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Effective Data Stewardship in Higher Education: Skills, Competences, and the Emerging Role of Open Data Stewards

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Abstract: The significance of open data in higher education stems from the changing tendencies toward open science, and open research in higher education encourages new ways of making scientific inquiry more transparent, collaborative, and accessible. This study focuses on the critical role of open data stewards in this transition, essential for managing and disseminating research data effectively in universities. Further, it highlights the increasing demand for structured training and professional policies for data stewards in academic settings. Building upon this context, the paper investigates the essential skills and competences required for effective data stewardship in higher education institutions by elaborating on a critical literature review, coupled with practical engagement in open data stewardship at universities, and providing insights into the roles and responsibilities of data stewards. This approach bridges the theoretical and practical aspects of data stewardship, offering a holistic view of the requirements for effective management and dissemination of data. In response to these identified needs, the paper proposes a structured curriculum for data stewardship, a direct response to the gaps identified in the literature, and the practical insights gained from the study. It addresses five competence categories for open data stewards, focusing on five critical streams of knowledge required to build a comprehensive understanding for open data managers. By advocating for a structured approach to data stewardship education, this work sets the foundation for improved data management in universities and serves as a critical step toward professionalizing the role of data stewards in higher education. The emphasis on the role of open data stewards is expected to advance data accessibility and sharing practices, fostering increased transparency, collaboration, and innovation in academic research. This approach contributes to the evolution of universities into open ecosystems, where there is a free flow of data for global education and research advancement.

Keywords: open data, HEIs, open data steward, open data steward occupational profile, open data curriculum

1. Introduction

The rise of open science represents a major shift in how research is conducted and disseminated. Based on the fundamental principles of transparency, collaboration, and accessibility, open science seeks to break down the barriers of traditional research, facilitating the unrestricted dissemination of knowledge within both the scientific community and the general public [1]. Earlier, it was identified that this change is reshaping the landscape of academic research, setting new standards for how scientific inquiry and discoveries are shared [2].

Universities play a key role in open data production, contributing to education, research, and institutional management. Data plays a crucial part in their multifaceted function, including research discoveries, evaluations of quality, specific operational information, learning analytics [3], and open educational resources (OERs). Moreover, universities play a crucial role in the open data ecosystem by serving as centers of knowledge, research, and innovation since they provide valuable contributions to both academic and societal progress [4–6].

The open data produced by universities serves as evidence of their dedication to openness and cooperative advancement. Research data has the potential to result in novel scientific findings [7], while the evaluation of data quality guarantees high educational standards [8]. Operational data, on the other hand, facilitates effective institutional administration, whereas learning data enables personalized educational experiences. In addition, the utilization of OERs promotes equal access to education, as highlighted by Hansen and Reich [9]. The implementation of an open data approach represents the conversion of institutions into open ecosystems, distinguished by the uninhibited exchange of information, hence promoting innovation and societal advancement. Universities are vital in an open ecosystem as they not only provide knowledge but also actively facilitate cooperation and community engagement. This enables them to advance the boundaries of global education and research [10].

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According to Demchenko and Stoy [11], an open data steward operates at the intersection of data governance, legal compliance, and technical data management, helping institutions to implement standardized and interoperable data-sharing policies. Therefore, open data stewards play a crucial role in facilitating the management, archiving, accessibility, quality, integrity, and ethical compliance of data. They serve as intermediaries between those who generate data and those who utilize it, assuming a vital responsibility in the management of open data [12]. Pascu and Burgelman [13] highlight the significance of data stewards in facilitating the shift toward open data. They contend that a significant obstacle to implementing open data is the time needed to acquire the requisite skills and experience. According to the GO FAIR organization, Europe alone needs around 500,000 data stewards, emphasizing the magnitude of the demand [14]. The importance of investing in data stewardship skills to enhance the speed and efficiency of scientific research is emphasized by this assessment, suggesting that dedicating just a small percentage of the funds given to data infrastructures might provide considerable assistance for this essential role in open science [15].

This study aims to investigate the essential skills and competences required by open data stewards in universities and research educational organizations to effectively support the open data aspect of open science. We investigate the essential skills and expertise required for open data stewards to efficiently oversee, curate, and facilitate the utilization of open data in academic and research environments. The study commenced with a narrative literature review, which is well-suited for complex and interdisciplinary domains such as open data stewardship. This approach facilitated a thorough comprehension of the subject matter from various viewpoints. The process progressed by actively participating in open data stewardship at universities, gaining a valuable understanding of the duties and obligations of data stewards, followed by conducting scholarly research on the latest trends in the field. Through careful analysis, five crucial competence categories for open data stewards were identified. These categories were determined based on their relevance to responsibilities, coverage of data management aspects, alignment with current trends, and emphasis on essential skills and knowledge. Finally, the study encompassed the creation of a curriculum for open data stewardship, which emphasized the identification of the intended audience, the establishment of learning goals, and the design of an interactive and captivating learning environment.

This paper aims to fill a notable gap found in the literature: the absence of structured training programs and comprehensive curricula tailored for data stewardship. Although data stewards have been acknowledged as crucial [16, 17], there is a perceptible lack of a clearly defined occupational profile or job description for data stewards in university settings. This paper presents a comprehensive framework for training and developing data stewards in higher education institutions (HEIs). This document highlights the necessary skills and competences required for this role, with a specific emphasis on the dynamic field of open data stewardship.

