Interweaving academic insights: advancing university knowledge management through a strategic data fabric framework

Lan Nguyen Thi Kim
Faculty of Library and Information Science, VNU University of Social Sciences and Humanities, Hanoi, Vietnam

Son Nguyen Hoang
VNU Library and Digital Knowledge Center, Hanoi, Vietnam, and

Hoa N. Nguyen
Department of Information Systems, VNU University of Engineering and Technology, Hanoi, Vietnam

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Abstract

Purpose – Effective knowledge management in large academic institutions is crucial for fostering innovation and improving educational practices. However, these institutions often face challenges, such as data fragmentation, siloed information systems and the complexity of integrating different data sources from various departments with complex hierarchical structures. To address these problems, the authors proposed a data fabric strategic framework that improves and enhances knowledge management by leveraging ontologies and knowledge graphs. This study aims to investigate the potential of knowledge graphs, ontological knowledge modelling and knowledge representation to improve knowledge management in large academic institutions. It also describes how technology can enhance knowledge accessibility and exchanges and improve decision-making processes based on insights from complex educational systems.

Design/methodology/approach – This study uses coordination theory as a foundational framework to analyse intricate data systems in preparation for constructing, the Wizard of Oz method to facilitate the systematic organisation and management of information and the execution of an ontology-based data fabric framework and knowledge graphs. The authors propose a data fabric strategic framework aimed at improving knowledge management by leveraging ontologies and knowledge graphs.

Findings – The final evaluation demonstrates that this approach effectively breaks down data silos, promotes research collaboration and improves decision-making processes in large academic settings, offering solution-oriented data fabric technologies applicable to universities and university federations globally.

Practical implications – The proposed system provides a more efficient way of managing and connecting fragmented academic resources, improving accessibility for both learners and educators. By interconnecting and streaming knowledge management process, the system can reduce not only operational costs but also expenses on doing scientific research.

Originality/value – Academic institutions prioritise time efficiency when acquiring vital data for improved scientific results. This emphasis extends beyond data governance to focus on how collective intelligence might improve organisational performance. The academic community has enhanced data utilisation through the implementation of data fabric technologies to improve data accessibility and data line tracking.

Keywords Data fabric, University federations, Knowledge management, Knowledge integration, Knowledge graph, Active metadata, Ontologies

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1. Introduction

Data and information management are undergoing a rapid transformation as a result of advanced technologies. Srivastava (2023) highlighted the shift from big data to generative artificial intelligence (AI), emphasising that digital transformation involves 80% people and 20% technology. Institutions are leveraging new technologies and human expertise to extract insights from diverse data sources, revealing their technical infrastructure and business ecosystems. Klaus Schwab's, (2017) "Fourth Industrial Revolution" describes the convergence of virtual and physical domains; this has fostered collective intelligence and transformed knowledge management (KM) in academia. Strategic data management and data fabric concepts are essential for harnessing this growing trend, driving breakthroughs in educational practices and paradigms. Many large academic institutions that encompass various universities, research institutes and departments operating under a single structure face unique challenges in KM. Vietnam National University at Hanoi (VNU), one such institution, is therefore considered a federation of universities. Consequently, each member university/institute formally operates with single and sometimes isolated autonomy, resulting in disparate information systems and siloed data management repositories across the VNU. This data fragmentation hinders efficient information and knowledge exchanges as well as collaboration opportunities, hampering the federation's ability to support research capabilities, foster innovation and enhance overall academic performance.

Ontologies provide a framework to identify and display concepts, entities, nodes and interactions within knowledge domains (Luo, 2023; Rakhra *et al.*, 2022). Knowledge graphs (KGs) have the potential to transform KM in academic institutions by enabling the capture, understanding, inter-relationship, categorisation, utilisation and stratification of massive amounts of data. They facilitate the integration of semi-structured and unstructured data across hierarchical structures, making the disseminated knowledge within large businesses more accessible and searchable.

Characterised as the "new oil" in the World Economic Forum study and accompanying the AI leadership report, data calls for actionable and insightful information (Forum, 2022, 2019). In the context of managing knowledge in complex academic settings, ontology is a key tool for encoding descriptions of semantic relationships between entities and nodes (DeBellis and Dutta, 2022; Lokala *et al.*, 2022; Malik *et al.*, 2021). By leveraging ontologies and KGs, together with a data strategic framework, university federations can overcome the challenges posed by autonomous operations and siloed systems, thereby enhancing knowledge sharing, collaborations and decision-making processes across the federation.

Research challenges: The integration of such structures into higher institutions presents several challenges:

- Modelling knowledge from member units' unprocessed information systems is not consistent. Different systems exhibit contextual operational knowledge. Research modelling differs from university knowledge modelling. First, huge enterprises/state-owned entities must address KM research.
- Data exchange is cumbersome and unneeded because university federation members control business data domestically. For instance, training management systems require learner tuition expenditures, not financial data. Business system data must be aggregated and provided proactively.
- Knowledge exploitation and sharing culture require both technical solutions and organisational tactics to stimulate not only big organisations but also university federations.

Contribution highlights: In response to the challenges, this study aims to enhance KM by taking a structured data architecture approach and modelling knowledge using ontologies and KGs. The comprehensive discussion on the strategic data framework VNU data fabric-based knowledge management platform (vDFKM), which we proposed in our preliminary work and presented at the International Conference on Computational Collective Intelligence conference (Lan and Nguyen, 2023), is a crucial contribution. In this study, we propose an in-depth extension to include not only technological solutions but also organisational strategies to overcome knowledge exchange barriers, emphasising human elements, technological procedures and the maximisation of academic knowledge applications. Our key contributions are summarised below.

- Proposing a method of modelling knowledge using KG-powered active metadata combined with ontologies methodologies. Addressing the issue of knowledge diversity in representing and modelling is crucial to develop a unified knowledge ontology that serves as a prevalent language across different departments, schools and disciplines. To put it another way, this ontological structure should be flexible enough to accommodate the majors and specificities of diverse domains while maintaining interoperability and coherence in modelling knowledge.
- Proposing an advanced data sharing and synthesis approach: Sharing data within organisations is always challenging and requires an intelligent data governance framework that not only regulates access but also supports smart synthesis of relevant data for information end users and related stakeholders. This process involves, firstly, the development of a smart data filter and synthesis algorithm to decisively determine the relativity and necessity of a data sharing scheme within a given school's system. To be more specific, this process leverages machine learning to train and learn from past data sharing processes and establish a new synthesis pattern, enhancing the decision-making process regarding what data needs to be shared in which format, particularly in relation to data privacy and ethical considerations.
- Promoting knowledge sharing culture: Enhancing the extent to which knowledge is used and shared among various units within a university federation is possible through the promotion of a collaborative culture and the application of technological advancements that enable seamless knowledge transfer. In addition to technological solutions, this calls for adopting organisational tactics that promote information sharing and implementing a centralised knowledge hub that facilitates the accessibility of knowledge objects from all units through aggregation, categorisation and indexing. Furthermore, incorporating incentive mechanisms to promote active participation and effective utilisation of the information hub is time- and resource-intensive.
- Using a Strategic Data Fabric Framework, specifically vDFKM, for management purposes: In addition to addressing the technological facets of data fusion and KM, the strategic data fabric framework should also include the organisational obstacles that impede the efficient exchange of knowledge regarding technological, procedural and human elements.

