A strategic approach to information literacy: data literacy. A systematic review

María Pinto; **David Caballero-Mariscal**; **Francisco-Javier García-Marco**; **Carmen Gómez-Camarero**

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María Pinto
https://orcid.org/0000-0002-3199-4509

Universidad de Granada
Facultad de Comunicación y Documentación
Campus Cartuja
18071 Granada, Spain
mpinto@ugr.es

David Caballero-Mariscal
https://orcid.org/0000-0001-6451-6047

Universidad de Granada
Facultad de Comunicación y Documentación
Campus Cartuja
18071 Granada, Spain
davidcaballero@ugr.es

Francisco-Javier García-Marco
https://orcid.org/0000-0002-6241-4060

Universidad de Zaragoza
Departamento de Ciencias de la Documentación
Pedro Cerbuna, 12
50009 Zaragoza, Spain
jgarcia@unizar.es ✉

Carmen Gómez-Camarero
https://orcid.org/0000-0001-8936-8087

Universidad de Málaga
Facultad de Filosofía y Letras
Campus de Teatinos
29071 Málaga, Spain
gomez@uma.es

Abstract

This research addresses the growing social importance of data from an educational perspective through data literacy (DL), seeking to integrate it into the broader information literacy (Infolit) movement. For this purpose, a systematic review was carried out of the papers in the main collection of the *Web of Science* that contain both concepts (DL and Infolit) and that were indexed up until March 2023. External aspects, such as the growth of the research and the identity, nationality, professional scope, and productivity of the authors, were taken into account. In addition, internal aspects, such as context (theory, frameworks, definitions, models, and related disciplines), objectives, methodology, results, conclusions, and recommendations, were analyzed to obtain a detailed perspective of the scientific research process adopted. A synchronic and diachronic analysis of the corpus of selected articles is offered, focusing on the aforementioned aspects. The researchers' consensus on the urgency of addressing data training both generally and specifically in the different disciplines, languages, environments, and levels is evident. The emergent, multisectoral, and interdisciplinary nature of data literacy as part of Infolit, which is being applied in the education of students at different levels, viz. professionals and citizens, is noted, although the training limitations of students and many professionals are evident. Consequently, it is imperative to include DL in curricula and training programs to contribute to the acquisition and development of these competencies in different areas. To this end, the joint work of teachers, librarians, researchers, and other professionals is imperative. There is a need to deepen the theoretical, practical, and applied fields, as well as to reach a common definition, form a basic model of DL competencies within Infolit, and create submodels that take into consideration the idiosyncrasies of each area of application.

Keywords

Data literacy; Information literacy; DA; Infolit; Research data management; Quantitative literacy; Systematic reviews.

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1. Introduction

1.1. Context and research problem

Information literacy (Infolit) constitutes one of the main functions in the field of libraries and information services, as it is responsible for training users to identify, acquire, process, use, and share information more effectively, autonomously, and ethically (*Sconul*, 2011; *ACRL*, 2015). As new media have popularized the use of new formats, the scope of Infolit has progressively expanded to incorporate not only text but also images, video, multimedia, digital information, and Internet media, until reaching its most elementary component, data. At present, as the minimum unit of actionable information, data have become the key to important scientific and technological movements such as Big Data, the Internet of Things (IoT), the semantic web, or artificial intelligence (**O'Leary**, 2013). Consequently, data literacy (DL) is currently one of the main research fronts in Infolit (**Calzada**; **Marzal**, 2013; **Koltay**, 2015).

Indeed, data have always been an essential part of scientific research, based on observations shared through careful recording and their transparent and objective transformation into results capable of supporting new knowledge (**Goodman**; **Royal**, 1988). However, before the data revolution brought about by information and communication technologies, their use was much more restricted owing to the high cost of accessibility, collection, and dissemination. In recent decades, information technology has facilitated these processes more effectively, and data are now very easily produced, processed, linked, and shared. The quantitative explosion in data availability and processing capacity, along with the confluence of both trends, has brought about a qualitative leap, opening the era of Big Data, data science, e-research, and intelligent components (**Manyika** *et al*., 2011; **Forbes**, 2019). In this context, it becomes necessary and urgent to incorporate the data phenomenon into Infolit (**Calzada**; **Marzal**, 2013; **Marzal**, 2020; **Koltay**, 2015; 2016ab; 2017ab; 2017ab; 2023). The systematic study of this process of data integration into the project of an integrative and integrated Infolit is the objective of this article.

1.2. Current state of affairs

Despite the relevance of DL and its relationship with Infolit, only a few studies –examined at the end of this section– have conducted a systematic review analyzing this aspect, although there are several narrative, critical, or bibliometric reviews that are of interest to this work.

Among the narrative reviews, studies by Marzal and collaborators (**Calzada-Prado**; **Marzal**, 2013; **Marzal**; **Borges**, 2017; **Marzal**, 2020) and **Koltay** (2015; 2016b; 2017a) reference the incorporation of DL and other literacies into Infolit. They encompass solid narrative reviews aimed at discussing their proposed scientific configuration of the discipline, models, and programs. The review by **Špiranec** *et al*. (2019) bases the inclusion of DL into Infolit on the concept of critical data literacy. They stress that this literacy is the most significant evidence of the relationship between DL and Infolit. Additional narrative reviews focus on the relationship of DL with other, more specific literacies. **Wang** *et al*. (2019) propose data literacy for safety professionals (DLSP), which implies that the higher education of future professionals should be based on fundamental competencies in Infolit as a foundation for the correct development of DL skills, which guarantees the ethical use of data as well as their handling, preservation, and dissemination. Only competent Infolit professionals will be able to deploy their data mastery skills. **Braun** and **Huwer** (2022) discuss the relevance of computer literacy as part of DL, and in turn of Infolit, addressing its level of integration into the curriculum.

From a bibliometric perspective, the works of **Zhang** and **Eichmann-Kalwara** (2019) and **Sheriff** and **Rathinam** (2023) address the relationship between different literacies and thus between Infolit and DL. Their brief theoretical frameworks serve as a starting point to confirm the need for systematic reviews that address this innovative perspective.

Finally, there are two very recent systematic reviews on DL that provide valuable information on the different aspects investigated herein (**Ghodoosi** *et al*., 2023; **Cui** *et al*., 2023). The former provides quantitative evidence and detailed analysis of the competencies addressed in the literature, but its research is focused on DL education. Focusing on related fields, there are systematic reviews by **Marchy** and **Juandi** (2023) on statistical literacy and by **Sheriff** and **Sevukan** (2021) on research data management (RDM).

From the point of view of originality, although the studies described in the last paragraph follow a systematic review methodology and offer evidence for partial or complementary aspects of this research –notably the work by **Ghodoosi** *et al*. (2023)– none systematically addresses the context and phases of the scientific process of DL to achieve a scientific construction of the discipline.

> "Data literacy (DL) is currently one of the main research fronts at Infolit"

1.3. Objectives

> Only competent Infolit professionals will be able to deploy their data mastery skills

The aim of this paper is to systematically review the literature on data literacy (DL) within the Infolit framework in the international scientific context. External aspects, such as the growth of such research and the identity, nationality, professional scope, and productivity of the authors, were characterized. In addition, internal aspects, such as context (theory, frameworks, definitions, models, and related disciplines), objectives, methodology, results, conclusions, and recommendations, were analyzed to provide a detailed perspective of the scientific research process adopted.

This research seeks to answer the following research questions:

1. How does the scientific production on DL and Infolit evolve in the corpus analyzed (authorship, disciplines, and countries)?
2. What are the research frameworks and the current status of the question at hand?
3. What research objectives stand out?
4. What methodologies are used (types of study, methods, techniques, sources, and tools)?
5. What are the main findings, conclusions, and recommendations?

2. Methodology

The methodology is composed of three phases: the selection of the working corpus, an external analysis of its characteristics, and a systematic content analysis.

2.1. Selection of the working corpus

To balance the volume of work that the content analysis requires with the need to work on a corpus sufficiently consistent in terms of impact and the relationship between the journals, it was decided, after several pilot searches, to work with a single reference corpus that would be representative and of high quality. From the two large corpuses that offer representativeness and quality –*Scopus* and *Web of Science* (*WoS*)– the main collection of the *Web of Science* was selected for this first study. *WoS* facilitates the objective collection of a more selective corpus through its differentiation into two levels –the *SCI+SSCI+A&HCI* and *Emerging Sources Citation Index* (*ESCI*)– on the basis of impact criteria (citation analysis of articles, authors, and editorial team; with an emphasis on content that does not immediately produce an impact in citations) (*Clarivate*, 2023). It also provides a different corpus than **Ghodoosi** *et al*. (2023), who searched *Google Scholar*, *Science Direct*, *ResearchGate*, and *Scopus*.

To answer the main objective of the research regarding the incorporation of DL into Infolit and the approach of DL from Infolit or at least their close relationship, a search equation was constructed from the intersection between the domains of Infolit and DL. The search was performed in the *Web of Science SCI+SSCI+A&HCI* databases in all languages on the "Topic" field (Title, Keywords, and Abstract) and with a time limit of March 3, 2023 (the day of the search) to include all records from the beginning of the database coverage, although from previous searches, only those from well into the 2000s were expected.

