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DOI
10.55612/s-5002-057-008

Publication date
2023

Document Version
Final published version

Published in
Interaction Design and Architecture(s)

Towards a framework for Open Data literacy in education: A systematic mapping review of Open Data skills and learning approaches

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Abstract. Open Data (OD) is defined as digital data that is made available with the technical and legal characteristics necessary to be freely used, reused, and redistributed by anyone, anytime and anywhere. Although OD can be seen as a commons, citizens often face challenges in accessing, using and making sense of available open datasets. Current literature identifies a lack of data expertise as one of the main barriers and emphasises the importance of strategies for training and teaching the appropriate competencies. Furthermore, a clear definition of OD skills and learning approaches is missed. A two-sided systematic mapping review with a focus on the educational domain was conducted to identify relevant OD skills and the approaches facilitating the development of these competencies. The results section presents a map of OD skills and learning approaches, while the discussion section elaborates on the potential of OD in education to empower students with skills and competencies to better understand their context, act in their everyday life environment and address future challenges. The current contribution is an OD literacy framework that puts OD at the centre of competence-based education, fostering responsible citizenship necessary for addressing today's societal challenges.

Keywords: Open Data Education, Open Data skills, Open Data competencies, Open Data literacy, Responsible citizenship, Competence-based education

1 Introduction and Background

As the societal importance of Open Data (OD) has increased in recent years, research in the field has expanded as well. The growing field now includes several research domains, including policy studies and education [1, 2]. Open datasets are available within a wide range of fields such as geography, agriculture, finance, and legal systems [3]. Local governments are increasingly opening datasets on social and technical aspects of cities, and research institutions are creating strategies for opening research data [4]. Examples include open datasets on geo-localisation of public services, mobility or air quality made available to citizens through OD portals. From a technical and governmental perspective, the availability of OD might contribute to improving public services and bringing transparency to government policies [5]. OD

might also be used, reused and shared in order for citizens and organisations to increase accountability and innovation, and create social value [6–8].

Although OD initiatives might permit citizens to freely use, modify and share OD as a new commons [9], different OD stakeholders are constrained by a lack of skills and resources [3, 6, 7, 10]. Several researchers have highlighted that a large percentage of citizens without technical backgrounds, often called non-specialists, non-data experts or lay audiences [11, 12], might face barriers associated with the complexity of handling the data and participation in the open-data process [13]. For example, OD users usually need to be familiar with dataset formats, statistics, text processing software, programming languages or interfaces [14]. These competencies are often associated with Data Literacy [15, 16] or Data Science according to proficiency level [17]. The openness of OD, however, might require the consideration of skills and competencies outside the Data Literacy spectrum. OD skills might allow users not only to technically manage available OD [1, 14–16], but also to understand what kind of perspectives it creates in an open and data-driven society [3]. There is a need to define what kind of skills and competencies are associated with using and understanding OD, and how to teach them. The OD field therefore calls for training a literate community in which all can benefit from OD, rather than only the most skilled citizens [3, 18]. OD education, including the integration of OD in educational systems, is thus gaining relevance. For example, the International Open Data Charter, formed by governments, civil society and experts from about 88 countries, suggests engaging with schools to assure the inclusion of OD in society [19].

Within education, OD may not only create an opportunity to interact directly with real facts, but also foster abilities to critically assess these facts [18, 20, 21], thus countering current criticisms of traditional educational models. Traditional curriculums are criticised for their inability to develop essential skills required for civic engagement and the labour market [5, 22]. The literature suggests a need within education to promote abilities to cope with new socio-cultural challenges and adapt to changes in technology and a data-driven society [15, 23, 24]. Although some authors have explored the potential of using OD in schools [21, 24], there is no common agreement on the definition of the skills and competencies needed or how to teach them.

This study aims to identify the OD skills and learning approaches present in the current literature and contribute to a common definition with a competence-based perspective. A systematic mapping review was conducted to identify the skills necessary for using OD and the learning approaches for teaching them in educational contexts. The methods section describes this process. A reference framework based on the design of learning activities was used to map and categorise 32 articles. Based on a Thematic Network Analysis, the results present six clusters which relate Skills for using OD to five elements associated with Learning Approaches (Learning Theory, Learning Activity, Learning Outcome, Learning Environment, Learners, and Other Participants). The results stress the interlinked relation between OD Skills and Learning Outcomes. Finally, the discussion and conclusion sections elaborate on a framework for OD literacy in education which might further drive research and development of tools and methods fostering OD use in education.

2 Methods

A two-sided systematic mapping review was conducted to map out and categorise existing literature to identify gaps and opportunities about the use of OD in education [25]. The mapping review had two focuses: uncovering OD skills enabling students

as non-data literate citizens to use OD, and to map the educational approaches to develop or support these competencies. After defining the scope of the review by developing inclusion and exclusion criteria according to the research question, a systematic review process based on the PRISMA flow was applied to identify relevant studies [26]. The PRISMA flow involves three main steps: (i) identifying potential studies through iterative searches using keywords; (ii) screening of abstracts and articles to meet inclusion and exclusion criteria; and (iii) determining the final selection of records for undertaking a qualitative synthesis. Finally, the selected articles were characterised after a thematic network analysis outlining a map of OD skills and learning approaches in education.