The remainder of this paper is organised as follows. Section 2 introduces some fundamental theory and related works in knowledge integration and management. Section 3 covers the methodology and research design. Section 4 presents our proposed method. Section 5 discusses and evaluates our proposed work. Finally, Section 6 summarises our contributions and outlines potential future endeavours.

2. Background and related works

The optimal realisation of the vision and mission objectives relies on the implementation of a strategic plan that successfully manages and leverages the huge information resources of the business and knowledge management system (KMS), given its unique set of features (Murali and Anouncia, 2022; Osman *et al.*, 2022; Sohrabi *et al.*, 2019; Tudorache, 2020; Wang *et al.*, 2023).

The construction of ontological structures represents a pivotal element in managing the deluge of information prevalent in modern educational settings (Mora *et al.*, 2022; Rezaei *et al.*, 2021). Ontologies serve as semantic networks, providing structured and orientated graphs that represent classes, concepts and the relationships between them. This structure becomes crucial in an environment characterised by information overload and the disconnection of vast, varied data (Zhu *et al.*, 2018). Gruber's definition of ontology as "an explicit specification of a conceptualization" (Gruber, 1993) underscores ontology's role in forming, connecting and formalising knowledge across various disciplines (Ferilli *et al.*, 2022; Lou *et al.*, 2020).

Data fabric, together with ontologies, offers a unified data management environment that enables real-time, secure access to data from multiple sources (IBM, 2023a). Gartner, a leading research and advisory company, emphasises the importance of enriching the data fabric with administrative and management data, transforming it into a comprehensive KM tool (Mark and Ehtisham, 2020). The integration of data fabric with ontological structures and KGs effectively captures and organises knowledge, simplifying stakeholder accessibility and utilisation (Chen *et al.*, 2018a; Jawad *et al.*, 2023).

Our prior work has explored the conceptual model of university KM via a data fabric approach, highlighting its efficacy in information creation and presentation (Lan and Nguyen, 2023). This model addresses the fragmented nature of data in large educational institutions, offering a pathway to cohesive and interconnected KM.

KGs, as introduced by Google in 2012, further enhance this landscape (Dai *et al.*, 2022; Li *et al.*, 2021). KGs structure data into entities and relationships, creating networks that render knowledge accessible and comprehensible to both humans and machines. The utility of KGs extends to diverse applications, including knowledge retrieval, question-answering and content recommendation (Ji *et al.*, 2022; Peng *et al.*, 2023; Pietrasik and Reformat, 2023). Numerous academic disciplines have extensively investigated and implemented KGs, significantly enhancing KM, data integration and educational environments. In the context of educational data management, Chen created KnowEdu, an automated system for creating educational KGs (Chen *et al.*, 2018b). This system enhanced the precision and efficacy of educational content delivery and personalised learning experiences by using data from pedagogical and educational assessments. Wang *et al.* (2023) proposed a framework for the application of knowledge mapping and data visualisation techniques to genealogical data. The framework uses KGs to organise and illustrate complex information. Chughtai *et al.* (2020) introduced an ontology-based article recommendation model that significantly enhances the process of identifying suitable reviewers for academic papers, with an emphasis on enhancing academic research through KGs. This model applies KGs to improve academic workflows by matching articles with reviewers and by using latent semantic analysis and entropy measures. The quality and predictive capabilities of data-driven models in research are enhanced using KGs to forecast absent uncertainties in experimental data in other instances. In addition, KGs are used to facilitate institutional KM and interdisciplinary studies. The integration of KGs into a variety of sources was emphasised by Zeng *et al.* (2023) and Senthil Kumaran and Latha (2023) to enhance the safety and improve their accuracy and efficiency.

In various industries, the ontological approach has been instrumental. Amazon Neptune's support for Resource Description Framework (RDF) exemplifies this utility in managing ontological data (Amazon, 2023). Thomson Reuters' Open Calais initiative, which leverages natural language processing and machine learning, uses ontologies for organising semantic metadata (Reuter, 2007). These applications highlight the versatility of ontologies in organising, analysing and retrieving domain-specific information.

Despite these advancements, KM in higher education and its scientific application continue to face challenges, particularly in the management of data silos. Effective KM systems require a unified structure where data fabric and other applications bolster data strategies and dissemination (Dawande *et al.*, 2023). This approach has demonstrated potential in various sectors, from software testing in the military (Gao *et al.*, 2022) to ontology-based frameworks in agriculture (Murali and Anouncia, 2022). The Industry 4.0 revolution further emphasises the need for data-driven, interoperable solutions, as seen in initiatives like InPro (Yang *et al.*, 2023) and Web Ontology Language (OWL)-based ontologies in the aerospace sector (Dai *et al.*, 2022).

Ontology has been extensively explored across many disciplines and interdisciplines, as seen in Table 1 and Figure 1. This strategy has helped develop data distillation, linkage and structure, enhanced geographic information systems and health-care decision-making and advanced political science. The merging of natural language processing and large language models has strengthened this method. Ontological frameworks render implicit knowledge machine-readable, improving data processing efficiency. Data discovery is better understood and contextualised when metadata is supplemented and integrated with ontologies, entities and nodes.

In conclusion, the integration of data fabrics, ontologies and KGs can improve academic data management and presentation, aiding decision-making and KM system optimisation. The proliferation of ontology-based frameworks across several areas signifies progress towards more sophisticated, context-sensitive systems. Such systems help organise and distribute specialised knowledge and inspire innovative decision support and predictive analytics methods.

3. Methodology and research design

3.1 Methodology

The research uses ontological structures, coordination theory (Crowston, 1997) and the Wizard of Oz (WOZ) to facilitate the systematic organisation and management of information within the University of Social Sciences and Humanities, VNU, Hanoi. Coordination theory helps figure out who is responsible for what in data management (Ding *et al.*, 2023; Kazantsev *et al.*, 2023) and how they depend on each other. Ontological structures add a semantic layer to how data are shown.

- Coordination theory application: This theory guides the organisation of communication channels and workflows within the university, ensuring efficient task management and information sharing.
- Ontological structure: This defines key academic concepts and relationships, enhancing understanding and functionality of the overall university's information systems. This structure enhances data integration and accessibility across various schools and departments, supporting better KM and decision-making.
- WOZ is used to simulate the functionality and interactions of the proposed ontological structure and for testing and refining how data are managed and accessed within the tested system (Schlögl *et al.*, 2015).