Likewise, as the field of DL is very recent, interdisciplinary, and with a terminology still under consolidation, all relevant related terms that could serve to express such interest were included, but always with a very close relationship to the concept of DL, such as quantitative or statistical literacy. The focus on these two literacies was justified because, in the exploratory work, it had been observed that they appeared in a highly interconnected way (**Hunt**, 2004; 2005; **Lackie**, 2004; **Shields**, 2005), and the results obtained with respect to DL-related literacies confirmed this historical evidence (Section 3.2.2). Furthermore, as some authors are reluctant to use the term "literacy," the search was extended using the most frequent alternative terms: "skills" or "competencies," appearing both in the singular and in the plural.

The search was performed in exact mode to completely control the search terms and avoid automatic lemmatization and stemming. We included journal articles and conference proceedings but excluded reviews and book chapters because we were looking for research reports with original results or proposals. The complete search equation is provided in Table 1.

Table 1. Search equation

TS=(("data literacy" OR "data literate" OR "data competence" OR "data competency" OR "data skill" OR "data literacies" OR "data literates" OR "data competences" OR "data competencies" OR "data skills" OR "data competent" OR "quantitative literacy" OR "quantitative literate" OR "quantitative competence" OR "quantitative competency" OR "quantitative skill" OR "quantitative literacies" OR "quantitative literates" OR "quantitative competences" OR "quantitative competencies" OR "quantitative skills" OR "quantitatively competent" OR "statistical literacy" OR "statistical literate" OR "statistical competence" OR "statistical competency" OR "statistical skill" OR "statistical literacies" OR "statistical literates" OR "statistical competences" OR "statistical competencies" OR "statistical skills" OR "statistically skillful" OR "statistically skilful" OR "data information literacy" OR "data information literate" OR "data information competence" OR "data information competency" OR "data information skill" OR "data information literacies" OR "data information literates" OR "data information competences" OR "data information competencies" OR "data information skills" OR "data information competent") AND ("information literacy" OR "information literacies" OR "information literate" OR "information literates" OR "information competence" OR "information competences" OR "information competency" OR "information competencies" OR "information competent" OR "information skill" OR "information skills" OR "information skillful" OR "information skilful"))

The corpus selection process, expressed in a *Preferred Reporting Items for Systematic Reviews and Meta-Analyses* (*Prisma*) flowchart (**Page** *et al*., 2021) in Fig. 1, resulted in 68 documents (Appendix 2). This number is acceptable for an analysis that requires full and comprehensive reading, and corresponds to one-tenth of the entire *WoS* domain of DL as resulting from the search TS=("data literacy" OR "data information literacy"), which provides 584 items, the oldest being from 2005.

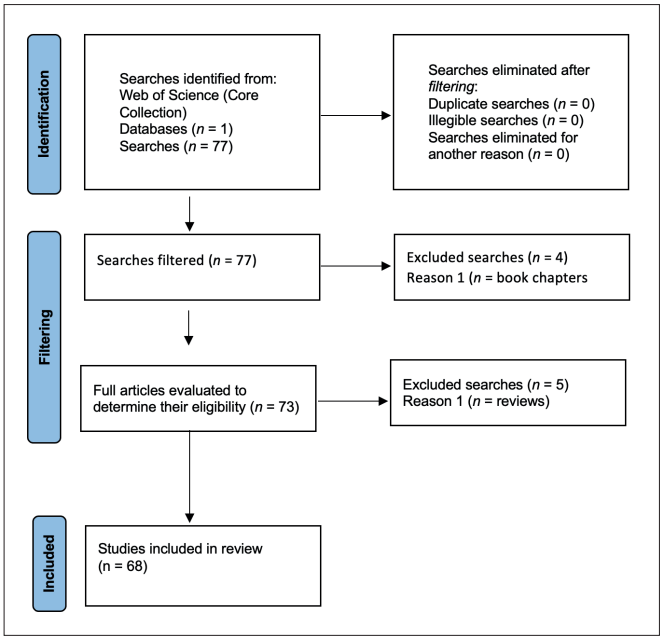

Figure 1. *Prisma* flowchart (**Page** *et al*., 2021)

2.2. Content analysis

Any systematic review requires studying the same variables in all searches. Since the aim of the research was to characterize the scientific development of the DL field within the framework of Infolit, the variables of analysis were the main factors and moments of the scientific research process. As inspiration for our template (Appendix 1), we used Gowin's V diagram (**Novak**; **Gowin**, 1948), which reveals the key aspects of each piece of research and was designed to facilitate the content analysis processes of scientific publications in educational contexts. The template consists of five macro areas, three of them divided into subareas, distributed into 36 variables. They address the general characterization of the work, the general framework (evolution, authorship, contextual definitions, frameworks and models, evidence, and gaps), objectives and purposes of research, methodology (types of study, methods/techniques, sources, and tools), and knowledge statements (results, conclusions, and recommendations). After piloting the template with eight articles, its validity was verified and it was applied to the rest of the document set.

For data extraction, the documents were distributed equally among the team members. For content analysis, the work was divided by area and each article was reviewed by at least two people. In this process, extracted (not assigned) terms, phrases, and paragraphs were used to faithfully respect the authors' approaches and reflect the original terminology. Two levels of inclusion classes were created: one to group synonyms and equivalent formulations, and the other to clarify their organization at a higher level and facilitate analysis. Where relevant and sufficient information was available, occurrences were computed to provide as objective and quantitative a picture as possible, e.g., for definitions.

Some variables have been treated idiosyncratically and require further explanation:

- For *related literacies*, references to other literacies that have been defined and integrated into the current state of affairs were considered, with the aim of filtering out minor references and focusing on those that have the most impact on DL research.
- For the research *objectives*, a logical categorization was made on the basis of the language used by the authors in the objectives and key words, grouping together those works that pursued similar objectives. Some studies formulated objectives that could be included in more than one category.
- In terms of *methodology*, we used the terminology used by the authors in their works, relying on them for the subsequent standardization on the taxonomy of research methods developed by Sage, disclosed by Lluís Codina: *https://www.lluiscodina.com/taxonomy-research-methods-sage*

Although several articles could be included in more than one type of study, owing to occasionally using complementary methodologies, they were assigned only to the main type so that the total count would correspond with the corpus and provide a proportional perspective. Furthermore, for the variables of method, technique, sources, and tools, given the frequent and natural cooccurrences, all were counted even if several occurred in the same study.

Subsequently, we worked on the interpretation of the analysis of the information extracted in weekly plenary sessions, with permanent feedback to present progress and discuss and agree on future actions.

3. Results and discussion

After an introductory characterization of the 68 documents analyzed, with respect to their evolution, subject matter, and authorship, the research questions posed above were systematically addressed: research frameworks (definitions, relationships, theories, models, and evidence), objectives, methodology, results, conclusions, and recommendations. Given the large number of aspects covered, the results and discussion are presented together in each section.

> "Every systematic review requires studying the same variables in all records"

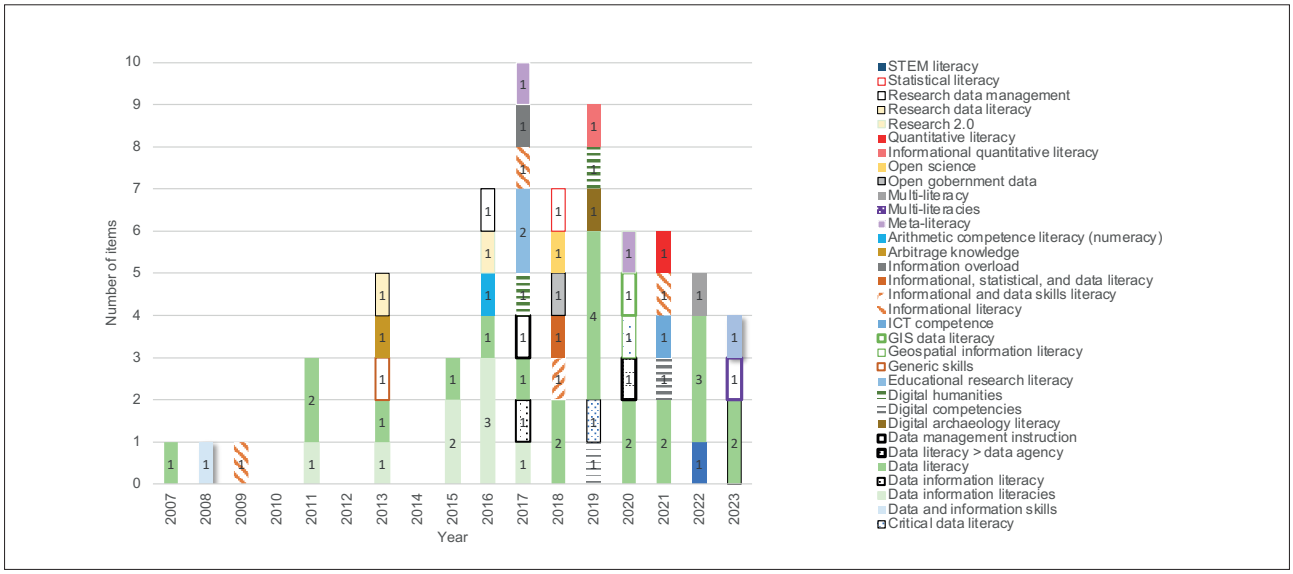

Figure 2. Evolution of research by main topics

3.1. Global characterization of the analyzed corpus

3.1.1. Growth and development of DL research

The evolution of the number of articles and the distribution of authors by their main topic of interest are presented here. The original terminology has been retained, with the legends reflecting the authors' conceptualization (Fig. 2). The topic may consist of a recognizable discipline (e.g., Infolit) or a field of interest that does not yet form a discipline (e.g., information and communication technology (ICT) training, generic skills, or open government data).