This work is structured as follows: the introduction, outlining the context and importance of open science and open data; Section 2 is the background, providing a comprehensive overview of open data and its implications in research; Section 3 is the research methodology, detailing the approach and methods used in our analysis; Section 4 is presenting the core competences and skills identified for open data stewards for HEIs; Section 5 presents the overview of a sample curriculum design for open data stewards with respective modules; and Sections 6 presents the conclusions, summarizing the insights gained.

2. Background

As more universities produce diverse sets of data, the role of HEIs in generating wide-ranging sets of information is becoming increasingly central.

The data generated by HEIs possesses a multifaceted and diverse character that extends beyond the traditional confines of academic research outputs. This encompasses a diverse array of data pertaining to educational procedures, research endeavors, and administrative operations. Furthermore, the data from HEIs is not only crucial for making internal academic and operational decisions, but it also has significant importance for external stakeholders such as policymakers, fellow researchers, and the general public. This data enables informed decision-making and contributes to societal progress. Nevertheless, the process of achieving efficient open data generation and utilization in HEIs is a challenging one, with obstacles to overcome such as technical barriers, apprehensions regarding data accuracy and confidentiality, absence of standardized protocols, and a scarcity of adequately skilled personnel to proficiently oversee and curate this data [4, 18].

In essence, HEIs play a crucial role in generating diverse data that contributes to their multifaceted functions in teaching, research, and social progress. The data generated by these institutions can be categorized into four main groups:

1) Open Research Data, which consists of data from scientific studies and research projects. The data encompasses several types, such as experimental, observational, simulation, and derived or compiled data. The availability of research data is crucial for scientific breakthroughs and advancements, and the act of openly sharing this data helps expedite the pace of research [1, 19, 20].

2) Open Educational Data, which includes resources used in teaching and learning; in the extensive ecosystem of HEIs, educational data plays a crucial function, becoming a vital and inseparable component of academic life, fundamental in influencing the overall educational experience. It includes, but is not limited to, detailed records of course offerings, insightful analytics on learning outcomes, and evaluations from academic assessments. Each of these data points has a role in the functioning of educational processes, leading to a comprehensive knowledge of the educational environment. Moreover, the emergence of Massive Open Online Courses (MOOCs), micro-learning, and personalized learning has significantly increased the volume and variety of educational data generated by HEIs. MOOCs, with their global reach, contribute extensive data on diverse learning patterns and preferences [21, 22]. Micro-learning, focusing on concise, targeted content, adds to this dataset with insights into effective content delivery and learner engagement [23]. In addition, the field of educational data is intrinsically linked to the concept of OERs.

3) Open Operational Data, which is related to the administrative and operational aspects of the institutions. The utilization of accessible operational data is crucial in HEIs since it facilitates transparency, improves decision-making, aids research and innovation, encourages civic participation, and stimulates economic growth. Open operational data, encompassing a multitude of operational facets, is indispensable for the efficacious governance and administration of HEIs. Comprising elements such as student records, staff information, financial data, and facilities management records is crucial for guiding HEIs toward operational excellence and institutional efficacy. For example, exploring the domain of student records, one discovers a vast repository of data illuminating student demographics, academic pathways, and engagement patterns.

4) Quality Assurance Data, which pertains to the evaluation and enhancement of institutional practices and standards. Quality-related open data produced in universities represents a critical aspect of the open data landscape within HEIs. This data contains a wide range of information that directly relates to the quality of education, research outcomes, institutional performance, and compliance with accreditation standards.

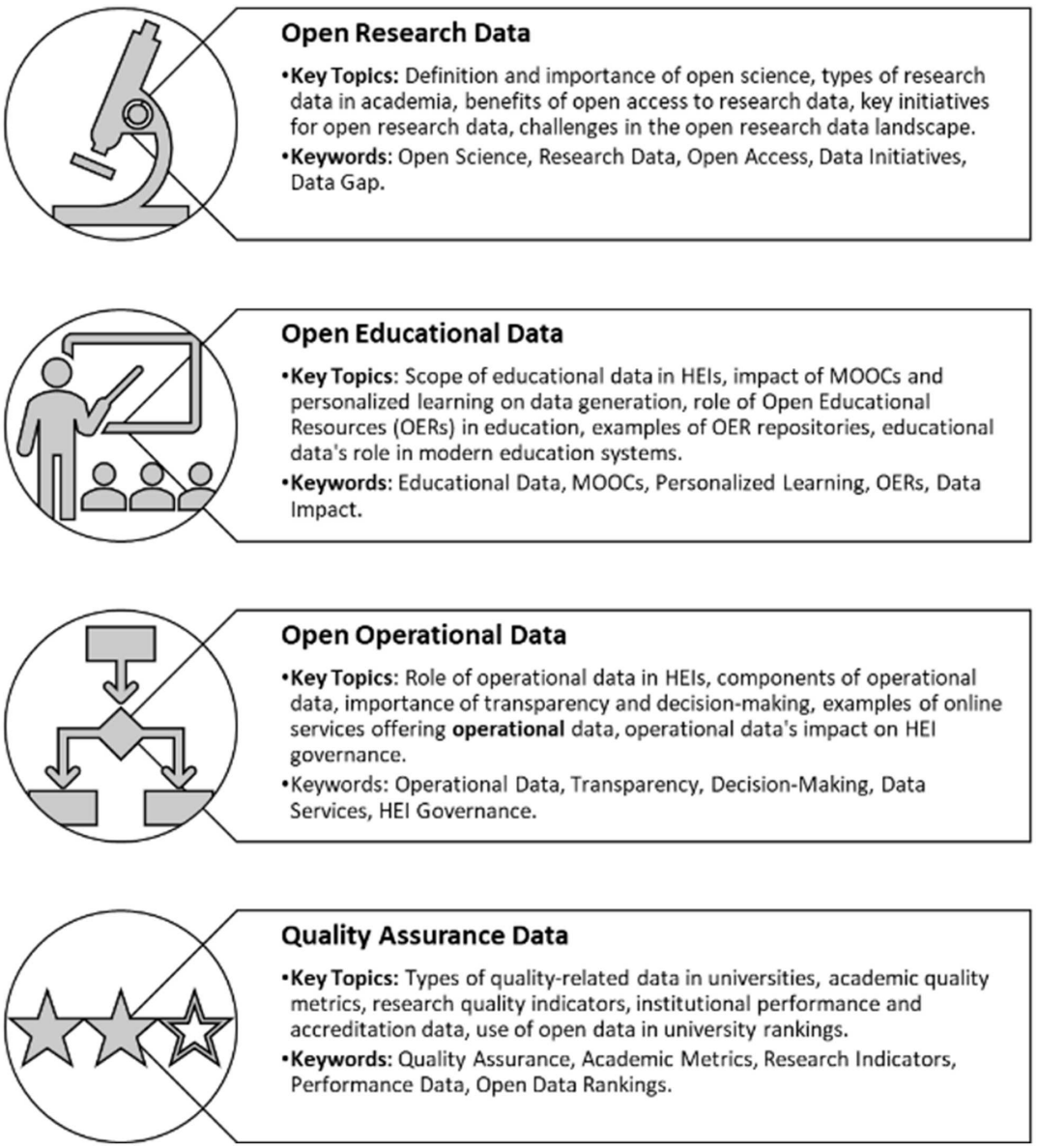
In the systematic review of Stojanov and Daniel, the applications of big data and analytics in higher education over the past decade are presented, focusing on their usage in supporting learning, teaching, and administration [24]. They suggest that big data can be used in a variety of ways and in different applications.