Table 1. Summary of literature reviews

Author	Focus area	Key findings	Relevance to research
(Yao *et al.*, 2019)	Educational data management	Jointly considers structural and literal information for embeddings	Improves data representation in educational KGs
(Chen *et al.*, 2018a)	Educational KGs	Automated system for constructing educational KGs	Automates KG construction for digital libraries
(Senthil Kumaran and Latha, 2023)	Digital libraries	Ontology-supported CF recommendation system	Enhances personalised learning resource recommendations
(Chughtai *et al.*, 2020)	Academic research	Ontology-based article recommendation model	Enhances academic workflows and peer review
(Wang *et al.*, 2023)	Genealogical data	Framework for knowledge mapping in genealogy	Applies knowledge mapping and visualisation in academics
(Ramalli and Pernici, 2023)	Experimental data management	KG embeddings to forecast missing uncertainties	Ensures data quality in experimental research
(Malczewski and Jelokhani-Niaraki, 2012)	Addressing the challenges in multicriteria spatial decision support systems	Ontology-based MC-SDSS using OWL	Integrates ontology and GIS in decision-making
(Lambrix, 2023)	Ontology engineering	Focuses on ontology repairing using abductive reasoning	Develops and maintains high-quality ontologies
(Antonini *et al.*, 2023)	Cultural heritage	Ontology design pattern for modelling experiences	Manages cultural heritage knowledge
(Roldán-Molina *et al.*, 2022)	Ontology improvement	Ontology-matching process using OntologyFixer	Improves automatically generated ontologies
(Zheng *et al.*, 2021)	Hazardous chemicals management	KG for managing hazardous chemicals with BERT-CRF model	Integrates KM in institutional settings
(Cui *et al.*, 2023)	Recipe ontologies and KGs	General recipe ontology model and KG for edible flowers	Develops versatile and user-focused KGs
(Zhang *et al.*, 2019)	Dangerous goods KM	KG for MDG to simplify retrieval and promote intelligent transportation	Manages complex, domain-specific knowledge
(Lee *et al.*, 2021)	Large KGs	Decomposing large ontology graphs for rating predictions	Improves efficiency and accuracy of large-scale KGs
(Kurbatova and Swiers, 2021)	Biomedical data integration	KG using cross-references between disease ontologies	Integrates and manages complex biomedical data

(*continued*)

Table 1. Continued

Author	Focus area	Key findings	Relevance to research
(Aryani *et al.*, 2020)	Open science graphs (OSGs)	Enhances FAIR principles by proving access to metadata, proposed interoperability framework with APIs	Support data exchange, academic data management
(Rahdari *et al.*, 2020)	Personalising information exploration	An information system with an open and controllable user model	The importance of user modelling for personalised information retrieval
(Gardasevic and Gazan, 2023)	KG for interdisciplinary PhD students	Developed a community-grounded, extensible KGs to capture and visualise relationships between people and information resources	The use of KGs to support information discovery and decision making
(Salatino *et al.*, 2021)	Research topic detection and prediction using scientific graphs	Developed a framework for detecting, analysing and forecasting research topics using a large-scale KG based on computer science ontology	Applications of KGs for research trend analysis and prediction

Source: Authors' own work

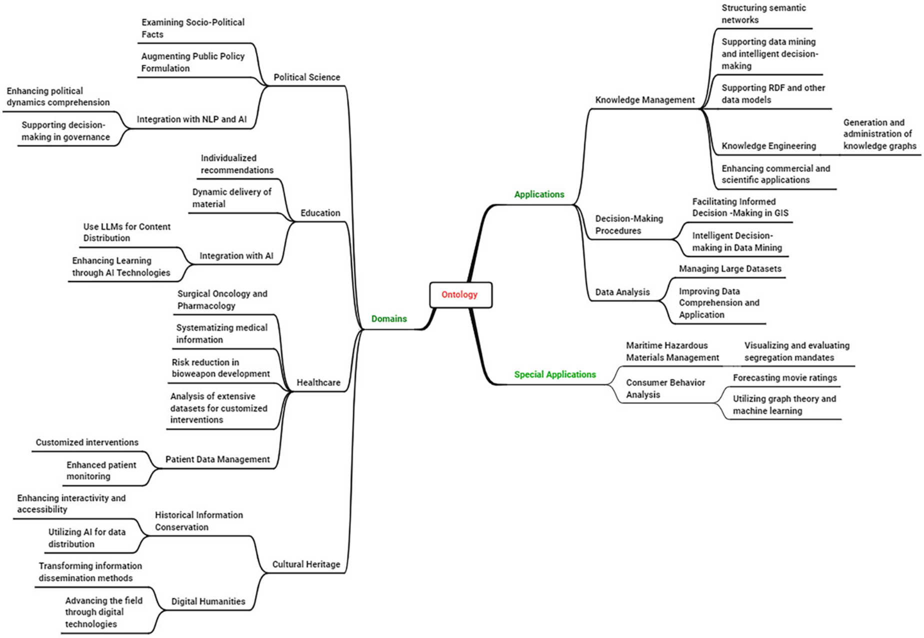

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Figure 1. Taxonomy of ontologies

3.2 Research design

This study proposes a general methodology that integrates a strategic data fabric KM approach with existing digital repository systems to address the challenges of knowledge modelling, fragmentation and user accessibility within large academic institutions and university federations. The approach includes aligning the ontologies of the data fabric framework with the current data formats of the systems, such as DSpace, to ensure comprehensive knowledge representation and data integration. The development and testing phrases include mapping and aligning the ontological structures with the metadata schemes of digital repositories, followed by pilot testing to assess the effectiveness and efficiency of the integration.

To validate the proposed method, a case study is chosen by applying this approach to the academic and scientific data of a university federation. We chose the University of Social Sciences and Humanities, a division of VNU, for this case study to pinpoint the challenges and advantages associated with the integration of the new system, while also providing contextual and semantic suggestions for alternative knowledge management systems. The insights gained from this proposed framework and its validation will help in refining the methodology and demonstrating its practical applicability to other institutions seeking to enhance their KM practices.

The practical implementation steps are the following:

- Task identification and division: Identifying key tasks and dividing them among involved stakeholders.

- Ontology development: Creating ontologies and integrating them into Neo4j, which defines academic concepts and relationships.
- Workflow design: Designing workflows to optimise data management processes.
- Pilot implementation: Testing the integrated system.
- Monitoring and feedback.
- Systematic refinement based on feedback and performance metrics.

4. Knowledge management approaches and proposed method

4.1 Ontological reasoning in data fabric and knowledge graph-enhanced knowledge management architecture

To effectively implement the ontological reasoning in the Data Fabric and KG-Enhanced KM architecture described in this section, it is essential to engage all stakeholders, including lecturers, students and administrators within our institution. By aligning with specific informational demands and institutional needs, stakeholders ensure that ontological knowledge models are comprehensive and applicable. Therefore, our ontology includes both academic and administrative domain knowledge. This architecture not only addresses institutional knowledge needs but also bolsters stakeholder engagement in KM.