The small number of publications identified the first half of the studied period (20.58%) contrasts with the bulk of the selected articles (79.42%), concentrated in the years after 2015. DL is therefore a very recent phenomenon, solidified in the last decade, and the first article on DL located in *WoS* is from 2007. After 3 years in which only one article was found and with some years without any at all, in the second decade the number of articles found increased. From 2016, output was steady until the present, with peaks in 2017 (10 items) and 2019 (9 items), but evening out from 2020 onwards. Such an increase in the literature on DL is also confirmed by **Ghodoosi** *et al*. (2023, p. 215). DL-focused items in general have a sustained presence from the start, with the strongest trend in 2019 and a smaller one in 2022. Those responding to the specific approach of data information literacy (DIL) are present between 2008 and 2017, and together they form the majority approach. Some papers that approach DL from the broader interest in Infolit have a presence during almost the entire period (**Sadioglu** *et al*., 2009; **Weber**, 2017; **Pinto** *et al*., 2021).

Quantitative and statistical literacy articles are found in *WoS* as of 2018, being in the minority despite having been specifically targeted in the search equation. Likewise, works that address DL from very specific literacies and disciplines are scarce, highlighting those related to geospatial, cartographic, and geographic information systems (GIS) literacy, which is consistent with the findings of **Ghodoosi** *et al*. (2023, p. 117). Papers on DL from the perspective of multi-literacies and meta-literacy appear in 2017 and have a sustained presence.

3.1.2. Authorship

The 151 authors in the analyzed corpus show highly diverse disciplinary origin, nationality, and productivity but with clear leaders. Regarding disciplinary background, authors belong to university libraries (36), education (34), information and communication (27), engineering and technology (15), psychology (6), archaeology (6), computer science (4), public administration (4), health management (3), business administration (4), publishing and technical communication (3), biology (3), chemistry (1), statistics (1), philosophy (1), bioethics (2), and digital humanities (1).

Regarding nationality, a wide range is observed: the United States (60), Spain and Australia (10), Germany (8), Poland and China (7), Belgium and Finland (6), Czechia (5), Austria and Croatia (4), Turkey and the Netherlands (3), Canada, Norway, and Switzerland (2), and Brazil, Colombia, Slovenia, and Indonesia (1). These data concur with those reported by **Ghodoosi** *et al*. (2023, p. 116). DL is a movement that started in the United States, followed in Europe, and is now rapidly spreading in development to other countries, as it is a response from the educational world to one of the main avenues of progress in the most developed economies.

In terms of the productivity of the set analyzed, Koltay is the author with the most articles (6), followed by Marzal and Vanhoof (3). Regarding co-authorship, most of the papers authored by several authors generally belong to the same area of knowledge and come from the same

> Data literacy involves understanding what data means, including how to read graphs and tables appropriately, draw correct conclusions

university, which is also consistent with the initial development of the discipline, starting from nuclei without deep exchange relationships, although incipient networks are being created, as will be seen below. There are also works developed by authors from different areas of knowledge, indicating collaboration between disciplines and the interdisciplinary nature of DL: library and information science, communication, business administration, education, ethics, philosophy, computer science, engineering, and psychology. Some of these interdisciplinary teams are made up of authors from various universities and countries: Croatia-Canada, Spain-Colombia, Spain-Brazil, Austria-Germany, and Austria-Germany-United States.

> DL has abandoned its initial niche as a confluence between information, quantitative and statistical literacy to interest specialists in many fields

3.2. Research frameworks: definitions, disciplinary relationships, and theoretical approaches

To study the theoretical and conceptual frameworks of the research, the introduction and literature review sections of the selected corpus were analyzed, with the following aspects being explored: definitions, related literacies, theories and models, and any evidence gaps encountered.

3.2.1. Definitions

The analysis of the definitions of DL and its specialties (DIL, research data literacy, scientific data literacy) makes it possible to trace the formation and evolution of DL as a concept. In the corpus analyzed, 31 articles (45.59%) provide their own definition while 29 (42.65%) cite other definitions. Many of them have had little impact: only 7 articles (10.29%) contain definitions of DL cited by other authors, and only 12 of 36 were cited more than once in the search as a whole, with only 2 being cited more than 10 times. **Carlson** *et al*. (2011) has 10 citations, and three others have similar numbers (**Carlson** *et al*., 2013, 1 citation; **Maybee** *et al*., 2015, 2 citations), while that of **Calzada-Prado**; **Marzal** (2013) has 12 citations.

For **Carlson** *et al*. (2011, p. 5)

> "[...] data literacy involves understanding what the data mean, including how to read figures and tables properly, draw correct conclusions from the data, and recognize when data are used in a misleading or inappropriate way".

For **Calzada-Prado** & **Marzal** (2013, p. 126),

> "Data literacy can therefore be defined as the component of information literacy that enables people to access, interpret, critically evaluate, manage, handle and ethically use data".

The analysis of definitions shows that DL is an emerging field: its current status consists mostly of definitions, but few of them are cited by other authors, as corroborated by **Verdi** (2023) using a different corpus. The appearance of some widely cited definitions reflects the beginning of the discipline's solidification, especially in connection with Infolit. The difference between the two most impactful definitions reflects the shift produced between the two editions of the Infolit framework by the *Association of College and Research Libraries* (*ACRL*; 2000; 2015) toward a more critical and responsible literacy that considers the user as a producer.

3.2.2. Related literacies

A key aspect of any new literacy is to establish its relationship with other literacies, particularly for information professionals with Infolit and its collaborators. A total of 29 related literacies defined 61 times were found in 28 papers (41.18%), showing a strong interdisciplinary perspective in almost half of them. After grouping the specialties with their main literacy and then into four categories (general, information, special, and integrated literacy), the results presented in Table 2 were obtained.

A total of 31.15% of the definitions observed are about Infolit. Numerical literacy ranks second (21.31%), with statistical literacy in the key position (13.11%), followed by quantitative and arithmetic literacy (8.20%), confirming the close relationship between these three disciplines since their beginnings (**Hunt**, 2004; 2005; **Lackie**, 2004; **Schield**, 2005), as well as the initial effort to establish the differences and relationships between them, which is also confirmed by **Ghodoosi** *et al*. (2023, p. 215). Special literacies account for 62.30%, which is consistent with the immense diversity of the authors' disciplinary origin (Section 3.1), and reflects the fact that DL attracts and promotes very specialized interests and approaches.

Figure 3 shows that interdisciplinarity has continued to grow and evolve over time. In the initial period, information and statistical literacy were significant, and since 2016 references to multiple literacies proliferate, which, after some stabilization, skyrocket in 2023. This demonstrates that DL has left its initial niche as a confluence between information, quantitative, and statistical literacy to interest specialists from many fields. This positive aspect has created a certain crisis of growth, expressed in the emergence of the concepts of multi-literacy and meta-literacy at the end of the period (2020-2023).

> From a chronological point of view, interdisciplinary publications are the most widespread

Table 2. Defined related literacies

Definiendum	No.	Subtotal	%	Total	%	Main topic
Literacy	1	1	1.64	1	1.64	General
Information literacy	15	19	31.15	19	31.15	Information
Critical information literacy	1					
Information fluency	1					
Information literacies	1					
Media and information literacy	0.5					
Computer and information literacy	0.5					
Special literacies				38	62.30	
Disciplinary literacy	2	4	6.56			General by discipline
Academic literacy	1					
Academic literacies	1					
Quantitative literacy	4	5	8.20			Numbers
Arithmetic literacy (numeracy)	1					
Statistical literacy	8	8	13.11			Statistics
Geo-literacy/spatial literacy	2	3	4.92			Maps
Cartographic literacy	1					
Media literacy	2	2.5	4.10			Average
Media and information literacy	0.5					
Visual literacy	2	2	3.28			Visual
Computer literacy	1	3.5	5.74			Computer science
Computer science and information literacy	0.5					
Digital literacy	2					
Scientific literacy	2	4	6.56			STEM
STEM literacy	1					
Critical STEM literacy	1					
Cultural literacy	1	1	1.64			Cultural
Health literacy	2	3	4.92			Health
eHealth literacy	1					
Educational research literacy	2	2	3.28			Education
Multi-literacy	1	1	1.64	3	4.92	Interactions
Multiple literacies	1	1	1.64			
Meta-literacy	1	1	1.64			
	61	61	100	61	100	