2.1 Defining the Scope of the Review

The scope of the review was determined by defining inclusion and exclusion criteria to ensure the relevance of the studies for identifying the skills and learning approaches that enable students as non-data literate citizens to use OD. Considering the novelty of the field and the exploratory aim of this study, the review was not restricted to a specific educational level, such as elementary school education, or to a specific kind of educational environment, such as formal or informal learning environments. Instead, two main considerations were defined as essential: OD being central in teaching and learning, and students directly engaging with OD. According to these considerations, inclusion and exclusion criteria were defined in terms of *OD education* and *Student engagement with OD*. Firstly, the scope considered studies focused on *OD Education* by considering OD as an educational resource or as the central topic of learning. This criterion was broad enough to allow a variety of educational characteristics to appear, such as different learner types, educational levels, actors involved or learning approaches. Secondly, it was key that through students' direct engagement with OD, they implicitly or explicitly developed OD competencies.

Finally, an additional criterion was related to the quality of records. Only peer reviewed studies were included, ensuring their quality and relevance. Furthermore, since records should address specific cases where skills and learning approaches could be mapped, conference proceedings or introductory publications were not considered. Table 1 summarises the main criteria defined to ensure the alignment of the reviewed studies with the research aim.

Table 1. Inclusion and exclusion criteria

Inclusion and exclusion criteria	Description
OD Education	• Open Data education is central in the study. • OD is used for educational purposes with a focus on skills development.
Student engagement with OD	• Studies involve students without professional knowledge in OD.
Quality of records	• Studies are peer reviewed. • Records address specific cases.

2.2 Identifying Potential Studies and Screening of Abstracts and Articles

The process of finding and selecting relevant articles involved first identifying potential studies through iterative searches using keywords. Then abstracts and articles were screened according to the inclusion and exclusion criteria. To ensure the complete and transparent reporting of the systematic review, the PRISMA statement was considered along the process [26]. Figure 1 outlines the systematic mapping review process according to the PRISMA flow.

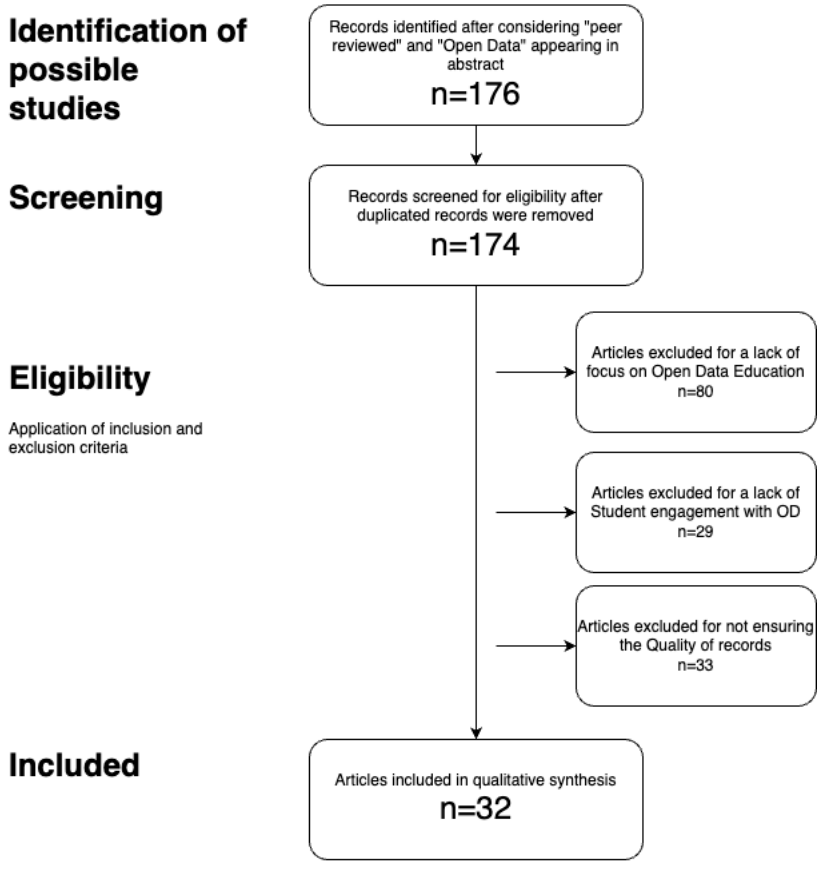

Fig. 1. Systematic mapping review process. PRISMA flow diagram modified from [26, 27]

Identifying Potential Studies. Iterative searches in current literature were conducted to discover the widest possible range of skills and learning approaches associated with the usage of OD by students in different educational contexts. Considering the exploratory aim of the review, various searches were conducted before defining the final selection of keywords and databases for conducting the systematic review flow presented in Figure 1.