Adopting common ontology standards: Ontology, in this context, is more than a methodology, it is a transformative tool for interpreting and representing data in a machine-readable format. Within academic settings, such as VNU for instance, ontologies are constructed by defining terms and concepts and enriching them semantically. This ontology could encompass core entities and enhance nodes and edge development in academic settings, such as courses, research projects, publications, faculty, students and administrative processes, each with defined properties and relationships. The integration of business semantics using ontology escalates to standardise descriptions across data architecture components. For example, subject-predicate-object format are used to describe relationships in its academic and administrative data, enhancing consistency in data presentation and improves interoperability among different departments.

This enrichment adds depth and contextual precision: Understanding research impact, citation networks, student performance trends or course relevancy across different programs; defining entities, properties and relationships; and enabling the extraction of meaningful conclusions from explicit data within the Data Fabric framework and KG structures. This context awareness building can assist in strategic decision-making in areas such as curriculum development, research collaboration or even research funding allocation. As illustrated in Figure 2, the integration of ontology and KG representations allows for the emergence of new academic insights and the discovery of implicit knowledge. The ontology currently in use incorporates a shared vocabulary and a set of governing rules. In this context, ontologies help ensure data quality by making implicit knowledge explicit. An academic institution can use ontologies to establish relationships and constraints that ensure high quality in not only student records but also research outputs and administrative databases; this approach facilitates the standardisation of data input formats and minimises the occurrence of errors.

Typically, we specify these rules using RDF Schema and OWL. This study integrates Neo4j into the vDFKM framework. While this technology does not explicitly support certain logical rules layers such as Semantic Web Rule Language, Rule Interchange Format and SPARQL Protocol and RDF Query Language Inferencing Notation and even though it does provide some interference capabilities, its interference capabilities are implemented through

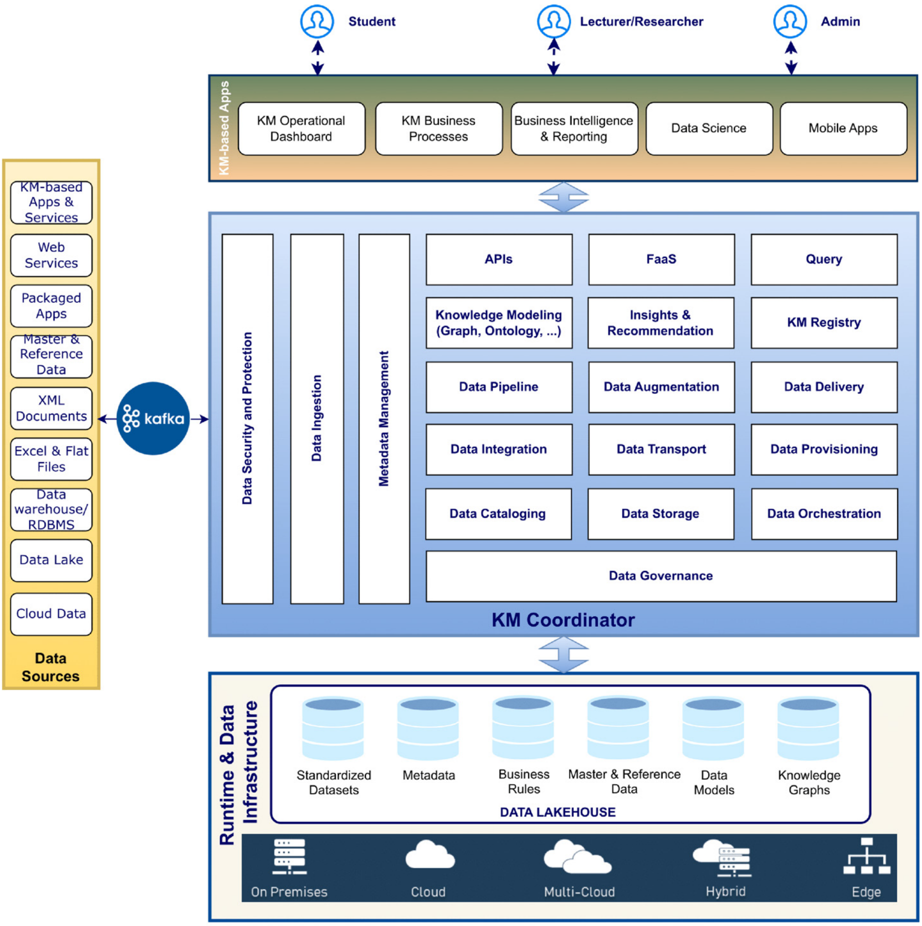

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Figure 2. General architecture of vDFKM – data fabric-based knowledge management platform

custom Cypher queries and Awesome Procedures on Cypher procedures, deriving meaningful relationships and insights from data. We selected Neo4j as the underlying technology for our KG implementation in this study for four key reasons, each offering several practical advantages, as outlined below:

(1) The nature of academic settings and databases comes from diverse sources across several departments, disciplines and majors. Unlike traditional relational databases, Neo4j can manage, query about and represent complex relationships within data. It allows for more direct querying and visualisation regarding complex data structures, resulting in more efficient relationship management.

(2) Performance and scalability: Neo4j efficiently manages large-scale graph data, delivering high performance in read and extraction operations. This makes Neo4j

particularly suitable for applications that require real or near-real time data access and updates, which are essential for managing the growing academic databases at the institution.

(3) Contextual richness: Neo4j can bring out and connect the data set's rich context and relationships. This makes it relatively good at finding and managing connections between different academic resources, improving the KG's overall understanding, usefulness and accessibility.

(4) Extensibility and flexibility: Neo4j's schema-free nature allows for flexible and dynamic data/knowledge modelling, crucial for integrating diverse data sources without necessitating significant restructuring. In subsection 4.3, we will delve deeper into this concept by presenting a case study that uses metadata from the university's digital library databases to represent a KG, illustrated in Figure 3 as a sample.

Academic institutions can create a structured knowledge base using ontologies to not only capture academic knowledge but also to help the institution in retaining it. This ability to reason and draw conclusions makes KGs more useful by making them better at giving contextually relevant suggestions and performing complicated data analyses where understanding the context and semantic relationships is important.