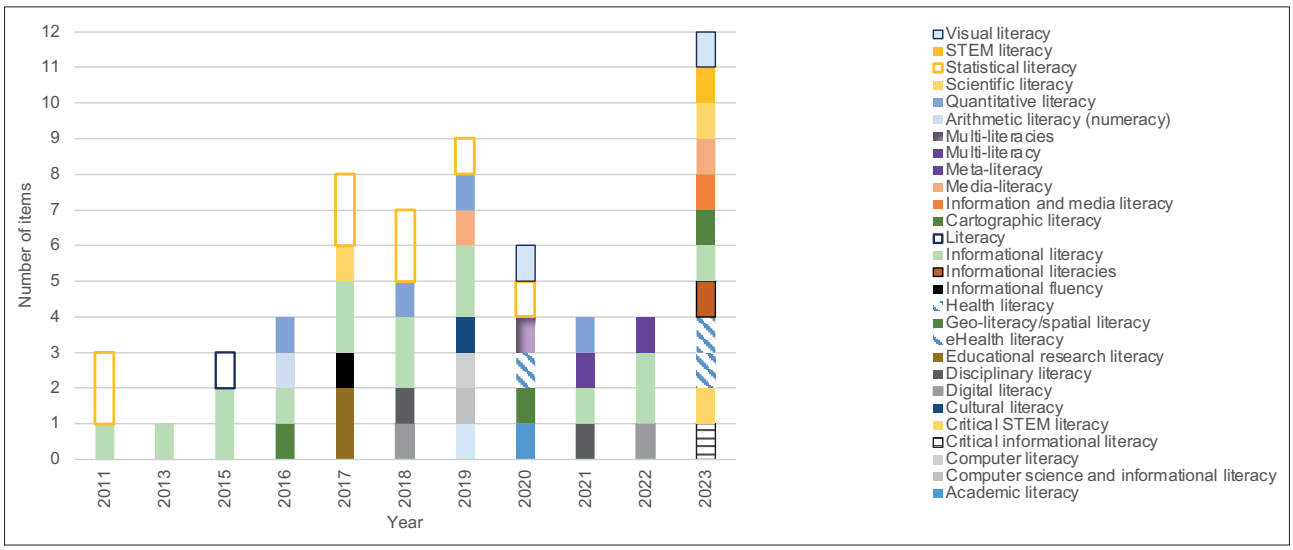

Figure 3. Annual evolution of the definitions of "other" literacies

3.2.3. Frameworks, theories, and reference models

The majority of publications (67.35%) address competency frameworks, most notably the *ACRL* (2000; 2015) papers on Infolit (6 occurrences), the *Core Competencies for Data Information Literacy* (**Carlson** *et al*., 2011) (6 occurrences), the **Calzada-Prado** & **Marzal** (2013) framework (2 occurrences), and the *DigComp* (2013; 2016) editions (4 occurrences). In addition, the four-level evaluation model from **Kirkpatrick** (1959) has 2 occurrences. The rest of the publications focus on the models used –curricular (8.16%), evaluation (6.12%), curriculum development (4.08%), educational management (2.04%)– and on some theories, such as informational, psychological, educational, and research (Fig. 4). Almost all of the papers reviewed are related to education, except for one that uses the SDG policy framework (**Mason** *et al*., 2016) and one on information pathologies that addresses DL as a tool (**Bawden**; **Robinson**, 2009). Therefore, the theoretical and methodological discussion is almost entirely educationally oriented, although increasingly specialized by discipline, and mainly focused on competency frameworks, models, and curriculum developments in data literacy, Infolit, and computer and information literacy.

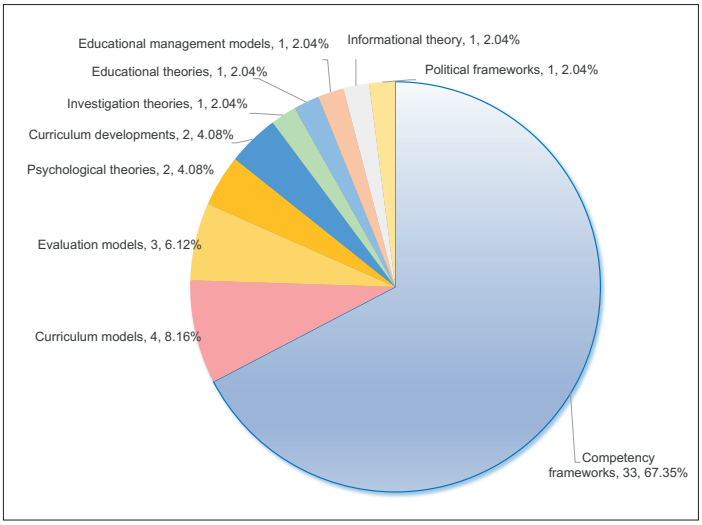

Figure 4. Frameworks, models, and reference theories

3.2.4. Evidence and gaps in research

Although the current status of DL demonstrates a general tendency to value data competencies, authors rarely share their citations and evidence, apart from some exceptions, such as the one stating that

> "less competent students are quite capable of finding and reproducing research information in tables, diagrams and summaries, while only advanced students are competent in evaluating scientific evidence and critically assessing research-based conclusions" (**Ophoff** *et al*., 2014, p. 269),

a sentiment that is shared by other authors. This evidence, which underpins the discussion on the importance of critical thinking in DL, converges with the many non-data-supported perspectives shared by other authors.

Although the reviewed publications suffer from some shortcomings, such as the absence of previous supporting publications, a scarcity of critical spirit in relation to DL, and infrequent definition of specific disciplinary frameworks, among others, some avenues of discussion can be surmised. Gaps have been identified linked to the limitations of general frameworks for addressing DL in specialized disciplines and settings (**Špiranec** *et al*., 2019; **O'Neill**, 2019; **Koltay**, 2023; **Valverde** *et al*., 2022). In fact, five articles using the *ACRL* framework as a reference complement it with more specific ones: geospatial information (**Appel**, 2020), business data (**Condon**; **Pothier**, 2022), digital humanities (**Locke**, 2017), maps (**Rutkowski**; **Williams**, 2020), and GIS (**Widener**; **Reese**, 2016). Likewise, in making the case for statistical literacy, **Tiro** (2018) argues for the autonomy of statistics from mathematics in education, and **Mason** *et al*. (2016) defend DL in the face of arithmetic and literary skills. Regarding open government data, **Gascó-Hernández** *et al*. (2018) note the data science deficit in computer and information literacy. **Cerny** (2021) tries to overcome a myopic understanding of digital skills. **Rubach** & **Lazarides** (2021) emphasize the need to assess the multiple dimensions and hierarchical structure of teachers' core beliefs on ICT competence. Against this backdrop, efforts and proposals for conciliation and clarification are emerging. **Marzal** (2020) identifies the need to reconcile the different literacy approaches to achieve meta-literacy, in which he agrees with **MacKey** & **Jacobson** (2014). In this direction, **Cui** *et al*. (2023) evaluate the convergence of literacies, focusing strictly on the particularities and similarities and affirming the central role of Infolit.

3.3. Objectives and disciplines of study

3.3.1. Research objectives

The objectives expressed in the selected papers were analyzed, grouping the existing formulations together. They were classified at the second level in higher categories: pragmatics (relevance), theory (definition, modeling), application (pilot projects), and evaluation. Since all the definitional articles also present claims regarding the importance of DL, the two categories were studied together, although detailing only those that are concerned with the field of study. The results are presented in Table 3.

The document count in the table exceeds that of the corpus because some documents present several objectives. The percentage is calculated out of the number of documents in the corpus (68), indicating the number of documents that address a given objective. Their sum is therefore greater than 100, for the same reason as that of the document count.

> "All the research reviewed agrees that DL emerges as a response to the growing importance of data in the evolution of society, the economy, technology and science"

Table 3. Objectives shared by the articles (those especially oriented to libraries are in *italics*)

Objectives	Articles	Number of occurrences	% of corpus
Establish the definition and relevance of DL (definition)		24	35.29
	Conceptual and terminological precision **Schneider** (2013); ***Calzada*** & ***Marzal*** (2013); **Koltay** (2015; 2016b; 2017a,b); **Shorish** (2015); **Marzal** & **Borges** (2017); **Šorgo** (2018); **Wiorogórska** *et al.* (2018); **Appel** (2019); **Špiranec** *et al.* (2019); **Rutkowski** & **Williams** (2020); **Tedre** (2020); **Smolnikova** (2020); **Marzal** (2020); **Ghodoosi** *et al.* (2023)	18	26.47
	DL relevance and global presentations ***Shorish*** (2015); **Mason** *et al.* (2016); ***Koltay*** (2016a); **Tiro** (2018); **O'Neill** (2019); **Smolnikova** (2020)	6	8.82
Establish DL competencies and integrate them into the curriculum (modeling)	**Stephenson** & **Schifter** (2007); ***Calzada*** & ***Marzal*** (2013); **Carlson** *et al.* (2011); **Vanhoof** *et al.* (2011; 2013); **Jeffryes** & **Johnston** (2013); **Schneider** (2013); **Maybee** *et al.* (2015); **Frank** & **Pharo** (2016); **Macy** & **Coates** (2016); **Boettger** *et al.* (2017); **Locke** (2017); **Phillips** & **Jahanshahi** (2017); **Šorgo** (2018); **Tiro** (2018); **Wiorogórska** *et al.* (2018); **Appel** (2019); **Cheng** *et al.* (2019); **Garwood** & **Poole** (2019); **Jewell** *et al.* (2019); **Kläre** & **Jung** (2019); **Pothier** & **Condon** (2022); **Wang** *et al.* (2019); ***Appel*** (2020); **Braun**; **Huwer** (2022); **Condon** & **Pothier** (2022); ***Martín-González*** & ***Iglesias-Rodríguez*** (2022); **Joyner** & **Parks** (2023).	28	41.18
Pilot projects: design, implement, and identify best practices in DL (application)	**Stephenson** & **Schifter** (2007); **Porter** *et al.* (2008); **Jeffryes** & **Johnston** (2013); ***Verbakel*** & ***Grootveld*** (2016); ***Widener*** & ***Reese*** (2016); ***Clement*** *et al.* (2017); **Phillips** & **Jahanshahi** (2017); **Weber** (2017); **Cook** *et al.* (2018); **Gascó-Hernández** *et al.* (2018); **Stark** *et al.* (2018); **Garwood** & **Poole** (2019); **Zorica** & **Kindzic** (2019); **Burress** *et al.* (2020); **Tedre** (2020); **Martín-González** & **Iglesias-Rodríguez** (2021); **Brock** *et al.* (2021); **Burress** (2022); **Valverde** *et al.* (2022); **Joyner** & **Parks** (2023); **Koltay** (2023)	21	30.88
Design, apply, and validate assessment tools in DL (evaluation)	**Sadioğlu** *et al.* (2009); **Verhaeghe** *et al.* (2011); **Calma** (2013); **Marzal** & **Borges** (2017); **Ophoff** *et al.* (2017a, b) **Phillips** & **Jahanshahi** (2017); **Drobikova** *et al.* (2018); **Cerny** (2021); **Deja** *et al.* (2021); **Pinto** *et al.* (2021); **Rubach** & **Lazarides** (2021); **Lin** *et al.* (2023); **Joyner** & **Parks** (2023)	13	19.12