An initial search across Google Scholar, Scopus and ScienceDirect was conducted using the following combination of keywords "Open Data" AND skills OR competences. As an initial screening of abstracts indicated that results were disconnected from the research scope, new keywords related to educational context were added and one database was selected for the review. Table 2 presents the final list of keywords. Keywords related to education were broad enough to allow different perspectives to appear. For example, both “learning” and “teaching” were included in order to reach different approaches. While words such as “school” and “student” were selected to assure the inclusion of formal educational contexts in keeping with the aim of the study, the inclusion and exclusion criteria also allowed other perspectives to appear. Results from the Scopus database were more relevant than those from the other databases due to the peer reviewed process and empirical approach of the studies. Therefore, the review was conducted across the Scopus database [23].

Table 2. Final keywords used for iterative searches.

Keywords		
Open Data	Skills	Education
	Competencies	Learning
	Capabilities	Teaching
		Schools
		Student

The following query was used: "Open Data" AND (skills OR competencies OR capabilities) AND (education OR learning OR teaching OR schools OR student). To assure relevance to the field, only abstracts containing “Open Data” were considered. In this way, 176 articles were identified. Duplicate records were removed. Finally, 174 articles were considered for screening of abstracts and articles for the application of the inclusion and exclusion criteria according to the research aim.

Screening of Abstracts and Articles, Eligibility, and Inclusion. Screening of articles and abstracts was essential for identification of the articles fulfilling the inclusion and exclusion criteria. After this step, a large number of the articles were excluded, resulting in a total of 32 articles included for categorisation. In accordance with the inclusion and exclusion criteria, articles were excluded for a lack of focus on OD Education, a lack of student engagement with OD and for not ensuring the quality of records criteria.

Articles Excluded for a Lack of Focus on OD Education. 80 records were excluded for a lack of focus on OD education. Although OD was used in an educational context, teaching or learning with OD was not essential in some studies. For example, some studies focused on the development of tech-based solutions, such as an environmental and geographical web-based atlas [28] or a framework for automatically retrieving data [29]. In other studies, OD was part of the collection phase in research projects about education [30, 31]. Finally, some studies focused on evaluating or mapping OD initiatives such as the evaluation of a massive open online course (MOOC) in the spatial domain [32], and a mapping of current uses of open government data [8].

Articles Excluded for a lack of student engagement with OD. A second criterion led to the exclusion of 29 articles focused on data experts. Users were data experts and developers engaging with technological solutions based on OD. For example, an inductive concept learning technique was used to expand vocabulary and ontologies for cross-domain geospatial analytics based on Linked Open Data Cloud [33], and a web-based learning environment was presented to foster innovation skills in software

development students [34].

Articles Excluded for not Ensuring the Quality of Records. 33 records were excluded according to the quality of records criteria. 30 records were introducing conference proceedings. Two records introduced editorial special issues [16, 35]. Finally, one more record was not accessible.

Thus 32 studies including articles, conference papers and book chapters were ultimately considered for mapping the Open Data skills and learning approaches. According to the inclusion criteria, these studies highlight the need for and/or development of certain skills in students using OD in different educational contexts. In the studies, OD is considered either as a central topic of learning or as an educational resource, and students engaged by using OD.

2.3 Characterisation of Articles Included for Mapping the Open Data Skills and Learning Approaches

The 32 records included were reviewed in depth to map the OD skills and learning approaches. According to the systematic mapping review process, a qualitative synthesis was performed. Therefore, an abductive reasoning process was adopted to form hypotheses through the discovery of new concepts, ideas or explanations [36]. In order to reflect the complexity of educational designs and gain deeper understanding on the interrelation of skills and learning approaches, the *Learning Activities Design Approach* by Helen Beetham [37] was chosen as a reference framework for the mapping and analysis process. Beetham's approach focuses on the design of learning activities by relating different aspects such as learners, other participants, learning outcome and learning environment. Figure 2 shows the interrelation of the elements.

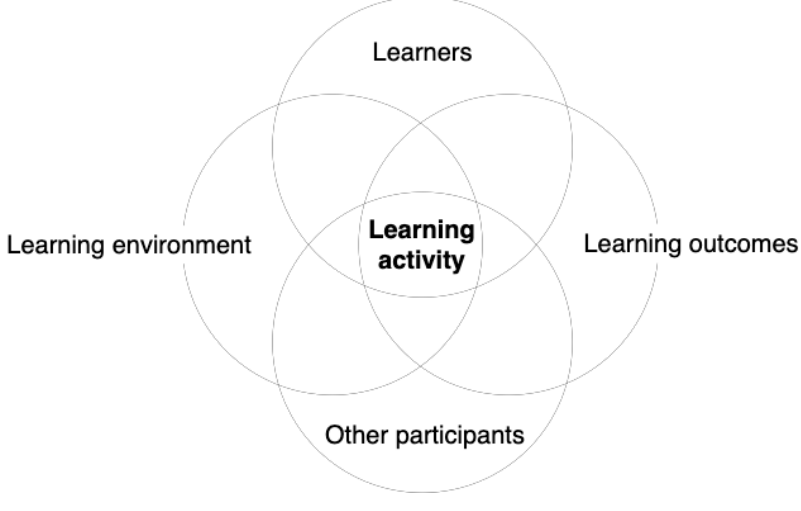

Fig. 2. Reference framework based on Beetham's Learning Activities Design Approach [37]

The current work considers these elements for mapping the learning approach plus a theoretical perspective. Table 3 describes the elements that were finally mapped and analysed during the categorisation process.