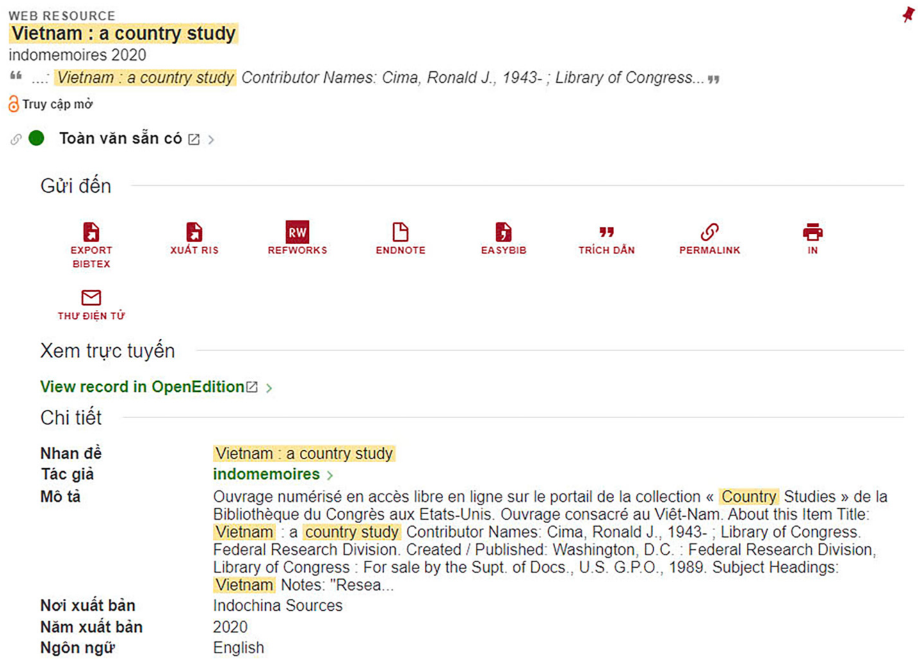

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Figure 3. A sample of metadata description

4.2 Why knowledge graphs? Tracking data lineage at academic institution

IBM (2023b) defined data lineage as “the methodology that elucidates the journey of data through its lifecycle, illuminating its origins, modifications and ultimate disposition within a data pipeline”. This concept is particularly pertinent within the realms of academia, where data proliferation (Sikos and Philp, 2020; Soedarmadji *et al.*, 2019) is common due to the multitudes of originating sources. A complex academic institution, such as VNU, which consists of 9 schools, more than 35 departments and many connected organisations, contributes to a rich tapestry of data through various transformations and channels. Understanding VNU’s complicated data linkages helps with data management and lineage. From collection and analysis to integration, the university’s hierarchy complicates data mosaic management. This complexity necessitates the updating and contextualisation of data to maintain relevance. This strategy increases data lineage modelling and understanding while maintaining semantic integrity.

Gartner (2023) highlighted the advancement of KGs, particularly their capacity to elucidate knowledge in synergy with generative AI, machine learning and large language models. Within this framework, KGs serve as a sophisticated mechanism to organise, interlink and exhibit knowledge in a structured format, comprising nodes and relational edges. This graphical representation not only makes it easier to understand complex and unstructured data but also makes it much easier to see how data came to be, thus aiding in the complicated process of data interpretation and analysis.

Figure 4 displays a screenshot of a current metadata record from our university library, specifically describing the materials titled “Vietnam: A Country Study”. This record serves as an example of how we plan to deconstruct and extract key information, such as the author, title, publication data and subject headings. We will then use this extracted metadata to construct a Knowledge Group (KG) within Neo4J, thereby demonstrating the transformation of traditional metadata into a more dynamic and interconnected data structure.

Deconstructing metadata: This process involves identifying key entities such as author, title, year of publication and other related content descriptions, including LCCN, online formats and subject headings.

- Creating nodes and relationships: Although the current metadata is based on library standards such as Dublin Core, it remains static and lacks interconnectedness. In Neo4j, we elevate this metadata by representing each entity as a node and establishing relationships between them, such as linking the titles, authors and publishers. This transforms the metadata from isolated entries into a dynamic, interconnected network, providing richer context and uncovering hidden relationships. This enhancement significantly improves the user’s ability to explore and interpret the material within a broader, interconnected information framework. For example, the “book” node is linked to the “author” node with an “Author_by” relationship and to the “publisher” node with a “published_by” relationship.
- Using Cypher queries in Neo4j.
- Enhancing visualisation: Figure 4 involves adding more nodes and relationships to present other relevant described elements as well as documents and their connections. We could illustrate this by transforming the static image into a dynamic graph that displays the correlations.
- Visualising the KG: As an example, the result in Figure 4 shows the structure of relationships between various entities.

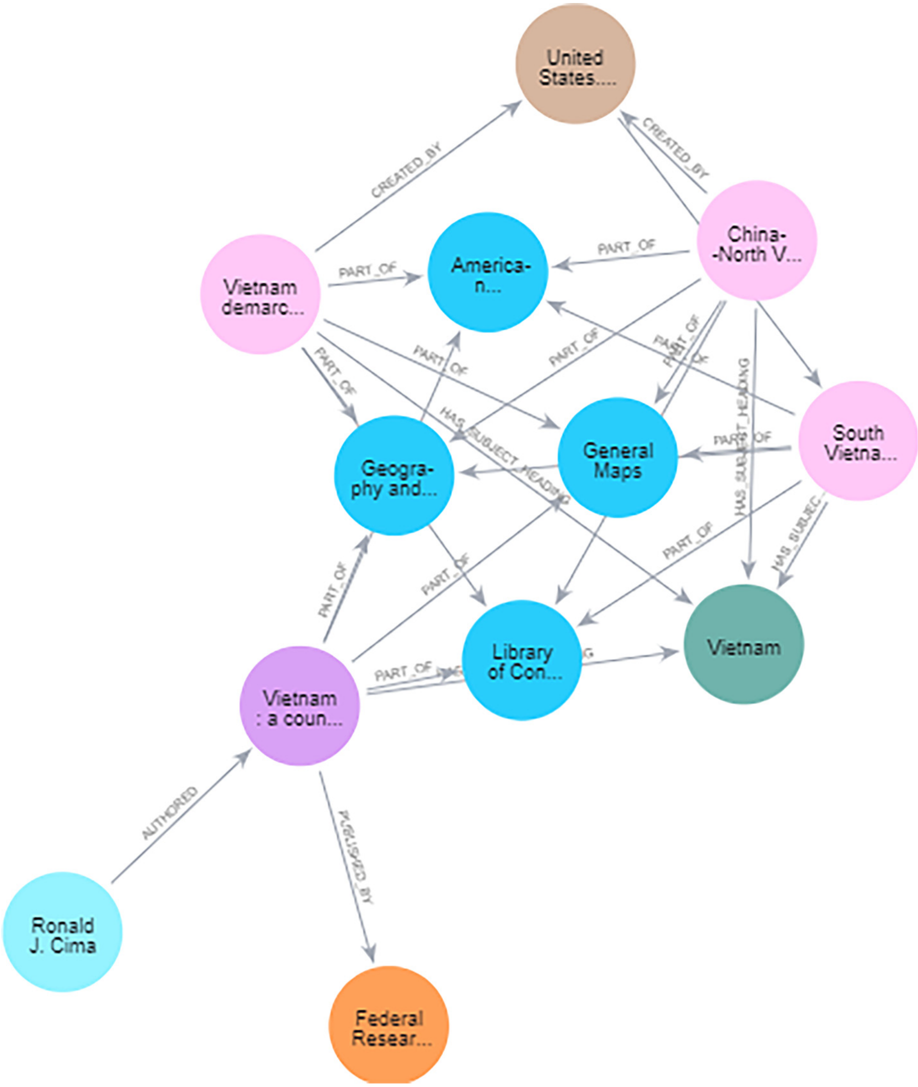

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Figure 4. Vietnam war: a context-driven knowledge graph