It can be seen that all of them are present throughout the period studied, including those of a vindicating/justifying nature. The evaluative objectives increase at the end of the period, which is logical, since previous experience is required, also being, as will be seen, a response to the recommendations of experts. Efforts to establish a competency model are significant, which is an objective that is present in 41.18% of the studies. Pilot projects for courses and programs constitute the next largest group with 30.38%. Efforts at conceptual and terminological precision –relating and defining DL with other related literacies, and stating its importance in the current social, economic, and scientific moment– constitute 26.47%. The works dealing with the evaluation of their actions represent 19.12%. Finally, those that justify the field and argue its relevance without entering into definitional problems constitute 8.82%. This classification of objectives has been used when analyzing the research results (Section 3.5).

3.3.2. Application disciplines

An important issue directly related to the objectives is in which fields these objectives are studied and applied. Most of the articles collected in this work (44 papers, 64.70%) describe research of a disciplinary nature, applying DL in a specific domain: 35.29% correspond to the social sciences, including education and communication-documentation; 14.71% to humanities; 8.82% to science, technology, engineering, and mathematics (STEM); and 5.88% to health sciences. This confirms the breadth and diversity of disciplines from which DL is approached, as well as the leadership of the social sciences –with more than half of the references having a disciplinary approach. The remaining publications (24, 35.30%) are interdisciplinary, demonstrating how Infolit and DL intersect beyond disciplinary boundaries (Figure 5). They address the relevance of DL, its definition, and cross-cutting proposals for competency frameworks.

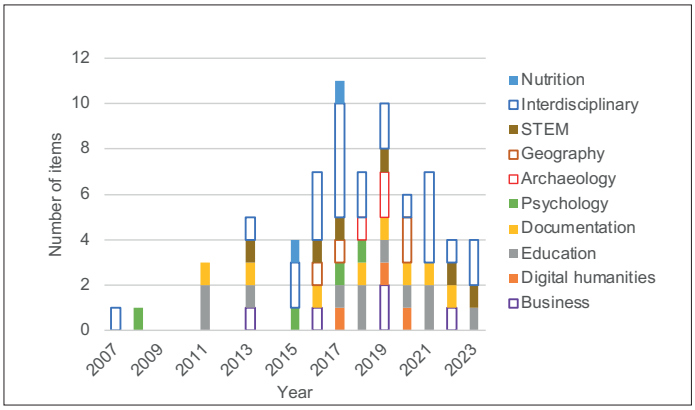

Figure 5. Disciplines

From a chronological point of view, interdisciplinary publications are the most widespread, with maximum presence in the years 2017 and 2021. Those referring to education and communication-documentation reach their peak in 2018 and 2019; those referring to STEM between 2013 and 2023; and disciplines such as geography, archaeo-

logy, and digital humanities, from the humanities, appear between 2016 and 2020. Finally, only token publications on DL in health sciences are present during the analyzed period.

3.4. Methodology and techniques applied in the analyzed articles

The types of studies, methods/techniques, sources of support, and tools used by the authors of the corpus studied on Infolit and DL (2007-2023) are analyzed in the next sections.

3.4.1. Types of studies

Four groups were identified in terms of types of study: applied (30, 44.12%), theoretical (25, 36.76%), experimental (7, 10.29%), and exploratory (6, 8.83%) (Fig. 6). Applied research is the only one that occurs throughout the entire period analyzed, with 2019 being the year with the highest number of publications. Theoretical research is present from 2013, with peaks of publications in 2016, 2020, and 2022, reflecting the more recent effort to consolidate the discipline. Experimental research is found in some publications from 2017 onwards, and exploratory research appears in papers published between 2007 and 2018. In general, the highest presence for both types occurs between 2016 and 2021, while the lowest is between 2007 and 2015. The highest number of records (10) addressing these four types of research was in 2017. These data are consistent with the development of DL as a discipline in the sense of a greater effort at theoretical systematization and a search for evidence through studies designed ad hoc, as opposed to the initial studies focused on data from an eminently practical perspective aimed at creating programs and courses on the basis of consensus among leaders and participants.

3.4.2. Methods and techniques

The methods most frequently used by the authors in the documents analyzed are as follows: literature review (27, 26.73%); descriptive (15, 14.00%), with a significant presence of training course design, especially in DL; exploratory (15, 14.85%), among which pilot studies, Delphi, and grounded theory have importance; evaluative (13, 12.87%), focused on the use of methods and tools for evaluating syllabuses, programs, and competencies in Infolit and DL; case studies (11, 10.89%), mainly oriented toward the attitude and behavior of undergraduate students in the management of DL skills; experimental (8, 7.92%); comparative (7, 6.93%), mainly diachronic comparisons; and systematic literature reviews (5, 4.95%), focused on specific topics of DL in education and which are a constant feature throughout the period. Regarding the chronological evolution of the methods, it is observed that there is a greater presence from 2016 onwards, with 2017 being the year in which the largest number of records is concentrated and a wide variety of methods converge, except for systematic literature reviews (Fig. 7). The proliferation of new methodologies is consistent with other evidence pointing to a rapid development of the discipline.

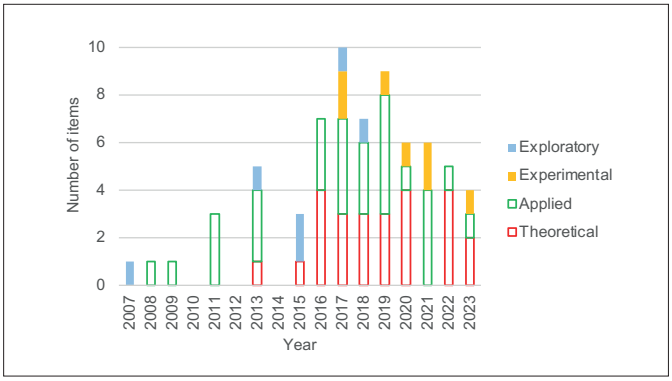

Figure 6. Type of study

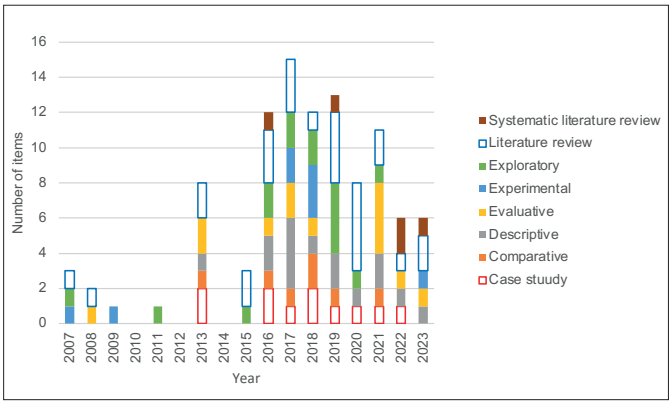

Figure 7. Methods

Among the most widely used techniques is qualitative analysis (21, 37.50%), employing both content analysis and expert panels and interviews. The authors use quantitative analysis techniques (9, 16.07%), such as descriptive and inferential statistics, to a lesser extent. Of the two data collection techniques, quantitative data collection is used somewhat more (15, 26.78%), preferably by means of tests, questionnaires, and rubrics. It is followed by qualitative techniques (11, 19.64%) based on interviews, case studies, focus groups, and the Delphi method. An analysis of the timeline of the period studied shows the coexistence of qualitative and quantitative techniques and their respective modes of data collection in a significant number of publications, mainly in the years 2013, 2021, and 2022 (Fig. 8). This variety of techniques is a consequence

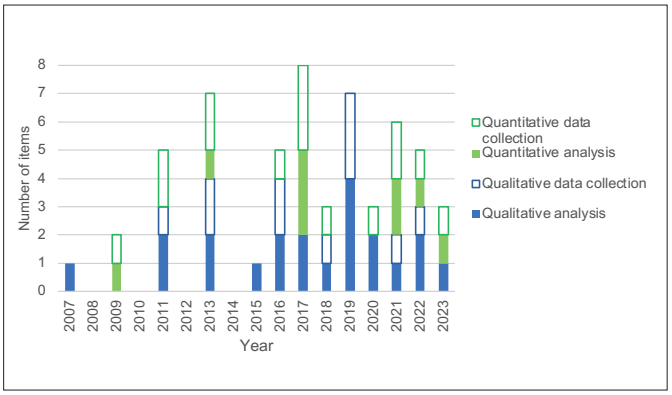

Figure 8. Techniques

of the disciplinary diversity of the authors, and constitutes a great richness and potential of this new emerging discipline within the Infolit framework.