Table 3. Elements mapped during the categorisation process based on [37]

Element		Description
Skills for using OD		Abilities and competencies needed for using OD in educational contexts
Learning Approach	Learning Theory	Theoretical approaches to understanding learning
	Learning Activity	Interaction of learner(s) with other people, tools, and resources. It is oriented to a specific outcome
	Learner(s)	Centre of the learning experiences. Who has identities (needs and motivations), competences (skills and knowledge), and roles (approaches and modes of participating)
	Other Participants	Other people involved and their role
	Learning environment	Affordances of the physical or virtual environment. Tools, resources, and artefacts.
	Learning Outcome	New knowledge, competencies, skills, and abilities.

Back-and-forth reasoning between theory and evidence from the studies allowed different iterations to occur while following a Thematic Network Analysis approach [38] that resulted in the identification of different clusters. Three main steps were conducted: (i) generating initial codes from textual data, (ii) creating categories of initial codes to summarise abstract principles, (iii) identifying clusters or global themes encapsulating a main idea, principle or claim [39].

(i) Generating initial codes from textual data. Initial codes corresponded to each of the elements of analysis presented in Table 3. Elements were coded using NVivo software in each study trying to keep the authors' wording as much as possible [40]. For example, skills were found as "statistical thinking" or "solving problems", learning approaches as "project-based learning" or "inquiry-based learning", learning activity as "collecting local data involving members of the community", learning outcomes as "advance the digital and data skills essential for future generations", learners as "secondary school students" or "postgraduate research students", and other participants as "non-profit organisations" or "research institutions". *(ii) Creating categories of initial codes to summarise abstract principles.* A second step was performed to create categories of initial codes found in each element. Categories were created according to association and similarity. For example, regarding the Skills for using OD, two categories were created: "skills related to managing data" and "skills related to engaging with local context". Regarding the learning environment, three categories were created: "formal environment", "informal environment" and "hybrid environment or formal/informal". *(iii) Identifying clusters or global themes.* Final clusters were created not only according to similarities amongst the mapped elements shown in Table 3 (Skills, Learning Approach, Activity, Outcome, Environment, Learners, and Other Participants), but also according to the interrelation between them. For example, Skills were found to be directly related to Learning Outcomes. The relation of Skills and Outcomes is at the same time associated with characteristics of the learners such as the educational level. In accordance with these interrelations, Learning Activities are designed, and other elements defined.

3 Results

The results present not only a map of OD Skills and Learning Approaches in education, but also the interrelations among them. Six clusters are presented based on the main Learning Outcomes mapped in each article included. These groups relate the Skills and elements of a Learning Approach (Learning Theory, Learning Activity, Learning Outcome, Learning Environment, Learners and Other Participants) to show that elements are not disconnected, but intrinsically interdependent among themselves. Table 4 presents the final clusters and mapped studies.

Table 4. Identified clusters.

Cluster/Learning Outcome	Results
Active citizenship	7 records [5, 18, 19, 38–41]
OD awareness	6 records [42–47]
Open science values	6 records [4, 15, 48–51]
Solving local problems	5 records [52–56]
Data fluent new professionals	4 records [12, 57–59]
Community engagement with local issues	4 records [60–63]

OD Skills. The studies implicitly or explicitly elaborate on skills or competencies related to various domains. For example, some authors use specific terms to stress the existence of cross-disciplinary skills associated with the use of OD, such as *transversal skills* [5, 21, 41], *critical data literacies* [42, 43], or *interdisciplinary data literacy skills* [44]. Furthermore, two groups of skills in educational contexts were identified: First, a group of skills related to managing data, which was labelled *Data Skills*. Second, a group of skills related to engaging with local contexts, which was labelled *Context Skills*. These two categories indicate that OD literacy comprises not only data management, but also the capacity to connect these technical abilities to real environments with a critical perspective. Table 5 presents an overview of the mapped skills.

Table 5. Overview of OD Skills.