The production and management of these data types present both opportunities and challenges for HEIs. Open data initiatives, such as those adopted by the University of Cambridge and the University of California [5, 6], highlight the growing interest in making HEI-generated data more accessible and usable for a broader audience. However, while open data has the potential to enhance transparency, accountability, and innovation, reaping its full benefits for society and the academic community necessitates a strategic approach to data management, stewardship, and governance.

Among the various challenges faced by open data, the need for data standardization stands out. Data from different HEIs may use varying formats, making meaningful comparisons and benchmarking extremely difficult, if not impossible. Clear policies and procedures are essential to manage data, ensure compliance with regulations, and address issues such as data ownership and usage rights, enabling benchmarking and continuous improvement [25–27].

The role of HEIs in producing and disseminating open data is thus crucial and multifaceted, requiring a strategic approach to overcome existing barriers and fully leverage the potential of open data [28]. Figure 1 highlights the key aspects of HEIs as open data producers.

Figure 1
HEIs as open data producers



Demchenko and Stoy [11] emphasize the growing importance of integrating the above knowledge areas into university curricula, proposing a Data Stewardship Professional Competence Framework that aligns competences with the FAIR data principles and organizational needs [15]. The FAIR data principles are a set of guiding principles designed to improve the findability, accessibility, interoperability, and reusability of data. FAIR principles ensure that data is well-managed and can be effectively used, shared, and cited across different research domains. This framework underscores the need for tailored educational approaches to equip data stewards with skills in metadata management, data governance, and cross-disciplinary collaboration, fostering a culture of effective and ethical data stewardship.

3. Research Methodology

This study adopts a constructivist approach, emphasizing the co-construction of knowledge through engagement with open data stewardship practices in higher education [29]. The research is grounded in an iterative process, incorporating insights from practical experience alongside a review of existing literature. The absence of predefined hypotheses aligns with the principles of Grounded Theory, allowing competencies and skill requirements for data stewards to emerge organically from the data.

Our initial step was to conduct a narrative literature review [30]. This type of review, unlike systematic reviews, does not start with a predetermined research question or a specified search strategy but rather with a general topic of interest. Such reviews are particularly suited to complex and interdisciplinary fields like open data stewardship, allowing for a comprehensive understanding of the topic from multiple perspectives.

In this context, we reviewed a wide range of sources, including peer-reviewed articles, conference proceedings, and institutional reports, all of which provided insights into open data stewardship, data governance in HEIs, and competency frameworks. Our search process relied on major academic databases such as Google Scholar, Scopus, and Web of Science, using key terms like "open data steward" and "FAIR data management." As we explored the literature, we also applied a snowballing technique, where we traced citations from key studies to uncover additional relevant sources, ensuring a comprehensive view of the topic.

To keep the review relevant, we focused on studies published within the last ten years, particularly those discussing competency and skills development for data stewards. However, we deliberately excluded studies that focused solely on technical data science or corporate data stewardship, as they did not align with the context of HEIs.

In our investigation, we cohered to the principles of Grounded Theory, allowing themes to emerge naturally from literature. This approach aligns with the constructivist perspective, as it allows for the content and structure of the inquiry to be emergent, based on the data [31]. We did not set specific hypotheses before conducting the literature review. Instead, we collected and analyzed data simultaneously, looking for themes and patterns that emerged organically. Furthermore, our research process unfolded iteratively across the stages, reflecting the evolving nature of the field of open data stewardship. As new technologies, policies, and challenges continuously reshape this domain, it becomes imperative to adapt and evolve the research focus to stay relevant. According to Charmaz [31], the inductive and iterative process of Grounded Theory analysis keeps the research focused and incisive, allowing for a higher level of abstraction and theoretical exploration.