> The results document the pressing needs of students and teachers in Infolit nuclear competencies as a basis for the acquisition and development of DL

3.4.3. Sources

The main source of support used by the authors are articles from international journals (44, 43.56%) in the social sciences, humanities, and STEM, as well as data files from institutional sources (14, 13.86%). Some studies are based on national and international standards of different professional associations (13, 12.81%), such as those of the *Society of College, National and University Libraries* (*Sconul*), the Network of Spanish University Libraries (*Red de Bibliotecas Universitarias Españolas*, *Rebiun*), the *International Society for Technology in Education* (*ISTE*), etc. Others are supported by the 2000 and 2015 *ALA/ACRL* Infolit standards and frameworks (10, 9.90%). Databases are also used as a source of analysis themselves: *ERIC*, *WoS*, *Scopus* (7, 6.93%); syllabus (5, 4.95%); *European Framework of Digital Competences for Citizenship* (*DigComp*; 4, 5.88%); websites (3, 2.97%); and panels of experts (2, 1.98%). From the timeline analyzed, a greater presence of a good part of the sources mentioned is observed in the period from 2016 to 2022, in line with the growth and diversification of research on the subject.

3.4.4. Tools

Among the tools most commonly used by the authors are the following: tests (7, 21.21%); computer-assisted qualitative analysis programs (6, 18.18%), such as *Nvivo*, *12 Plus*, *Maxqda*, and *Atlas.ti*; and computer-assisted quantitative analysis programs (6, 18.18%), used for statistical analysis such as *SPSS*, *R statistical*, *Mplus 8.1*, *MeLIL*, *Qualtrics*, and *VOSviewer*, with the latter being used for the construction and visualization of bibliometric networks. Surveys and rubrics (6, 18.18%) and *Prisma* templates (4, 12.12%), a checklist of the requirements to be met by a systematic literature review, were also used. In the chronological evolution of the period studied, the years 2019 and 2022 show a greater number of works that use several of these tools simultaneously.

3.5. Results, conclusions, and recommendations of the analyzed articles

The results, conclusions, and recommendations obtained are presented according to the categorization of the objectives section of the works analyzed (Section 3.3): justification and definition, competency models, pilot projects of courses and programs, and evaluation.

3.5.1. Definition and relevance of DL

All the research reviewed agrees that DL is emerging as a response to the growing importance of data in the evolution of society (e-democracy, social media), the economy (data-driven economy), technology (semantic web, big data), and science (open data, open science, data-driven science, e-science). In this context, it is understood that DL is a necessary response from within the field of education to these social changes. In short, DL is configured as an indispensable tool to facilitate full participation in modern societies (**Smolnikova**, 2020), and constitutes a crucial and growing field that affects all areas of higher education (**Koltay**, 2015; **Shorish**, 2015; **Šorgo**, 2018; **Cheng** *et al*., 2019; **Braun**; **Huwer**, 2022).

Although most of the works reviewed focus on DL in the university realm, the *National Movement for Statistical Literacy in Indonesia* extends the idea of DL to pre-university levels (**Tiro**, 2018), and the continuing concern of teacher educators on the issue (**Sadioğlu** *et al*. 2009; **Rubach**; **Lazarides**, 2021; **Lin** *et al*., 2023) foreshadows that DL will gradually spread to other educational levels.

In the university context, educational concerns have not been the only driving force. On the contrary, the movement is mainly initiated by the need to train practicing and trainee researchers in research data management using libraries as a tool to change ingrained habits and generalize new concepts and best practices (research data management, RDM) (**Schneider**, 2013; **Shorish**, 2015; **Koltay**, 2016b; 2017b; **Šorgo**, 2018; **Appel**, 2019; **Špiranec** *et al*., 2019; **Rutkowski**; **Williams**, 2020; **Marzal**; **Borges**, 2017; **Tedre** *et al*., 2020; **Smolnikova**, 2020). In 2007, the *National Science Foundation* published its *Cyberinfrastructure Vision for 21st Century Discovery*, and one of its objectives was

> "to support state-of-the-art innovation in data management and distribution systems, including digital libraries and educational environments that are expected to contribute to many of the scientific breakthroughs of the 21st century" (*National Science Foundation*, 2007, p. 9).

This vision spread rapidly among developed *Organisation for Economic Co-operation and Development* (*OECD*) countries through the policy of requiring open data in scientific projects. The data information literacy movement (**Carlson**; **Johnson**, 2015) is one of the responses to the necessity to train scientists in new open science policies.

Despite this consensus on the importance of DL, there is a wide range of interpretations and perspectives on the concept and the associated skills and competencies (Table 3). This fact had also been demonstrated when analyzing the definitions of DL presented in Section 3.2.1 and for the case of related literacies in Section 3.2.2. As a result of the different approaches, specific data literacies

> Understanding, interpreting, representing, storing, using, managing and sharing data are crucial to raising awareness and training and ultimately building a data culture

emerge (Table 4), although most of them end up dealing with the same set of concepts. As a result, the positive wealth brought about by diversity is counterbalanced by the problem of dispersion of effort.

Table 4. Alternative approaches to DL and specialized DL

DL thematic area	Literacy type	Related disciplines	Contributions	Authors
Research	Research data literacy (RDL)	Research data management (RDM) and its subarea, data reuse management (DRM)	Infolit as a backbone of DL for research Importance of research management plans as a tool to support the acquisition of Infolit and DL.	**Schneider** (2013) **Šorgo** (2018) **Wiorogórska** *et al.* (2018)
Higher education	Data information literacy (DIL)	Interdisciplinary	DL as a foundation for the acquisition of Infolit core competencies in higher education for faculty, students, and libraries	**Mason** *et al.* (2016) **Shorish** (2015)
	Education data literacy (EDL)	Interdisciplinary	DL as a core competency of teachers and educational managers	**Deja** *et al.* (2021) **Lin** *et al.* (2022)
Critical thinking	Critical data literacy (CDL) Critical DIL for big data	Social sciences	Pragmatic dimension of CDL: a tool against infoxication and disinformation. A critical view is required to promote training in the context of big data.	**Špiranec** *et al.* (2019) **O' Neill** (2019) **Smolnikova** (2020) **Marzal** (2020)
Citizenship training	Data literacy for professional security (DLPS)		Big Data security challenges: widespread use, rapid development, and growth of security in research data (SRD) systems. Data-driven security management must be implemented.	**Wang** *et al.* (2019)
Specific areas of knowledge	Quantitative information literacy (QIL)	Science, Technology, Engineering, and Mathematics (STEM; scientific and technical disciplines) Social sciences	Open educational resource Data EDUcation: DL for the acquisition of competences in quantitative analysis	**Kläre** & **Jung** (2019)
	Geographic–spatial DIL	Geographical information systems (GIS)	Emphasize the need to assimilate new avenues of visual ethnography.	**Appel** (2020), **Rutkowski** & **Williams** (2020)

To bring order to this picture, several works have been devoted to establishing the identity of DL and its relationship with other forms of literacy, especially Infolit (**Calzada-Prado**; **Marzal**, 2013; **Koltay**, 2015; 2017a; 2022; **Marzal**; **Borges**, 2017; **Marzal**, 2020). It was already seen that the definitions of **Carlson** *et al*. (2013); **Maybee** *et al*., (2015) and that of **Calzada-Prado** & **Marzal** (2013) have acquired a reference level, and that they share as a basis the *ACRL* framework and the transition to a greater emphasis on the active, critical, and ethical roles of all DL components (Section 3.2.1). **Marzal** (2020) proposes a taxonomic model for the multiple forms of literacy in an attempt to clarify the picture of multi-literacies, and **Ghodoosi** *et al*. (2023) provide a systematic review of the literature focused on competencies that also addresses key issues in the definition of DL.

3.5.2. DL modeling: establishing competencies and integrating them into the curriculum

As seen in the previous section, calls for intensified data management training for all academic staff (**Wiorogórska** *et al*., 2018) through comprehensive and flexible projects (**Šorgo**, 2018) and open resources (**Kläre**; **Jung**, 2019) have multiplied throughout the period. To this end, several interdisciplinary competency proposals are available from the outset, such as the data information literacy competency model (**Carlson** *et al*., 2011), the result of the work of a large number of academic libraries; the two-dimensional matrix for the implementation of research data literacy (RDL) curricula as a subdiscipline of research data management (RDM) in different disciplines (**Schneider**, 2013); and the core competency model of **Calzada** & **Marzal** (2013). Other general models aimed at training in research data management have followed, such as open inventory (**Koltay**, 2016a) or the *Essentials 4 Data Support* course aimed at librarians and computer scientists (**Verbakel**; **Grootveld**, 2016).

In another avenue of work, **Rubach** & **Lazarides** (2021) have developed a tool to measure teachers' ICT competence, with dimensions including Infolit and DL: Infolit, storage, communication–collaboration, content creation, security, problem solving, and reflection.

The first comprehensive review of the scientific literature on the implementation of DL in the university curriculum appeared in 2023 (**Ghodoosi** *et al*., 2023), providing a comparison between different competency models. This article has become a reference for any competency project as well as for the establishment of a core set.

> In diachronic evolution, the relevance of the use of technologies and, in particular, mobile devices is verified

The results document the pressing needs of students and teachers in Infolit core competencies as a basis for the acquisition and development of DL. For this reason, there are various programs that integrate both literacies into the curricula on the basis of a diagnosis of the needs encountered (**Carlson** *et al*. 2011; **Maybee** *et al*. 2015; **Frank**; **Pharo**, 2016; **Macy**; **Coates**, 2016). Other studies demonstrate the crucial nature of these competencies for subsequent professional development (**Boettger** *et al*., 2017; **Phillips**; **Jahanshahi**, 2017). Overall, the available satisfaction scores are good, with both teachers and students confirming that they stimulate their interest in data and competence in their interpretation and management, with an overall positive impact on their learning and curricular advancement, as well as regarding the relevance of Infolit as a foundation for DL (**Koltay**, 2015a; 2017; **Šorgo**, 2018; **Braun**; **Huwer**, 2022).