Data Skills	Context Skills
• Computational thinking • Data documentation • Finding OD • Assessing OD • Interpreting data • Statistical thinking • Data visualisation • Data privacy awareness • Analytical skills • Leveraging OD • Prototyping • Data Ethics	• Problem analysis • Conceptualisation • Identifying problems in real-world settings • Collecting data in real-world settings • Engaging with a community • Local problem solving • Storytelling • Decision Making • Interdisciplinary research skills

Data Skills are associated with different competencies for using and understanding OD from a data management perspective. Some of these competencies, such as "Computational Thinking", have been related to the domain of Data Literacy [16]. Data Literacy has been defined as a combination of technical and

statistical skills with the ability to draw meaning by interpreting and analysing data [17, 52]. On the other hand, more Data Skills are related to a specific domain of OD such as *Finding* [5, 21, 24] and *Leveraging OD* [22, 42, 43].

Context Skills allow learners to relate or engage with the context and a community. The context and the community might be different according to each learning outcome. For example, learning activities and outcomes could relate to the student's own community [45], the community of a local school [21], a scientific community [18], or a remote or vulnerable area [46].

Although Table 5 provides an overview of all the mapped skills, when considering the Learning approaches, the list of skills is connected to the Learning Outcome. Therefore, each cluster or learning outcome is outlined in terms of specific OD Skills associated with the other elements as follows.

Clusters: Learning Outcomes. Learning outcomes were identified as clusters or *Global themes* that encapsulate a main goal by relating skills, learners, learning theories, learning environment, learning activities and other participants. These thus reflect the possible achievements that can be obtained by defining and designing different elements of a learning approach that develops a set of different skills. The six clusters show a variety of ways to approach the development of skills for using OD in different educational contexts.

Each cluster is then defined by describing its goal as a Learning Outcome and showing a map of skills and learning approach elements. Table 6 summarises the categories found within each mapped element.

Table 6. General results by mapped element

Element		Results Description
Skills for using OD		Two categories of skills were identified: Data Skills and Context skills
Learning Approach	Learning Theory	Various theoretical approaches considered by the studies reviewed
	Learners	Students in various educational levels from primary education to postgraduate education
	Other Participants	People inside and outside the school with a relevant role for the development of the Learning Activity
	Learning environment	Three categories were identified: Formal, Informal and Hybrid (Formal/Informal) environments
	Learning Outcome	Six categories of learning outcomes were identified, corresponding to the main six clusters
	Learning Activity	Manifold learning activities provide examples of the interplay of the other elements

3.1 Active Citizenship. Most of the articles reviewed were found in this group. Within this cluster, the development of skills for using OD is connected to cultivating active citizens who can contribute critically to society. For example, active citizenship is promoted by engaging with local and global issues [5, 21] through activities such as publishing visualisations of open government data [47]. Table 7 summarises the map of skills and learning approaches associated with this learning outcome.

Table 7. Map of OD Skills and Learning approaches associated with Active Citizenship.

OD Skills	
Data Skills	-Finding OD -Assessing OD -Interpreting data -Statistical thinking -Data visualisation -Leveraging OD -Data privacy awareness
Context Skills	-Identifying problems in real-world settings -Collecting data in real-world settings -Engaging with a community
Learning Approach	
Learning Theory	-Project-based learning -Problem-based learning
Learners	-Secondary school students -Undergraduate students
Other Participants	-Non-profit organisations -OD civic associations-Teachers
Learning Environment	-Formal: classroom activities -Hybrid (Formal/Informal): classroom activities connected to activities in communities -Tools: sensors, open mapping tools, simplified datasets, open databases
Learning Activity	-Collecting local data involving members of the community -Analysing OD in workshops framed in civic projects -Creating visualisations of OD for the community -Participation in public hackathons -Workshops to leverage OD and visualisations

OD Skills are relevant in both the data and context domains. Within the Data domain, competencies make evident a user's engagement, not only in interpreting available open datasets, but also in creating and publishing their own. The main learning theories are project- and problem-based learning. Students are in secondary school or undergraduate programmes. Other participants, such as non-profit organisations, play a role in connecting the learners and the community. Learning activities occur in both formal educational settings and in real-world settings such as neighbourhoods or vulnerable areas. Therefore community involvement is a main activity for advancing the data and context skills in real-world settings. Two kinds of community involvement are identified: Firstly, students as part of the community, engaging with the community from within, and secondly, students as external actors, engaging with a community from without. In an example of the first case, elementary school students are engaged in collecting data with sensors in real-world settings [20]. In the second case, undergraduate students are engaged in teaching open mapping tools to a vulnerable community in order to map a local area together [38].

3.2 OD Awareness. In consideration of the societal transition towards digitalisation and datafication, studies in this group have the common goal of increasing student awareness of OD. Students are in primary and secondary school levels. Table 8 summarises the map of skills and learning approaches associated with this learning outcome.

Table 8. Map of OD Skills and Learning approaches associated with Open Data Awareness.