3.1. Stage 1: practical engagement in open data stewardship at universities

To concretely begin our research, we drew on our direct involvement in various projects and initiatives related to open data stewardship at universities. These engagements provided practical insights into the roles and responsibilities of open data stewards, shaping our initial understanding and guiding our focus on this emerging professional profile. This practical foundation, enriched by our hands-on experience, offered a unique lens through which to view and understand the intricacies of data stewardship in academic settings.

3.2. Stage 2: scholarly inquiry for exploring current trends in open data stewardship

Building upon this practical foundation, the study broadened its scope to include current trends and advancements in open data stewardship, thus enriching the initial understanding with a forward-looking perspective. This phase marked the transition from practical engagement to structured academic exploration, integrating experiential knowledge with scholarly research.

The literature review was conducted through a narrative approach, examining each aspect of open data stewardship through existing academic literature, case studies, and relevant institutional documents. This methodology provided a rich, data-sharing view, connecting theoretical frameworks with practical implementations in the university context.

This review resulted in five categories of competences for open data stewards, presented in the following section. The key criteria for selecting these categories were:

1) Relevance to the core responsibilities of open data stewards: The competences should directly address the essential tasks and challenges faced by open data stewards in managing and promoting open data within universities.
2) Coverage of the multifaceted nature of open data management: The categories should encompass the various aspects of open data governance, including technical, legal, domain-specific, analytical, communication, and project management aspects.
3) Alignment with current trends and best practices: The competences should reflect the latest developments in open data practices and reflect the best practices adopted by leading institutions.
4) Emphasis on skills and knowledge required for effective open data stewardship: The competences should focus on the skills and knowledge that are essential for open data stewards to make informed decisions, collaborate effectively, and contribute to the successful implementation of open data initiatives within universities.

By considering these criteria, five categories of competences for open data stewards were identified as the most comprehensive and relevant framework for developing and equipping individuals with the necessary skills and knowledge to effectively manage and promote open data within universities.

3.3. Stage 3: developing a curriculum to support open data stewardship

Curriculum development is a multidimensional effort, comprising a sequence of interconnected steps, each contributing to the creation of an effective and engaging learning experience. This process is characterized by an iterative nature, requiring continuous

refinement and adaptation to ensure alignment with the evolving needs of the target audience and the ever-changing landscape of open data stewardship.

The first critical step in this process lies in meticulously defining the target audience. In our specific context, the intended participants encompass a diverse range of individuals and institutions, including the HEIs workforce, educational organizations, and entities primarily dedicated to fostering open science principles. Understanding the specific knowledge, skills, and experiences of this audience is crucial to tailor the curriculum's content and delivery effectively.

Once the target audience had been identified, the next step was to articulate clear and measurable learning objectives. These objectives serve as the guiding framework for the curriculum's development, ensuring that it is focused on equipping participants with the competences essential for effective open data stewardship.

The curriculum should be a flexible and captivating collection of learning activities, integrating various teaching methods to accommodate different learning styles and preferences. Lectures, workshops, case studies, and hands-on exercises should interweave seamlessly, fostering active participation, critical thinking, and practical application of knowledge.

While this study primarily focuses on capturing the required knowledge and defining the learning objectives for the development of the curriculum, it is essential to acknowledge the iterative nature of the process. Regular review and piloting of the curriculum are paramount to ensure its effectiveness and relevance in the ever-evolving landscape of open data stewardship.

4. Discussion on the Findings

Open data stewards are critical in managing and promoting the responsible use of open data within universities. They need to possess a comprehensive set of skills and knowledge to effectively handle the complexities of open data governance, dissemination, and utilization. The five categories of competences that emerged represent the crucial areas where open data stewards should direct their expertise as follows:

1) Data technical competences: Open data stewards must have a solid understanding of data management and storage principles, data cleansing and preprocessing techniques, programming skills for data analysis and mining, and the ability to integrate heterogeneous repositories and utilize linked data standards. These technical skills are essential for ensuring the quality, accessibility, and interoperability of open data assets [32].
2) Legal and ethical competences: Open data stewards must be well-versed in data protection and privacy laws, intellectual property regulations, and ethical considerations related to the responsible use of open data. They need to understand the legal and ethical implications of sharing data [20] with the public and ensuring that data privacy is protected while maximizing the benefits of open data. The integration of ethical competences in data stewardship aligns closely with the principles of Fairness, Accountability, Transparency, and Ethics (FATE), as highlighted by Memarian and Doleck [33], where they emphasize the critical need for ethical frameworks in higher education, particularly in the application of Artificial Intelligence (AI) for decision-making and data governance.
3) University domain-specific competences: Open data stewards should have a deep understanding of the specific needs and requirements of the research domains or fields of study within the university. This includes knowing how to manage research data, supporting educational development, structuring learning management systems (LMS), and adhering to the principles of open science.
4) Data analysis and interpretation competences: Open data stewards should be proficient in data analysis techniques, data visualization methods, and data interpretation skills. They

Table 1
Data technical competences

A. Data technical competences: The ability to collect, process, and publish data requires technical skills, such as proficiency in data management and storage, data cleaning and preprocessing, and data security.