Another significant result that emerges at the end of the period studied in relation to curriculum development is the urgency to act in the face of epistemological and methodological changes arising from intensive data analysis (Big Data) and machine learning, for which theoretical concepts such as data agency in relation to Infolit and other literacies have been proposed as a framework to address the educational challenges of the new sociotechnical reality (e.g., **Tedre** *et al*., 2020).

Finally, the fundamental role that academic libraries have played in the deployment of DL since the beginning of the movement is worth highlighting. The results have three main directions: the incorporation of DL into Infolit by academic librarians in a systematic way based on competency frameworks; support for training in research data management; and some more isolated efforts in specialized data management. Systematic analyses of such efforts in specific areas are becoming available, such as that of **Martín-González** & **Iglesias-Rodríguez** (2022) for Spanish Resource Center for Learning and Research (*Centro de Recursos para el Aprendizaje y la Investigación*, CRAI) libraries.

In terms of recommendations, the authors share the urgency that DL competencies be acquired in undergraduate education, depending on the different fields of specialization, as they contribute decisively to critical thinking and basic citizenship skills (**Pothier**; **Condon**, 2019; **Martín-González**; **Iglesias-Rodríguez**, 2022). In this sense, there is a demand for investment in DL training, at both the curricular and professional level (**Boettger** *et al*., 2017; **Ophoff** *et al*., 2017a; **Ophoff** *et al*., 2017b), and it is recommended that teachers, librarians, and researchers delve deeper into the relevance, dimensions, and variables of DL (**Marzal**, 2020; **Pinto** *et al*., 2021). Further deepening of the development of a consensual competency framework integrated with but set apart from other literacies is also recommended (see review by **Ghodoosi** *et al*., 2023).

3.5.3. Application: pilot projects for design, implementation, and identification of best practices in DL

A large body of discipline-specific pilot projects is available, some of them with several pilots and comparative results (Table 5). The area of social sciences is particularly important, as it encompasses more than half of the references. Almost all of them adopt active teaching methodologies, in particular project-based learning, whether ad hoc or real, as part of their undergraduate, graduate, and doctoral studies and work.

On the one hand, there is a lack of students in these fundamental skills, while on the other, there are limitations in the academic curricula that require the implementation of complementary programs and courses.

All these projects conclude that understanding, interpreting, representing, storing, using, managing, and sharing data is crucial (**Stephenson**; **Caravello**, 2007) to raising awareness and empowering and ultimately building a data culture (**Vanhoof**; **Mahieu**, 2013) through DL.

In the most recent period, the application of the problems of infoxication (**Koltay**, 2022) and disinformation (**Valverde** *et al*., 2022) is emphasized in connection with the multi-literacy movement and the growing emphasis on critical thinking. Faculty learning communities (FLCs) are an excellent platform for addressing these growing issues in the world of data and information (**Burress** *et al.*, 2020; **Burress**, 2022), emphasizing the need to work openly and collaboratively.

3.5.4. Evaluation of competencies, programs, and courses

An important part of the research effort has been devoted to the assessment of these competencies, as well as to the validation of specific tools. The evaluation process begins with pilot studies that include the collection of indicators. **Sadioğlu** *et al*. (2009) present experiences in the training of teachers of experimental sciences and early childhood education through an evaluation that resulted in very distinct DL levels.

There are three related papers **–Vanhoof** *et al*. (2011; 2013) and **Verhaeghe** *et al*. (2011)– that develop the influencing factors, feedback use, and perceived school performance feedback (SPF) effects model, investigating the use and interpretation of educational statistics in primary schools and the relationship between DL competencies and school improvement. They conclude that school principals' perception of performance and actual use of student information requires reinforcement and implementation measures, particularly through professional development and external support.

Calma's (2013) study assesses generic skills in business administration students in Australian universities using ad hoc designed rubrics. **Marzal** & **Borges** (2017) propose an evaluation model applicable to higher education. **Ophoff** *et al*.

Table 5. DL pilot projects

Disciplines	References	No.
Social and human sciences (all)		**13.5**
Social sciences		**11**
Business administration	**Jewell** *et al.*, 2019; **Pothier** & **Condon**, 2019; **Condon** & **Pothier**, 2022	2
Anthropology and other social sciences	**Stephenson** & **Schifter**, 2007	1
Digital archaeology	**Cook** *et al.*, 2018; **Zorica** & **Kindzic**, 2019	1
Political science	**Maybee** *et al.*, 2015	0.5
Social sciences	**Carlson** *et al.*, 2011	0.5
Communication and documentation	**Martín-González** & **Iglesias-Rodríguez**, 2022	1
Security management	**Wang** *et al.*, 2019	1
Technical communication	**Boettger** *et al.*, 2017	1
Geography and geospatial science	**Widener** & **Reese**, 2016; **Brawn** & **Huwer**, 2022; **Appel**, 2020	3
Humanities		**2.5**
Humanities	**Carlson** *et al.*, 2011	0.5
Liberal arts	**Locke**, 2017	1
Digital humanities	**Garwood** & **Poole**, 2019	1
Health sciences		**4.5**
Nutrition	**Maybee** *et al.*, 2015	0.5
Psychology	**Brock** *et al.*, 2021	1
Health	**Porter** *et al.*, 2008; **Stark** *et al.*, 2018	2
Public health	**Macy** & **Coates**, 2016	1
Sciences		**4**
Biology	**Jeffryes** & **Johnston**, 2013; **Weber**, 2017	2
Meteorology	**Frank** & **Pharo**, 2016	1
Microbiology and biology	**Joyner** & **Parks**, 2023	1
Engineering sciences		**4**
Information technology	**Braun** & **Huwer**, 2022	1
Engineering	**Phillips** & **Jahanshahi**, 2017	1
Civil engineering	**Jeffryes** & **Johnston**, 2013	1
Computer science	**Cheng** *et al.*, 2019	1
Total		**26**

(2017a; 2007b) develop an educational research literacy assessment tool and analyze the differences in educational science students. **Phillips** & **Jahanshahi** (2017) measure the relevance and effectiveness of a DL training course in engineering. **Drobikova** *et al*. (2018) investigate attitudes toward data sharing and research data management in doctoral students at *Charles University* using a questionnaire. **Cerny** (2021) uses the *DigComp* self-assessment questionnaire to measure and analyze changes in the digital competence profile of information and library studies students at *Masaryk University* in Czechia. **Deja** *et al*. (2021) investigate the impact of DL on psychological empowerment in the workplace of newly employed graduates. **Pinto** *et al*. (2021) identify the level of development and implementation of Infolit in Spanish university libraries through a content analysis of their websites using the *MeLIL* self-assessment-evaluation tool. **Rubach** & **Lazarides** (2021) develop and validate an instrument to assess teachers' ICT competencies along several dimensions. **Lin** *et al*. (2023) reveal the relationship between teachers' attitudes toward ICT, DL, and digital competence in teaching and student empowerment. **Joyner** & **Parks** (2023) discuss the impact of course-based research experiences that facilitate multiple pathways to develop science technology literacy skills, specifically in microbiology.

In this regard, various tools, both qualitative and quantitative, have been identified to measure the effectiveness of the different programs (Table 6). These tools are the first to analyze the confluence between Infolit and DL. The diachronic evolution shows the relevance of the use of technologies, and in particular, of mobile devices.

Despite the efforts made, the conclusions of the authors from the studies analyzed confirm the gaps indicated in the current status of DL regarding the absence of sufficient indicators and quantitative studies. This aspect was also noted in the methodology section (3.4.1), since empirical (8, 7.92%) and quantitative (9, 16.07%) studies in general are fewer than qualitative studies (21, 37.50%). Therefore, empirical evidence calls for more experimental and quantitative studies (**Deja** *et al*., 2021; **Burress**, 2022).

Table 6. Tools used

Tool	Description	Contributions	Authors
ERL	Evaluation of programs in different universities in education research literacy (ERL), Infolit, and statistical literacy (SL).	They are the first tools that measure the confluence between Infolit and DL, as well as their projection, for future researchers.	**Calma** (2013) **Ophoff** *et al.* (2017ab)
ICT	It measures the relationships between attitudes toward information and communication technologies (ICT), DL, and digital skills.	Attitudes toward technologies do not seem to have a significant impact on digital learning competencies. This instrument links DL, Infolit, and technologies.	**Lin** *et al.* (2022)
Open data analysis	Qualitative tool for analyzing open government repositories (open data government).	Promotes access to government data, transparency, citizen participation, innovation, and motivation.	**Gascó-Hernández** *et al.* (2018).
MeLIL	Measures the visibility of Infolit through the web services of Spanish university libraries.	Awareness of the relevance of Infolit and the usefulness of *MeLIL* as a self-assessment evaluation tool for international collaborative work.	**Pinto** *et al.* (2021)
DID3	The Digging into Data 3 challenge	Teacher and student competencies in digital humanities.	**Garwood** & **Poole** (2019)

4. Conclusions and future avenues of work

From the study of the literature analyzed, conclusions can be drawn as to both the theoretical development of the discipline and the evidence obtained in the training proposals and their current limitations, from which a set of recommendations can be made for the discipline's agenda, highlighting the need for further studies on all fronts: theoretical, empirical, and applicative.