	OD Skills
Data Skills	-Computational thinking -Data visualisation -Data privacy awareness
Context Skills	-Problem analysis
	Learning Approach
Learning Theory	-Inquiry- based learning -Authentic learning -Experiential learning through gameplay
Learners	-Primary school students -Secondary school students
Other Participants	-Teachers
Learning Environment	-Formal: classroom activities in STEM courses -Tools: OD interface, PET Robots. open visualisation software (Tableau, Google Maps and Think Speak data server), simplified datasets and OD bases
Learning Activity	-Testing an OD web interface -Workshops for using open research data -Workshops for solving a given set of problems through collecting and sharing data

The combination of *Data Skills and Context Skills* contributes to a basic comprehension of OD and provides a basic analysis applied to school subjects such as mathematics, geography and science [48]. *Data skills* include Computational thinking, Data visualisation and Data privacy awareness. Computational Thinking is the ability to use computer science principles, such as decomposition, pattern recognition, abstraction and automation, to solve problems [49]. *Context Skills* focus on problem analysis.

Learning Activities are proposed in a formal academic environment led by teachers. The relation with OD occurs in two ways: simplified open datasets are used in a classroom activity [50], or data is collected by students inside the classroom and shared with other students [51]. Tools such as OD interface, PET Robots, open visualisation software (Tableau, Google Maps and Think Speak data server), simplified datasets and OD bases support teachers and students in using OD to achieve the learning outcome.

3.3 Open Science Values. In this cluster, the final goal is to prepare postgraduate research students to manage and open their research outcomes. However, the engagement with real-world settings occurred with the main goal of disseminating their scientific results. Table 9 summarises the map of skills and learning approaches associated with this learning outcome.

Table 9. Map of OD Skills and Learning approaches associated with Open Science Values.

	OD Skills
Data Skills	-Finding OD -Assessing OD -Interpreting data -Data visualisation -Data ethics -Data documentation -Leveraging OD
Context Skills	-Storytelling

	-Interdisciplinary research capabilities
	Learning Approach
Learning Theory	-Problem-based learning
Learners	-Graduate research students
Other Participants	-Research institutions -Research groups -Government
Learning Environment	-Hybrid (Formal/Informal): classroom activities connected to activities in research institutions -Tools: OD platforms and open datasets
Learning Activity	-Using open data platforms during lectures, readings, tutorials, and educational modules -Peer-reviewing datasets -Learners working in research groups

Data documentation is central to the research process, while Data ethics are relevant to the assessment of whether certain research data should be open or not [51] and to anonymisation practices, for example in health-related research data [4]. Furthermore, *Context Skills* such as storytelling and interdisciplinary research capabilities enable research students to communicate their research outcomes to a broader public and to work with non-scientific professionals. Finally, Learning Activities are developed in Hybrid (Formal/Informal) environments such as classrooms and research institutions as collaborative research projects [45].

3.4 Solving Local Problems. This learning outcome aims to create solutions for local problems using OD. Local problems are issues faced by the school or university's local community. For studies in this cluster, increasing students' awareness of social issues is as important as developing technical skills. The learning outcome is the result of curricular and extracurricular activities in formal academic environments where students communicate closely with other participants such as problem and data owners, and data experts. Table 10 summarises the map of skills and learning approaches associated with this learning outcome.

Table 10. Map of OD Skills and Learning approaches associated with Solving Local Problems.

	OD Skills
Data Skills	-Finding OD -Assessing OD -Interpreting data -Data visualisation -Analytical skills -Prototyping
Context Skills	-Identifying problems in real-world settings -Local problem solving -Decision making
	Learning Approach
Learning Theory	-Project-based learning
Learners	-Secondary school students -High school students -Undergraduate students
Other Participants	-Problem and data owners (local government and community members) -Civic associations -Researchers -Data experts

Learning Environment	-Formal: classroom activities -Hybrid (Formal/Informal): extracurricular school project -Tools: sensors, IoT, algorithms
Learning Activity	-Proposing solutions for local problems, participating in workshops, receiving mentoring from experts -Participating in public hackathons to solve local problems -Presenting solutions to problem owners.

Students are in secondary, high school or undergraduate programmes. Other participants, such as problem and data owners, are closely involved in the learning activities. The combination of Data and Context skills helps the learner understand a local problem and propose solutions. Although the purpose of this cluster is solving local problems, solutions can have varying levels of development. Solutions are determined by each learning process and may be highly technical, or not. Students can thus develop *Data Skills* at a basic or advanced level according to their solution. For example, one group of undergraduate students enrolled in an elective course developed algorithms to prototype a product using sensor and open data [49], while a group of elementary school students engaged in a public hackathon based on Human-centred design brainstorm and present conceptual solutions to problems in their municipality [52].

3.5 Data Fluent New Professionals. Research in this cluster focuses on promoting students' data fluency by advancing data skills that are needed by and relevant to various disciplines in current labour markets. Students are in non-technical undergraduate or graduate programmes in domains such as health research [53], statistics [14] or weather [54]. Table 11 summarises the map of skills and learning approaches associated with this learning outcome.

Table 11. Map of OD Skills and Learning approaches associated with Data Fluent New Professionals.