Competence	Characteristics	References
Data management processes	The collection and management of the organization's data, in this context, also encompass concerns regarding data governance and release processes.	[4, 10, 32, 34–42]
Data storage	It concerns matters of data storage but also the identification and management of the appropriate infrastructure that will be made available to the organization for long-term storage.	[4, 10, 34, 39, 41]
Data cleansing and preprocessing	Using clean data is an important part of drawing the right conclusions. Errors often could be the result of human mistakes in data entry, such as mistyping or incorrect abbreviations.	[42–45]
Programming	Open data development and data mining include programming skills and knowledge of programming techniques.	[37, 39, 43]
Enriching data	One dataset is rarely enough to gain insight. By combining multiple datasets, it is possible to obtain a more detailed picture.	[41, 42]
Integration of heterogeneous repositories	Integrating heterogeneous repositories and publishing their metadata as linked data.	[4, 37, 41, 43, 46]
Data security	Protecting data from internal or external corruption and illegal access protects a university from financial loss, stakeholders' trust degradation, university reputational erosion, etc.	[10, 34, 35, 38, 40, 41, 43]

should be able to extract meaningful insights from open data and communicate these findings effectively to various stakeholders.

5) Communication, collaboration, and project management competences: Open data stewards need strong communication, collaboration, and project management skills to effectively disseminate and promote open data. They should be able to work with researchers, stakeholders, and communities to share data, knowledge, and insights. Additionally, they should have the ability to lead data initiatives and manage projects from conception to implementation, including budgeting, timeline management, and stakeholder engagement.

In summary, the five categories of competences for open data stewards provide a comprehensive framework for developing the skills and knowledge necessary to effectively manage and promote the responsible use of open data within universities. These competences address the technical (Table 1), legal (Table 2), domain-specific (Table 3), analytical (Table 4), communication, and project management (Table 5) aspects of open data governance. By acquiring and applying these competences, open data stewards can make significant contributions to the advancement of open science and the creation of a more transparent and knowledge-driven university environment.

5. Sample Curriculum for Open Data Stewards

In this section, we introduce a sample curriculum for open data stewards, emphasizing that this is just one of many potential variations. Depending on the audience type, knowledge level, and specific needs, tailored iterations of this curriculum can be developed, ensuring that each version is optimally designed to cater to the unique educational requirements and learning styles of different groups.

The curriculum has been developed as a result of the research methodology and thorough analysis detailed in the previous sections. It reflects the synthesis of relevant works, tailored to meet the diverse needs and knowledge levels of different audiences. This example encompasses five key subsections: Introductory Modules, Data Management and Exploitation, Management Modules, Legal Issues and Ethics, and Higher Education Data Challenges and Case Studies. Each subsection is carefully designed to address specific aspects of open data stewardship, providing a comprehensive educational framework for individuals keen on excelling in the dynamic and critical field of open data.

Figure 2 presents an overview of the sample curriculum presented in the following subsections.

Table 2
Legal and ethical competences

B. Legal and ethical competences: Ensuring that data is open while also protecting privacy, intellectual property, and other legal rights requires knowledge of data protection and privacy laws as well as ethical considerations related to the responsible use of data.

Competence	Characteristics	References
Knowledge of data protection laws	Covers the rights, licenses, and data protection regarding what people can do with the data.	[10, 35, 38–43]
Knowledge of data privacy laws	Open data may leak valuable information to third parties, for example, competitors. In this sense, knowledge of intellectual property law in science projects with companies and with other research organizations is necessary.	[4, 33–35, 38–40, 42, 43, 47, 48]
Ethical skills	Ethical and commercial interests can affect whether the data can be made open access.	[33–35, 40, 49, 50]

Table 3
HEI-specific competences

C. HEI-specific competences: Understanding the specific needs and requirements of the research domain or field of study is important for developing relevant data and ensuring that it is of high quality.

Competence	Characteristics	References
Managing research data	Transparency and accessibility to science outputs as well as authorization and participation in research.	[4, 10, 34, 35, 41–43, 48, 49]
Educational development	Monitoring the educational processes within an HEI.	[4, 10, 35, 50, 51]
Structuring learning management systems	A learning management system is designed to make things easier for all stakeholders by using it to plan, deliver, and evaluate a learning process. However, it needs appropriate people to structure and manage it so that it functions properly.	[10, 34, 35, 37, 51]
Understanding open science principles	Concerning key principles of open science that direct the work of research teams at universities, such as transparency, accessibility to science outputs, authorization, and participation in science outputs.	[4, 10, 41, 43, 48, 51–53]

Table 4
Data analysis and interpretation competences

D. Data analysis and interpretation competences: The ability to analyze and interpret data, identify trends and patterns, and draw meaningful conclusions is critical for making effective use of open data.		
Competence	Characteristics	References
Data analysis	Concerns the provision of statistics through analyzing raw data to discover trends and metrics, make predictions, and eventually draw conclusions about the hidden information included in useful datasets regarding students, research, finances, etc.	[10, 24, 34, 39, 41, 54, 55]
Visualizing data	Visualizations are a useful way of interpreting data, and they help us to unlock insight.	[24, 39, 41–43]
Interpreting data	This is an important feature as it allows users to understand and interpret data through previews and visualizations.	[24, 42, 43, 54, 55]

