analysis of higher education governance and an examination of the regimes of power and knowledge represented by the complicated domain and by computational thinking narratives.

Beyond critical pedagogy and the Cynefin framework, there are other theoretical foundations that could be drawn upon to counter the approaches currently dominating data literacy. As noted earlier in the paper, the field of education is uniquely positioned to lead a broad and meaningful shift in how higher education fosters data literacy and addresses datafication.

Overall, our work confirms that the intersection of data literacy and faculty development is, as yet, largely limited to efforts to increase data skills rather than explore datafication as change. There is little common understanding of what data literacies might be valuable to higher education staff, across disciplines, nor what implications data has for the field of academia as a whole. This research suggests that the dominant technical or complicated perspective on data literacy and professional learning may not be sufficient either to promote meaningful adult learning nor actual critical engagement with a powerful cultural shift in higher education.

Our perspective is that data literacy faculty development should balance societal goals, institutional goals, and individual, contextual practices. We are interested in trying to frame what complex, critical professional learning about datafication in the academic context could look like in faculty development research that will build on the foundation begun here.

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Appendix 1 – Full Database for the Classification of Articles

| Fields | Description | Subfields: codes assigned |
|---|---|---|
| Authors | Progressive number of Author: 1st, 2nd, ...n | Name and Surname of the Publication's author |
| Title | Publication Title | Title assigned by the authors |
| Year | Year of publication | Number |
| Source title | Journal, Conference or other information indicating the type and context of publication | Title/name of the source |
| Cited by | Number of authors citing the publication under analysis | Number |
| DOI | Digital Object Identifier | Specific DOI |
| Document Type | Type of publication | Article |
| | | Book |
| | | Book Chapter |
| | | Conference Paper |
| | | Note |
| | | Review |

| | | |
|---|---|---|
| | | Not categorized |
| Publication_ Source | Scientific Database where the publication was found: Scopus, WOS, DOAJ, Google Scholar. The code indicates whether the paper was found in one or more specific databases | 0 |
| | | 1 |
| Abstract | Synthesis of the research as provided by the authors | Abstract found in the article or database |
| Research Topic | Connected to the overarching disciplinary field where the research can be placed, and based on the keywords given by the authors. | Teachers' professional learning |
| | | Faculty Development |
| | | Science Education |
| | | Research Training/Development |
| | | Media Education |
| | | Civic Education |
| | | Teaching |
| | | Learning |
| | | Arts Education |

| | | |
|---|---|---|
| Educational Level | Characterization of the educational level taking into consideration the lifelong learning spectrum | Early Education and Care |
| | | K12 |
| | | Teacher Education |
| | | Professional Learning |
| | | Adult Learning |
| | | Higher Education |
| Data Literacy Definition | (1) The conceptual and empirical definitions given to the construct of Data Literacy. The concept relates the way the phenomenon is characterized overall, beyond the specific type of practices. Therefore, it relates to the ontological level. The categories have been elaborated over the work of Pangrazio&Selwyn, 2019. and Tygel&Kirsch, 2016. We provide here a synthetical definition:<br>(2) Data Safety/Management refers to data handling to produce evidence. It can be both applied to the research or to educational management, and it encompass data curation to support research or evaluative claims. | Data Safety/Data Management |
| | | Data Science |
| | | Data in Education |
| | | Data Hacking |
| | | Critical Approach to Data |
| | | Unclear theoretical positioning |

Dichiaro di aver disegnato, progettato e implementato la ricerca presente in questo articolo. Ho scritto interamente i seguenti paragrafi: Introduction, Background 2.1, Methodology Results.

| | | |
|---|---|---|
| | (3) Data Science introduces the technical practices of data production/extraction, elaboration, visualization and communication through more or less statistical and computer science skills. It is connected also to the usage of data as educational resource.<br>(4) Data in Education identifies the usage of pedagogical data-driven decisions, particularly the usage of learning analytics.<br>(5) Data Hacking defines all citizen forms of engagement with open government data or open research data in order to learn, improve own life conditions, or generate new social practices. The term “hacking has been adopted in connection to the activist approach where data is browsed, extracted and integrated into narratives that challenge the system or empower the users.<br>(6) Critical Approach to Data implies a vision of personal, social, or technical/research data where the users go beyond data handling (technical abilities) and embedding into social life, but they reflect over the cultural, semiotic | |

| | | |
|---|---|---|
| | and political nature of data in its context of production.<br>(7) Unclear Theoretical approach referst | |
| Overall approach to data | The type of epistemological positioning relating data (according to Milan&van der Velden, 2016 and authors' elaboration).<br>(8) Reactive stands for approaches that see data in a dystopic way, where the people take action to defend privacy and avoid personal data collection or tracking. It is a defensive positioning.<br>(9) Proactive encompass approaches where data is see as utopia, and people make every effort to capture data value. The focus of activity deals with data handling, collection, extraction, visualization, communication and integration into technical and technological innovation.<br>(10) Complex stands for a vision where data is considered as layered system, where reactive and proactive epistemologies are embedded, but there is an effort of social and cultural contextualization that leads to actors- | Re-Active<br>Pro-Active<br>Complex |

| | | |
|---|---|---|
| | understanding of all possible scenarios and to search and decide own best way. | |

The Full List of Papers retrievable at the Open Dataset (Raffaghelli & Clougher, 2019)


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Appendix 2 – Key Words Map

| Main Cluster's Term | Occurrences | Relevance Score | Clustered Terms | Occurrences | Relevance Score |
|---|---|---|---|---|---|
| Context | 35 | 0,4941 | Attitude | 11 | 0,587 |
| | | | Classroom | 14 | 1,782 |
| | | | Decision | 20 | 1,562 |
| | | | Educator | 24 | 1,301 |
| | | | Evidence | 21 | 1,914 |
| | | | Implication | 20 | 0,913 |
| | | | Intervention | 16 | 3,250 |
| | | | Interview | 16 | 0,809 |
| | | | Participant | 11 | 1,113 |
| | | | School | 29 | 1,479 |
| | | | Teacher | 33 | 2,804 |
| | | | Year | 15 | 0,951 |
| Information | 27 | 0,3694 | Area | 16 | 0,346 |
| | | | Course | 18 | 0,681 |
| | | | Data Management | 21 | 2,587 |
| | | | Experience | 20 | 0,457 |
| | | | Insight | 13 | 0,400 |
| | | | Issue | 19 | 1,498 |
| | | | librarian | 19 | 2,359 |

| | | | | | |
|---|---|---|---|---|---|
| | | | Order | 10 | 0,387 |
| | | | Part | 21 | 0,868 |
| | | | Researcher | 25 | 1,012 |
| | | | Topic | 12 | 0,710 |
| | | | University | 23 | 0,684 |
| | | | User | 16 | 0,456 |
| Science | 30 | 0,4062 | Ability | 19 | 0,344 |
| | | | Article | 21 | 0,254 |
| | | | Big Data | 18 | 0,714 |
| | | | Competency | 16 | 0,880 |
| | | | Field | 16 | 0,553 |
| | | | Mathematics | 11 | 0,836 |
| | | | Science | 30 | 0,406 |
| | | | Technology | 20 | 0,693 |
| Opportunity | 19 | 0,3988 | Focus | 17 | 0,437 |
| | | | Number | 14 | 0,509 |

For more details on the keyword map please see the Open Dataset (Raffaghelli & Clougher, 2019)

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