At some point, the complexity of a graph can indeed become overwhelming as the number of nodes increases. For example, a graph with 12 nodes (Figure 5) and the specifications initially presented in Figure 5 offers a clear and manageable visual that allows for a detailed exploration of relationships and connections. However, as the graph expands to 39 nodes or more, the visualisation gets increasingly complex and challenging to interpret. To mitigate this, we can implement strategies such as filtering redundant nodes, aggregating similar

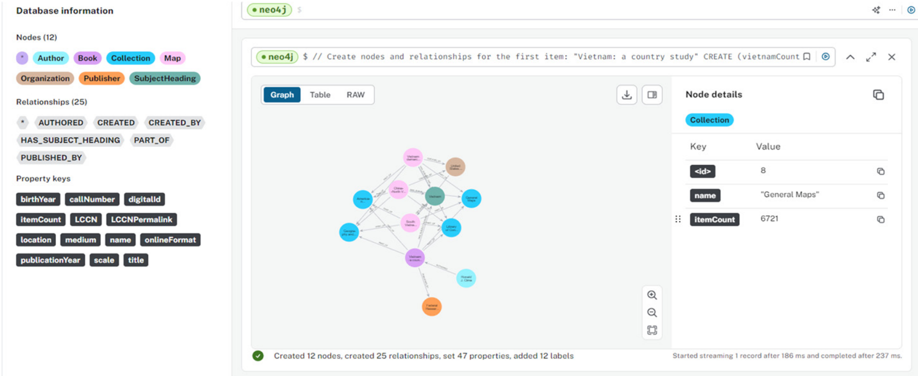

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Figure 5. Detailed cyphers and graph in the context of Vietnam as a country

nodes and relationships and using metadata to reduce visual clusters while preserving essential contextual information. This approach ensures that, even as the data set grows, the KGs continue to serve as valuable tools for understanding the complexity of data structures. Moreover, the VNU Library and Digital Knowledge Centre is now using Dublin Core–based metadata to describe our materials and transferring from Dublin Core to a KG format significantly enhances our ability to explore context-specific data. Unlike the static nature of Dublin Core, KGs provide a dynamic, frequently updated and interconnected representation of data, allowing for the discovery of hidden relationships and deeper contextual insights. This transition is crucial for organising, managing and understanding the rich, multifaceted data within academic environments such as VNU.

Breaking data silos with this KG lets organisations share information more effectively. Context creates knowledge, according to Lin *et al.* (2023); Peng *et al.* (2023); Wu *et al.* (2023); and Zhong *et al.* (2023). This dynamic visualisation offers a wide variety of perspectives to satisfy users' goals and job-specific information demands. The KG is vital for preserving the Vietnam War's legacy and understanding its repercussions on society and beyond.

4.3 Trustworthy with data strategic framework

The creation and deployment of ontologies are key to our data management strategy (illustrated in Figure 6), facilitating the effective organisation of academic library data for stakeholders. This approach enhances the library data lake, streaming of data collection and user engagement at VNU. We prioritise relevant, well-organised metadata to capture semantic richness. Figure 6 illustrates the data journey and simplifies metadata maintenance. In this case, KGs aid in data pattern recognition and lineage analysis. The system integrates structured and unstructured data, offering machine- and human-friendly formats.

The proposed vDFKM framework consists of eight key components, each playing a crucial role in managing and enriching academic data, as detailed below:

- *Data acquisition*: Capturing physical or digital materials and extracting essential metadata, including titles, authors and publication information.

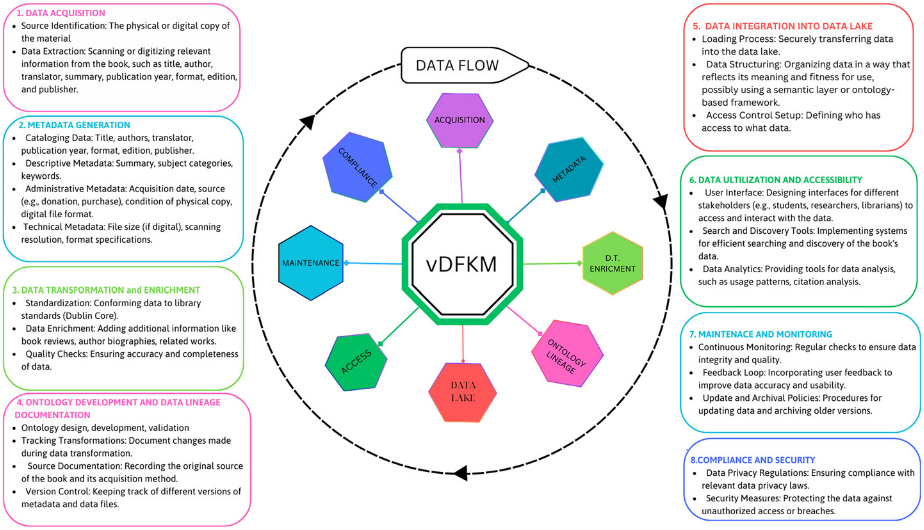

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Figure 6. Data strategic framework

- *Metadata generation*: Producing descriptive, administrative and technical metadata, ensuring comprehensive cataloguing and standardisation.
- *Data transformation and enrichment*: Enhancing and standardising data to conform to library standards (in this case, Dublin Core) while adding value through additional contextual information.
- *Ontology development and data lineage documentation*: Ensuring ontology-based data structuring, tracking transformations and implementing version control to maintain data accuracy and historical integrity.
- *Data integration into data lake*: Organising and structuring data in a centralised repository for efficient access and governance, harnessing a semantic or ontology-based layer.
- *Data utilisation and accessibility*: Facilitating access to the integrated data through user-friendly interfaces and search tools, providing analytics and discovery functions.
- *Maintenance and monitoring*: Continuously monitoring data quality, incorporating feedback loops to improve accuracy and updating archival policies.
- *Compliance and security*: Ensuring data privacy, security and compliance with legal standards, protecting data from unauthorised access.

These components are interlinked within the vDFKM framework, supporting data integrity and enrichment, thus ensuring that the entire data flow from acquisition to utilisation is not only efficient but also secure and accurate.