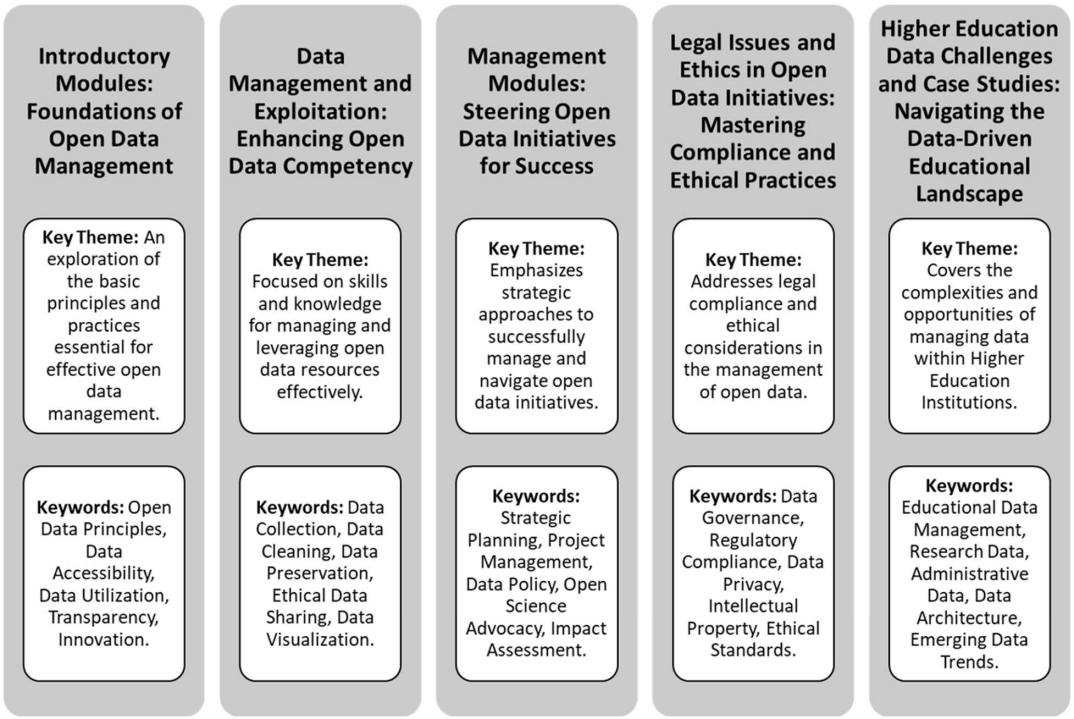
Table 5
Communication, collaboration, and project management competences

E. Communication, collaboration, and project management competences: Effective collaboration with researchers, stakeholders, and communities is essential for developing and maintaining open data initiatives. This involves coordinating interdisciplinary efforts, engaging with institutional partners, and working collectively to establish multifaceted frameworks and governance policies. In contrast, communication and dissemination focus on sharing research outputs, making data accessible, and engaging broader audiences. This includes presenting findings, publishing datasets, writing reports, and conducting training sessions to promote open data literacy. Standardization in this context refers to both technical standards and general management protocols. On the technical side, it involves adhering to FAIR data principles, metadata standards, interoperability frameworks, etc. Additionally, this competence category, among others, includes project management skills, which involve leading data initiatives, managing budgets, coordinating timelines, and overseeing long-term strategic planning to ensure the successful implementation of open data practices.		
Competence	Characteristics	References
Dissemination and communication	An important action within the process of opening data is its dissemination and communication, which will give greater visibility and obtain feedback useful in improving services.	[10, 39, 47, 50]
Publication of open data	Concerns about tools used in the context of data publishing, linking, promotion, etc.	[4, 10, 39, 43, 47]
Collaboration	Collaboration is necessitated by the use of open data, as it not only enhances an organization's transparency through the potential for data reuse in the future but also fosters a collaborative environment that accelerates innovation.	[4, 10, 20, 39, 43, 48, 50]
Standardization	Concerns about defining and understanding standards that are technical documents designed to be used as a rule, guideline, specification, definition, and publishing protocols. They are agreed upon by consensus and can be used consistently to ensure that products, processes, and services are fit for their purpose.	[4, 10, 43]
Leadership and project management	The ability to lead data initiatives and manage projects from conception to implementation. This includes the ability to develop and manage budgets and timelines and to work with different stakeholders.	[10, 39, 48]
Strategic thinking	The ability to think strategically and develop long-term plans for data management and use.	[10, 43, 48]

5.1. Introductory modules: foundations of open data management

In the context of data accessibility and utilization, open data is recognized for its role in promoting transparency, empowerment, and innovation [56]. It enables individuals to make informed decisions, encourages collaboration among diverse communities, and drives research and innovation across various disciplines. To fully realize the transformative potential of open data, we need to engage in a comprehensive exploration of the principles, policies, and practices essential for its effective management. The learning objectives of this knowledge stream are focused on providing learners with a strong foundation in open data management principles, equipping them with data science and programming skills, and introducing

Figure 2
Overview of sample curriculum for open data stewards



them to the fundamental aspects of efficient data management. On the completion of these modules, participants will have the ability to:

1) Understand the core principles and policies that guide open data management, ensuring that our actions align with the values of openness, accessibility, and reusability.
2) Master the fundamental concepts and techniques of data science and analytics, equipping one to transform raw data into actionable insights.
3) Develop proficiency in programming languages relevant to open data analysis, enabling us to automate tasks and streamline workflows.

5.2. Data management and exploitation: enhancing open data competency

The knowledge stream on "Data Management and Exploitation" aims to equip learners with the skills and knowledge needed to effectively manage and leverage open data resources. This category comprises four essential modules, each designed to provide learners with a deep understanding of data collection and cleaning, data storage and preservation, data sharing, and collaboration, as well as data analysis and visualization. Additionally, they will learn about data quality assessment and management, a critical aspect of open data projects.