OD Skills	
Data Skills	-Finding OD -Assessing OD -Interpreting data -Data visualisation -Analytical skills -Prototyping
Context Skills	-Problem solving -Decision making
Learning Approach	
Learning Theory	- Inquiry based learning
Learners	-Undergraduate students -Graduate research students
Other Participants	-Teachers -Research institutions
Learning Environment	-Formal: classroom activities -Informal: libraries -Tools: OD bases, OD platforms, open datasets, Jupyter Notebook, Python
Learning Activity	-Open content courses and individual consultation -Creating product/services based on OD -Using and co-relating OD

OD Skills are primarily focused on the Data domain, towards achieving advanced use of data. Analytical skills are thus central. These skills include correlating data

through the discovery of relatable and interesting datasets that can be combined [55], as well as management of programming languages and coding, allowing users to retrieve big open data. Learning activities are developed in formal or informal environments such as the classroom or libraries. Activities are highly diverse and can range from co-relating OD to developing products based on OD.

3.6 Community Engagement with local issues. Research in this group has the goal of engaging community stakeholders in framing local problems. In this context, educational institutions (schools and universities) appear as relevant actors in local communities; students are thus considered experts of their own community. This learning outcome is achieved by creating social learning environments [56] where stakeholders in the community, such as citizens, local government and non-profit organisations, collaboratively interact. The main characteristic of this Learning Outcome is that skills develop organically by connecting people with different competencies and knowledge. Table 12 summarises the map of skills and learning approaches associated with this learning outcome.

Table 12. Map of OD Skills and Learning approaches associated with Community Engagement with Local Issues.

OD Skills	
Data Skills	-Collaborative data skills
Context Skills	-Conceptualisation -Collaborative problem solving
Learning Approach	
Learning Theory	-Social learning ecosystems -Social-situated learning -Experiential learning through gameplay
Learners	-Students in any educational level -Graduate research students
Other Participants	-Government -Community stakeholders -Non-profit organisations
Learning Environment	- Informal: public events, local libraries, and non-profit organisations -Tools: OD-based games, open mapping software
Learning Activity	-Participating in local and national public hackathons to engage with a local problem. -Engaging in workshops to bring community stakeholders together -Making decisions about local issues

OD skills associated with this Learning Outcome are primarily collective rather than individual to address data management and problem solving. For example, during a public hackathon, members of the local community work in groups to conceptualise local problems and develop high or low fidelity prototypes according to the competencies of individuals in the group [56]. Within the group, a dynamic of sharing and social learning allows all members to improve their skills. The learning activities occurred in informal educational settings led by municipalities or local actors.

4 Discussion and Conclusions

One of the main conclusions according to the results is that OD skills and learning approaches in educational contexts cannot be seen as separate categories but are instead closely interrelated. According to the results, six expected learning outcomes determine what OD skills are necessary and what kind of learning elements can help to promote them. Further research might help understand different levels of proficiency according to a particular educational context. Several pathways – depending on the expected learning outcome – can be adopted to teach skills for using OD. For example, some educational approaches may be focused on the technical aspects, while others may be focused on social aspects such as civic and community engagement. The expected learning outcome may nonetheless be the compass for making decisions regarding what skills to teach and how to teach them.

Elements of Learning Approaches to OD Competencies. In the first layer of a framework for OD learning design, Skills, Students and Learning outcomes are interconnected. Skills for using OD are associated with the expected learning outcome and student characteristics, such as educational level. In a second layer, learning theories or theoretical learning approaches provide a foundation for the design and development of learning activities, which then determine learning environments and other participants. Figure 3 relates the different elements.

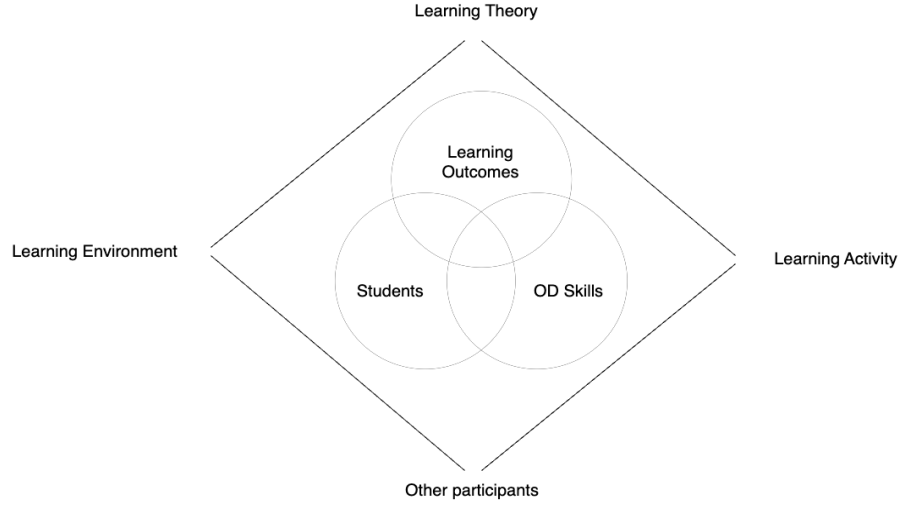

Fig. 3. Relation between elements of learning approaches to OD Competencies.