5. Experiments and evaluation

To validate the effectiveness and capability of our proposed method, the project is now deployed currently at our VNU Library and Digital Knowledge Centre (VNU-LDKC) to address the following research questions:

RQ1. How does the ontological structure accommodate and represent the diversity of knowledge domains across various academic disciplines/inter-disciplines at a complex academic institution such as VNU?

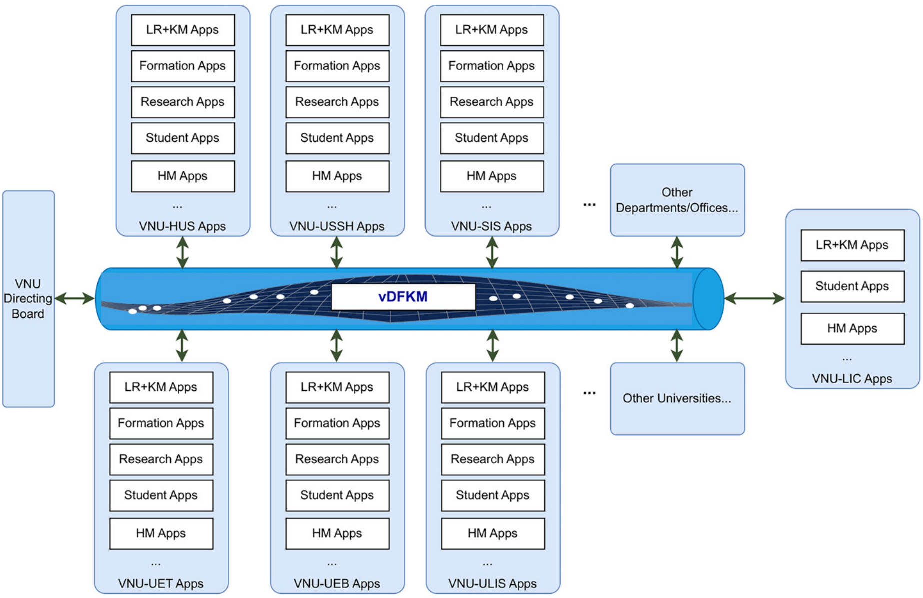
RQ2. Is the KG-based method of modelling data from the business systems of member units adequate and effective for enhancing the performance of knowledge modelling in large-scale organisations?

RQ3. How does the vDFKM platform, with its data fabric design, enhance the efficacy of knowledge aggregation, sharing and mining operations based on active metadata from business systems in various organisational units?

RQ4. What ethical and legal factors must an academic institution consider when using data fabric for data and KM and how can these be addressed?

5.1 Deployment model of vDFKM

To answer *RQ3*, a prototype of the vDFKM platform was implemented at VNU. With the KM requirements described in Section 4, vDFKM was piloted with VNU-LDKC as the management focal point. Figure 7 depicts the vDFKM deployment architecture at VNU. Based on the vDFKM



Source: Authors' own work

Figure 7. vDFKM-based knowledge management for VNU

platform, operational systems at each member university can integrate and share data and knowledge. In the data lakehouse of vDFKM, all aggregated data from business systems of VNU member units will be centrally handled. The vDFKM platform handles data gathering, integration, knowledge modelling, sharing, coordination and administration for all active metadata.

For deployment of vDFKM, we experimentally installed this open-source platform; specifically, the complete Runtime and Data Infrastructure component is deployed via Kubernetes (runtime - https://kubernetes.io/) and Delta Lakehouse (https://delta.io). The coordination of KM operations is based on the expansion of functions from the open-source framework Kamu-Data (https://github.com/kamu-data).

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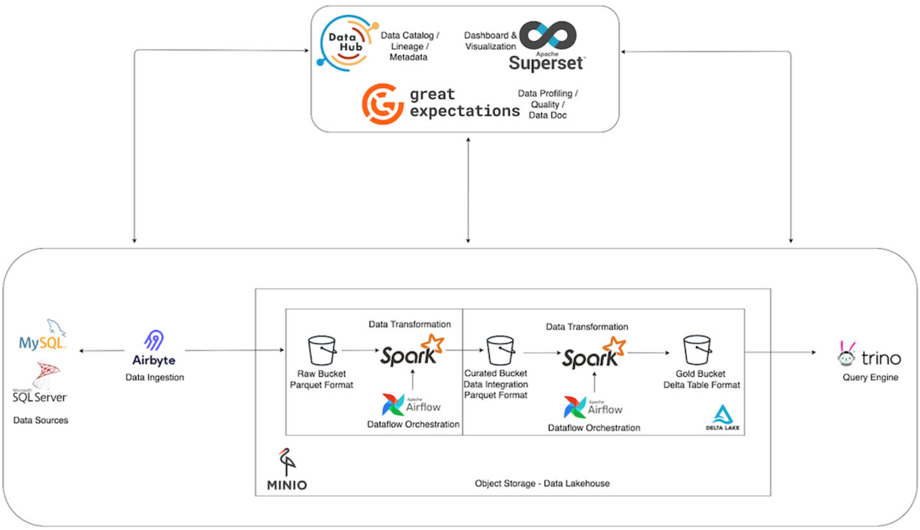
All vDFKM functions are delivered as microservices through Rest APIs. Moreover, we offer these functions as a FaaS (Function as a Service) service via the open-source platform Serverless (https://github.com/serverless/serverless). Primary tools of vDFKM are illustrated in Figure 8.

5.2 DSpace integration with data fabric framework

Figure 9 depicts the two stages of data integration into a KG. The following is a list of some of the frequent events and scenarios that foster interdisciplinary research and knowledge transfer between departments and schools:

- Teachers and students can collaborate on projects and share annotated resource lists via this pipeline at VNU. Teachers and students can also incorporate email and social media for updates and recommendations. Students researched the vDFKM platform and used Neo4J KGs in DSpace for intuitive learning maps (Figure 4).