The learning objectives of this knowledge stream are:

1) Identify suitable data collection methods for specific research inquiries.
2) Assess data quality to ensure its dependability and precision.
3) Implement effective techniques for data cleaning and preprocessing.
4) Gain insights into the ethical and legal aspects associated with data sharing.
5) Choose appropriate data analysis methods based on data type and research objectives.
6) Develop proficiency in data profiling, cleansing, and transformation to enhance data quality.
7) Create compelling data visualizations to effectively communicate findings and insights to stakeholders.

5.3. Management modules: steering open data initiatives for success

The need for effective administration of open data initiatives arises from the rapid proliferation of data sources, diverse stakeholder interests, and evolving regulatory landscapes, demanding a strategic approach to ensure the success of these initiatives. The challenges surrounding data collection, quality assurance, storage, sharing, and analysis demand careful consideration and proactive management. Strategic management of data issues is crucial in this context, since it involves developing and implementing effective strategies that not only tackle current data concerns but also correspond with wider corporate objectives and social expectations. By recognizing the significance of steering open data initiatives through strategic management, organizations can unlock the full potential of their data resources, fostering transparency, innovation, and informed decision-making.

The learning objectives of this knowledge stream are:

1) Develop a strategic mindset to identify, prioritize, and leverage open data opportunities aligned with organizational goals and objectives.
2) Apply effective project management principles and practices to plan, execute, and monitor open data initiatives, ensuring operational excellence and impact.
3) Understand and practice ethical data citation and attribution, recognizing the importance of proper credit and recognition in open data projects.

4) Promote open science principles and advocate for data policies that uphold ethical and equitable open data practices.
5) Master techniques for disseminating open data to diverse audiences, emphasizing data literacy and user engagement for wider reach.
6) Measure the impact of open data initiatives and assess their success in achieving intended outcomes, fostering accountability and improvement.

5.4. Legal issues and ethics in open data initiatives: mastering compliance and ethical practices

Understanding the legal and ethical implications of open data projects is extremely important for their appropriate utilization. This section explores the complex interplay between compliance with the law, ethical obligations, and effective handling of open data, highlighting the necessity of integrating open data strategies with both legal standards and ethical considerations, thereby ensuring judicious data management and building trust among diverse stakeholders. Given the variations in open data regulations in various countries, this part of the curriculum should take into consideration international standards, such as the General Data Protection Regulation (GDPR), the Freedom of Information Act in the United States, and other open science recommendations.

The modules in this part aim to provide learners with the essential knowledge and competences needed to proficiently navigate these intricate domains and develop compliance in diverse institutional and geographic contexts. Upon completing this knowledge stream, learners will be able to:

1) Develop a comprehensive understanding of data governance, focusing on its legal and ethical dimensions in open data management, while considering international regulatory frameworks.
2) Identify and effectively mitigate potential risks associated with the management of open data, ensuring responsible handling.
3) Apply ethical principles in practical data management scenarios, demonstrating a commitment to ethical standards in open data initiatives.
4) Navigate the legal and regulatory landscape pertaining to open data, understanding its implications and ensuring compliance in a global context.
5) Understand the critical role of open data standards and interoperability in promoting effective data sharing and usage across platforms and organizations.
6) Foster a culture of transparency, accountability, and ethical conduct in the management and dissemination of open data.

5.5. Higher education data challenges and case studies: navigating the data-driven educational landscape

This section focuses on the diverse challenges and opportunities in managing data within HEIs, encompassing educational processes, research, administrative procedures, and the integration of emerging trends in open data management. The modules outlined below provide comprehensive insights into various aspects of data management in HEIs, equipping learners with the skills and knowledge to leverage data for strategic decision-making, compliance, and innovation in educational settings.

Upon completing this knowledge stream, learners will:

1) Understand the complexities of managing educational data within HEIs, including data generated by LMS and other educational platforms.
2) Gain insights into best practices for research data management (RDM) across the research lifecycle, focusing on ethical, legal, and open science principles.
3) Acquire knowledge of managing administrative data in HEIs, understanding its significance, and ensuring compliance with data governance standards.
4) Explore the modern data infrastructure and architecture within HEIs, emphasizing open data principles and practices.
5) Be aware of emerging trends in open data management, understanding their implications for HEIs and the broader educational sector.

5.6. Applications for open data stewardship curriculum

As presented above, the Open Data Steward Curriculum could be applied in various institutional contexts where structured data stewardship is essential for data governance, compliance, and research efficiency. Many universities, especially those that are research oriented, have implemented similar initiatives, demonstrating the need for competency-based training in this field.

At TU Delft in the Netherlands, a faculty-specific data stewardship program integrates training on FAIR principles, metadata standards, and legal compliance, ensuring that data is effectively managed across disciplines[1]. Similarly, the University of California [5] developed a system-wide open data policy supported by training on data ethics, reproducibility, and governance, helping researchers align with the guidelines of the funding programs.

At the University of Cambridge (UK) [6], an RDM training program provides workshops on data citation, repository management, and intellectual property rights, fostering a strong open science culture. For example, the "Managing Your Research Data" training program is offered to all PhD students and postdoctoral researchers, providing guidance on data management practices. Meanwhile, Nordic universities, such as the University of Helsinki and Stockholm University[2], have pioneered cross-border open data collaborations, emphasizing interoperability, GDPR compliance, and sustainability-focused data use.