Towards a framework for Open Data Literacy in Education. Current research in the OD field tends to relate necessary skills directly to Data Literacy. The results of this study show not only that there is another group of skills related to engaging with a local context (*Context Skills),* but also show the complexity of defining learning approaches for teaching these OD Skills. Yet a close interconnection of learning design elements connects classrooms with the real-world through OD and OD learning activities.

A framework for OD Literacy in education is thus outlined in connection to a learning outcome that relates skills for using OD to a learning approach for developing them. Figure 4 shows a cartesian plane formed by the intersection of two

axes that are perpendicular to each other. The horizontal axis represents *Data Skills*, towards an advanced use of OD, and the vertical axis represents *Context Skills*, towards a higher real-world engagement. These two axes are the drivers present in the six mapped learning outcomes. This cartesian plane shows three learning outcomes towards real-world engagement and advanced use of data (Active citizenship, Solving local problems and Open science values). These outcomes are related to learning approaches such as problem- and project-based learning and are developed in a combination of formal and informal environments.

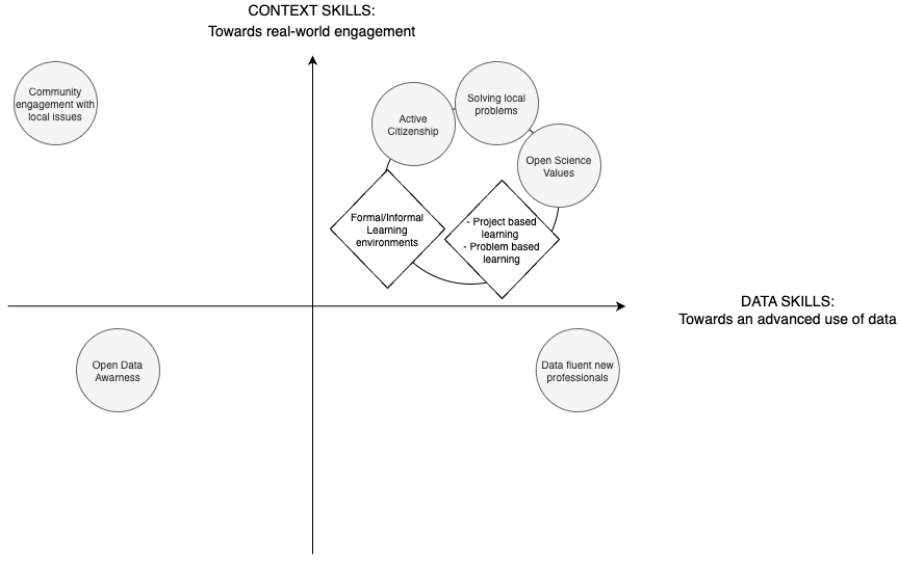

Fig. 4. Framework for OD Literacy in education.

Depending upon learning goals, an educational design might be driven towards real-world engagement or towards an advanced use of data. A framework for Open Data Literacy in education helps define the learning outcomes that could foster a specific combination of OD Skills. Then, the various elements for defining a learning approach could be addressed.

OD Literacy for responsible citizenship. Open Data Literacy in education might contribute to creating complex learning ecosystems [22] where Open Data is blended with civic engagement. The combination of *Data Skills and Context Skills* drives learning designs towards a higher engagement with real-world settings and real-world data. OD education might contribute to a competence-based education towards community capacity building [56], and cultivate learners engaged in communities that can co-develop capabilities [57].

Limitations and Further Research. Although current literature in the field of Open Data Education is scarce, the literature is increasing exponentially. This could expand the current results and provide novel perspectives. This mapping review focused on mapping academic literature. Further research considering sources such as grey literature might also contribute to identifying new trends and innovations in learning approaches within the fields of Data Literacy and OD Education.

In education, the integration and adoption of Open Data for solving real-world problems requires not only defining open data skills but also identifying tools and active learning methodologies [15, 58]. Therefore, future research is needed to gain more detailed knowledge about the values, needs and motivations of students in specific educational contexts, eventually leading to novel educational designs. For example, computer science undergraduate students and elementary school students might have different motivations for using Open Data as an educational resource, resulting in the need for more specific considerations regarding the OD skills and learning approaches.

Acknowledgments. This study is funded by the ODECO Marie Skłodowska-Curie Innovative Training Network (H2020-MSCA-ITN-2020, grant agreement 955569), which aims to address challenges in the creation of user driven, circular, skill-based and inclusive Open Data ecosystems (ODECO – Towards a Sustainable Open Data ECOsystem, 2021).

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Alejandra Celis Vargas: Conceptualisation, Methodology, Investigation, Writing- Original draft. **Rikke Magnussen:** Conceptualisation, Methodology, Writing-Reviewing and Editing. **Ingrid Mulder:** Conceptualisation, Methodology, Writing- Reviewing and Editing. **Birger Larsen:** Writing-Reviewing and Editing.

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