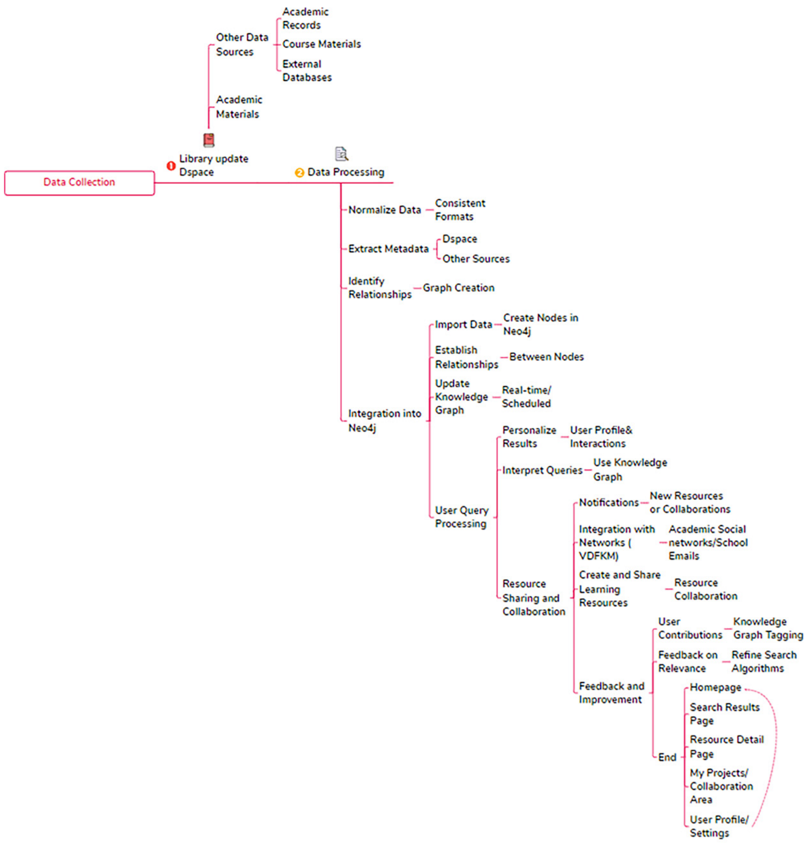
Source: Authors' own work

Figure 8. Open-source tools used in vDFKM platform

- Doing a literature review or systematic literature review: Finding updated resources for highly cited papers relevant to one's research conserves time for postgraduates and improves their scientific work by suggesting direct matches and connecting ontological structures, subjects and writers.
- Interdisciplinary research and lifelong learning: Subscribers receive alerts on resources and advancements related to their interests and keywords, facilitated by data fabric technologies that connect decentralised systems such as user profiles and homepages.

5.3 Evaluation and discussion

VNU's system can customise ontological data fabric frameworks to accommodate the requirements of lecturers, students and administrators. This approach leverages data fabric technologies (KGs for real-time insights), overcoming traditional database limitations, thus



Source: Authors' own work

Figure 9. Data flow: from fragmented data to connected knowledge graph

answering *RQ1*. Tracking data generation and use ensures data integrity. The semantic layer helps stakeholders navigate and understand diverse data sets, optimising KM across the institution (Figure 8). VNU uses a strategic data framework to analyse and integrate library items, research data and curriculum, thereby bridging information gaps in higher education. This framework maximises data value, emphasises user trust, uses agile processes and ensures careful data management for effective data tracking. However, we have well acknowledged that the current implementation has primarily been tested on bibliographic metadata, which is a specific subset of the university's overall data landscape. The research's initial initiative focus has allowed the team to develop and validate the foundational elements of KG and data fabric technologies. As the study progresses, we recognise the importance of extending this system to encompass a wider range of data sets (all belonging to schools and departments), including administrative, curricular and research data, to address the broader needs of all stakeholders at VNU. Future work will involve integrating additional ontological frameworks and enhancing the system's semantic capabilities to fully capture and realise its potential in addressing the complex and diverse requirements of the university environment. In addition, the development of upgraded features, including the integration of local Vietnamese academic databases and the use of Linked Data technologies, will be thoroughly explored to further enhance the system's functionality and interoperability.

The VNU-LDKC is just starting to implement and share expertise at universities. This shows that the current mechanism for sharing knowledge among colleges is continually evolving. The fact that it is still in its early stages indicates that work needs to be done to improve and expand the system. Thus, academic exchange of information, ideas and research discoveries remains nascent and may not be optimal. The communication and application of information at the collegiate level can be further improved.

Regarding *RQ2* and *RQ3*, leveraging KGs to represent and model knowledge could be promising for large, hierarchical organisations such as VNU, and the ability to capture complex relationships using nodes and relationships has improved research collaboration, facilitated data-driven insights and fostered in-depth discussions to overcome the older system's limitations. Implementing vDFKM is a novel technique to update the KMS. It reveals operational efficiencies acquired through time-consuming research and helps the VNU make actionable decisions.

Ethical and legal considerations (*RQ4*) are important in KMS implementation. Barriers to data privacy, AI algorithmic bias and intellectual property infringement are the major concerns. The frameworks cover data strategies, lineage and monitoring, but VNU uses data fabric technologies to comply with local and international data protection laws. Throughout the deployment, the ethical and legal perspectives of students, faculty and administrators were carefully considered.

6. Conclusions

The findings of this research have laid a strong foundation for KM not only in university federations, where embracing and implementing data fabric transformation is crucial and significant. In the future, the outlined directions could strengthen the empirical grounding framework to broaden the contextual applicability. By addressing these challenges, this research aiming at improving knowledge sharing and management not only revolutionises how organisations manage and share but also expands the possibilities for using and reusing the knowledge. Future plans include expanding research collaboration among academic institutions, integrating diverse data sources with a focus on interoperability and enhancing the semantic capabilities of knowledge sharing and management systems. By embracing these technologies, universities can strengthen interconnected ecosystems that support lifelong learning and interdisciplinary and transdisciplinary research.

This strategic vision leverages technological advancement, signifying a paradigm shift in academia's roles in societies. By using data fabric technologies, institutions can set up effective KM systems and foster a lifelong learning community, thereby enriching the educational landscape.

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About the authors

Lan Nguyen Thi Kim is an esteemed lecturer with a decade of experience in library and information management. Currently, she is advancing her expertise as a PhD candidate at the Computing Department of Atlantic Technological University in Donegal, Ireland. Specialising in Digital Library Learning, her research now delves into knowledge management, focusing on optimising knowledge systems to augment organisational and individual performance. Lan is passionate about fostering knowledge sharing and exchange to drive innovation and growth within the academic community.

Dr. Son Nguyen Hoang, currently serves as the Director of the Library and Digital Knowledge Centre at Vietnam National University, Hanoi. With an extensive background in information science and digital knowledge management, Dr. Son has played a pivotal role in the advancement of digital libraries and the integration of digital resources for academic and research excellence. Under Dr Son's leadership, the Library and Digital Knowledge Centre has seen significant growth in its digital collections and has become a cornerstone for research and learning at Vietnam National University. Dr. Son is committed to enhancing the accessibility and utilisation of digital knowledge resources, fostering an environment of continuous learning and innovation.

Dr Hoa N. Nguyen is currently an Associate Professor of the Department of Information Systems at the VNU University of Engineering and Technology, Hanoi, Vietnam. He received the engineer's degree in computer science from Hanoi University of Science and Technology in 1999, and the PhD degree in computer science from Joseph Fourier University, France in 2005. Before joining the VNU University of Engineering and Technology, he joined the University of Tours, France, as an assistant professor in the computer department of Blois. He is invited as a professor of the Paris-Sud University in 2009. He has been appointed as the Head of the Department of Information Systems in 2010 and an Associate Professor in 2015. His research interests focus on AI-powered Systems, Big Data Management, Cyber Security and Biometric Security. Hoa N. Nguyen is the corresponding author and can be contacted at: hoa.nguyen@vnu.edu.vn