The curriculum could be particularly useful in cases where HEIs, research centers, and governmental agencies aim to establish data stewardship roles, implement open data policies, or develop interdisciplinary data-sharing initiatives. These examples highlight how structured training programs can support institutions in advancing data management practices, fostering collaboration, and ensuring long-term accessibility and ethical use of open data.

HEIs have successfully implemented data stewardship training by adopting available best practices. TU Delft's tailored training program addresses discipline-specific data needs, ensuring effective data management. The University of California embedded stewardship training into governance structures, while the University of Cambridge provided hands-on workshops and real-world case studies. Nordic universities fostered cross-institutional collaboration, enhancing interoperability and open data sharing. The proposed

[1] TU Deft, https://www.tudelft.nl/en/library/research-data-management/r/support/data-stewardship

[2] FAIR Nordic EPOS Data Hub, https://www.helsinki.fi/en/infrastructures/nordic-epos/fair-nordic-epos-data-hub

Open Data Steward Curriculum offers a systematic approach, and we claim that it could be tailored to address these needs, offering a flexible framework adaptable to diverse HEI contexts.

6. Conclusions

Data plays a fundamental role in the paradigm of open science, while open data acts as the cornerstone for scientific inquiry, innovation, and knowledge dissemination. By processing student records and academic transcripts, or their research data and administrative procedures, vast amounts of possible innovations, decision-making processes, and transparency can be initiated. Therefore, in order to fully utilize this vast potential, it is necessary to have a dedicated team of open data stewards that have expertise in principles, techniques, and practices related to open data management.

Open data stewards serve as the guardians of HEIs' data assets, ensuring that they are collected, managed, and shared responsibly. They are the catalysts of transformation, leveraging data to improve student outcomes, enhancing faculty productivity, advocating for openness, and optimizing institutional efficiency.

This article aimed to explore and define the crucial skills and competences necessary for effective data stewardship in higher education, particularly focusing on the emerging role of open data stewards. The research was driven by the need to understand the evolving demands of open data and the implications for data management in academic settings.

Our research identified five key competence categories for open data stewards: Introductory Modules, Data Management, Strategic Management Modules, Legal Issues and Ethics, and Higher Education Data Challenges and Case Studies. These categories encompass a comprehensive framework addressing both theoretical knowledge and practical skills necessary for managing and promoting open data in universities.

This study contributes to academic literature by providing a detailed framework for the training and development of data stewards in higher education. It emphasizes the importance of equipping these professionals with a broad range of competencies, aligning with the latest trends in open data practices and the evolving landscape of higher education.

The findings of this paper have significant implications for HEIs. By understanding the need and by adopting the proposed curriculum framework, universities can enhance the skills of their data stewards, ensuring they are well-prepared to manage the growing complexity and volume of data in academic institutions. This advancement will facilitate improved data management practices, leading to increased transparency, collaboration, and innovation in research.

6.1. Limitations and future work

The limitations of this work are primarily twofold. First, the findings and recommendations are grounded in a literature review, which, while comprehensive, may not capture the full scope of practical experiences and current practices in data stewardship within HEIs. Literature reviews synthesize existing information, but they can be limited by the data available in published works, which may not reflect the most recent developments or undocumented industry practices.

Second, the proposed curriculum and the role of open data stewards, as outlined in this paper, have not been empirically tested through a pilot study. Without validation from actual implementation, there remains uncertainty regarding the curriculum's effectiveness in real-world settings.

The future work for this project will concentrate on empirically validating the proposed curriculum for open data stewards through pilot studies in various HEIs. These pilot implementations would assess the effectiveness, adaptability, and practical impact of the curriculum in real-world settings. Key performance indicators, such as participant skill acquisition, institutional adoption, and feedback from open data stewards, could be used to refine the framework.

Additionally, to enrich the theoretical foundation laid out by the literature review, future work should also focus on gathering and analyzing practical insights from current open data stewards, data managers, and academic professionals. Including detailed case studies and interviews would provide a more comprehensive understanding of the practical aspects of data stewardship in HEIs and add valuable real-world perspectives to the research.

Moreover, with the rise of AI, the curriculum could incorporate training on AI-driven data curation, machine learning applications for metadata management, and blockchain for data integrity [57]. Furthermore, the shift toward citizen science and participatory data governance calls for new competencies in data ethics, community engagement, and responsible AI. This implies that the importance of open data and open science is growing, and therefore, we need to continuously update the proposed curriculum contents and offer customized learning pathways.

Finally, engaging in collaborations with industry practitioners and academic experts in the field of open data and data management would provide an opportunity to validate and enrich the curriculum. These collaborations can help in aligning the curriculum with industry standards and expectations, as well as in identifying potential areas of improvement [58].

By focusing on these areas, future work can significantly enhance the quality and applicability of the research, ensuring that the curriculum for open data stewards is both robust and relevant to the evolving needs of HEIs.

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Conflicts of Interest

The authors declare that they have no conflicts of interest to this work.

Data Availability Statement

Data are available from the corresponding author upon reasonable request.

Author Contribution Statement

Panos Fitsilis: Conceptualization, Writing – original draft, Writing – review & editing, Supervision. **Vyron Damasiotis:** Methodology, Data curation, Writing – original draft, Writing – review & editing. **Charalampos Dervenis:** Methodology, Data curation, Writing – review & editing. **Vasileios Kyriatzis:** Methodology, Data curation, Writing – review & editing. **Paraskevi Tsoutsa:** Methodology, Data curation, Writing – review & editing, Visualization.

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