The results confirm that DL is an emerging and rapidly growing field with great relevance in higher education. All of its components, including the library, have a fundamental role in the implementation and acquisition of DL in the university. The diversity of disciplines and areas of knowledge in which DL plays an essential role, and the interrelationship between the different literacies –especially between Infolit and DL– are also noted. Libraries have proven to be a suitable agent for implementing DL policies and programs for academics and students as well as for citizens and professionals because of their interdisciplinary nature and the strength of their commitment to networking and social and ethical responsibility.

In terms of empirical evidence, there is evidence of gaps in the data competence of a large part of the university student body and sometimes of faculty and educational administrators as well, but also of their enthusiasm to fill this gap as soon as they are given the opportunity. In this sense, the literature review reflects the main efforts made in the field of DL: (a) the valuation of data as a key resource, (b) the effort to raise awareness among the relevant components (faculty, librarians, researchers, and data managers), and (c) the development of proposals for competency frameworks, training programs, and pilot projects that actively contribute to their acquisition. The evaluation of competencies and actions has not been sufficiently developed and lacks a set of common indicators for comparison.

In its disciplinary development, DL is presented as an emerging field that encompasses different areas of knowledge and has achieved great relevance in higher education, both in specialized disciplines and in its interdisciplinary dimension. However, DL is also a complex and fractured field. Even in its Infolit-inspired subset, which is the one studied in this paper, DL branches into different proposals, such as information literacy in data (**Mason** *et al*., 2016; **Šorgo**, 2018); educational literacy in data (**Deja** *et al*., 2021; **Lin** *et al*., 2022); critical literacy in data (**Špiranec** *et al*., 2019; **O'Neill**, 2019; **Smolnikova**, 2020); geospatial visual literacy (**Appel**, 2020; **Rutkowski**; **Williams**, 2020); and other related literacies such as statistical literacy (**Wiorogórska** *et al*., 2018), quantitative information literacy (QIL) (**Kläre**; **Jung**, 2019), and data reuse management (**Schneider**, 2013). This panorama constitutes the other side of the interdisciplinary nature of DL, which approaches data from the diversity of symbolic languages, specific media, and disciplinary orientations.

In the face of the great diversity that transpires, Infolit is presented precisely as a solid axis on which to articulate DL, and therefore the rest of literacies, especially in its current approach that values the active and creative roles, responsibility, and the critical capacity of the literate (*ACRL*, 2015). Despite the heterogeneity of definitions and the proposal of different approaches, a consensus is emerging, reflected in the most cited works (**Carlson** *et al.*, 2011, 2013; **Maybee** *et al*., 2015; **Calzada-Prado**; **Marzal**, 2013) that detail its competency features in relation to Infolit: access, interpret, critically evaluate, manage, handle, and ethically use data, thus showing the value of Infolit in the acquisition and development of DL in a critical and active way.

In fact, the different approaches recognize the close relationship between DL and Infolit, as data are used, transformed, illustrated, discussed, and shared within broader documents and contexts. Furthermore, given the impact of the semantic web, Big Data, open data, e-science, and e-citizenship, it is impossible to think of information without reference to data and its derivatives: Infolit is des-

> "In its disciplinary development, DL is presented as an emerging field that covers different areas of knowledge and that achieves great relevance in higher education"

tined to undergo a major transformation and to become the "common house" of instrumental literacies. There is a theoretical rationale for this mutual dependence: from the paradigm of the information pyramid –shared in numerous disciplines and one of the theoretical bases of information science– the trilogy of data, information, and knowledge form a structured system that mutually condition each other (**García-Marco**, 2011). Sharing knowledge has always required transmitting pyramids of knowledge that can be tested, validated, and reused in scientific and citizen discussion; information and communication technologies have empowered this process and turned it into one of the key elements of digital transformation. The educational effort, i.e., literacy, cannot ignore the consistency of the data-information-knowledge framework, which must be approached jointly. While the knowledge layer is the responsibility of the disciplines, the standardization and cross-processing of the information and data layers is a key opportunity for information professionals in their educational efforts through Infolit. For all these reasons, it is possible to predict the growing success of DL within Infolit, and of Infolit –transformed and more analytical– as a framework for DL.

> "Sharing knowledge has always required transmitting pyramids of knowledge that can be contrasted, validated and reused in scientific and citizen discussion"

In this context, the role of information professionals –e.g., academic and public librarians, archivists, document and data administrators, content and data curators, etc.– while nuclear, cannot be isolated. Rather, they should be placed at the service of the broad networks of academics, researchers, technicians, and managers involved in building a society and an economy on the basis of data and its systematic exploitation. It is therefore the time to create and establish broad coalitions rather than falling into a struggle for protagonism, which can result in inefficiencies and dispersion of effort, especially in environments where data-oriented communities are still small and isolated. The corpus of works analyzed shows numerous excellent examples of such collaboration.

Finally, some recommendations for future research are presented here: (a) to continue to investigate Infolit as a vector for the acquisition of DL in the face of current societal challenges (e-research, open data, semantic web, Big Data, and artificial intelligence); (b) to advocate for a greater definitional consistency of DL within the framework of the postulates of the current *ACRL*; (c) to define educational institutional policies and plans that include a catalog of the core competencies of DL within the framework of Infolit, promoting the libraries' role of coaching in this process, together with academic staff; (d) to carry out empirical studies that allow for the evaluation of training actions and programs in different specialties, environments, and with diverse subjects; (e) to address the special fields of DL with specific developments and proposals along the lines that *ACRL* has been carrying out in the last decade with its adaptations for the different disciplines; and (f) to develop sets of indicators suitable for the evaluation of the acquisition of competencies; of policies, programs, courses, and actions; and of the participating components.

Regarding the continuation of this research, it is important: (a) to replicate this study using other similar authoritative sources (notably *Scopus*) and in other languages (e.g., Spanish and Portuguese) to expand the reference collection, since a limitation of this study is the use of the *WoS Core Collection* as the sole source, chosen because it constitutes a compact corpus in terms of selection criteria; (b) to resort to sources that include publications not referenced in the impact indexes to investigate the origins of the discipline or its development in different geographical or linguistic environments; and (c) finally, to periodically monitor the evolution of the field by replicating such systematic reviews at least every 5 years. On this latter point, it is recommended that a research group be set up to encourage studies across the entire disciplinary, media, and geographic matrices of DL.

Beyond the conclusions and recommendations related to Infolit and DL, this research also attempts to make a methodological contribution by rigorously combining the systematic review approach with an analysis of the context and phases of scientific research. This is an innovative, albeit initial, proposal that could be used in other fields of research.

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The documentary corpus was composed of the works whose bibliographic references appear in blue in this section.

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6. Appendixes

Appendix 1. Data collection form

0.Bibliographic reference of the article

1. Overall characterization
   - 1.1. Evolution of DL within the framework of Infolit
     - a. Specialty
     - b. Year
   - 1.2. Authorship (disciplinary/professional field, nationality, productivity)
     - a. Author
     - b. Discipline
     - c. Year

2. Research frameworks
   - 2.1. Definitions
     - a. Author
     - b. Year
     - c. Definition
   - 2.2. Disciplinary relations in the field of literacies: related literacies
     - a. Macro-category
       - i. General
       - ii. Infolit
       - iii. Special
       - iv. Integrated
     - b. Type
     - c. Year
   - 2.3. Frameworks, theories, and reference models
     - a. Designation
     - b. Responsible party
     - c. Year
     - d. Type
       - i. Research frameworks (perspectives, theories, and models)
       - ii. Legal and educational management frameworks (competency models, curricula, courses, evaluation models)
   - 2.4. Evidence and gaps
     - a. Type
     - b. Year
     - c. Verbatim citation

3. Research objectives
   - 3.1. Objectives
     - a. Type
       - i. Relevance
       - ii. Conceptualization

iii. Competency framework
iv. Application
v. Evaluation
b. Topic
c. Author
d. Year
3.2. Purpose
a. Discipline of application
b. Year

4. Methodology
a. Types of studies
i. Disciplinary/interdisciplinary
ii. Applied
iii. Experimental
iv. Exploratory
v. Theoretical
b. Methods
i. Comparative
ii. Descriptive
iii. Case studies
iv. Evaluative
v. Experimental
vi. Exploratory
vii. Literature review
c. Techniques
i. Qualitative analysis (content analysis, expert panel, etc.)
ii. Quantitative analysis (descriptive, inferential)
iii. Qualitative data collection (interviews, case study, focus group, Delphi, etc.)
iv. Quantitative data collection (tests, questionnaires, rubrics, etc.)
d. Sources
i. Journal articles
ii. Specialized databases
iii. National and international standards
iv. *ACRL* framework
v. Institutional sources
vi. Websites
vii. Expert panels
viii. Syllabus
e. Tools
i. Surveys
ii. Templates
iii. Computer-assisted programs
iv. Information visualization programs
v. Rubrics
vi. Test
f. Year

5. Knowledge statements (results, conclusions, and recommendations)
a. Type of knowledge statement
i. Result: stemming from the methodology used
ii. Conclusion: in relation to the status of the issue
iii. Recommendation: in relation to the context of action
b. Corresponding objective
c. Basic description
d. Contribution
e. Author
f. Year

Appendix 2. Corpus of documents

The documentary corpus was composed of the works whose bibliographic references appear in blue in the References section.