Proposed Data Literacy Competency Framework through Literature Analysis

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ABSTRACT

With the advent of the Fourth Industrial Revolution and the era of big data, the ability to handle data has become essential. This has heightened the importance and necessity of data literacy competencies. The purpose of this study is to propose a framework for data literacy competencies. To achieve this goal, data literacy frameworks from eight countries and twelve pieces of literature on data literacy competencies were analyzed and synthesized, resulting in five categories and twenty-three competencies. The five categories are: data understanding and ethics, data collection and management, data analysis and evaluation, data utilization, and data governance and systems. It is hoped that the data literacy competency framework proposed in this study will serve as a foundational resource for policies, curricula, and the enhancement of individual data literacy competencies.

1. Introduction

At the core of the Fourth Industrial Revolution lie advanced and intelligent information technologies such as artificial intelligence (AI), the Internet of Things (IoT), cloud computing, and big data. Recently, the emergence of generative AI like ChatGPT, based on big data, in daily life has further emphasized the importance and necessity of data literacy. This development underscores the ethical use of data and related technologies.

In line with these technological advancements, the 2022 revised education curriculum in South Korea places a strong emphasis on foundational knowledge in artificial intelligence, specifically highlighting the importance of data literacy. In primary and secondary education, data-related content is incorporated across various subjects. Notably, in high schools, a new subject called 'Data Science' has been introduced in recognition of the importance of data. This subject aims to cultivate data literacy by teaching various data processing methodologies. It enables students to critically analyze

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the growing volume of data and fosters the development of digital citizens who possess insights into future societal and environmental changes and a sense of responsible self-directedness (Ministry of Education, 2022).

Furthermore, data literacy is emphasized as a core competency in 21st-century higher education, regarded as essential in foundational liberal arts education and as a basic skill for democratic citizenship (Kim Hye-Young, 2020). The necessity of data literacy is increasingly recognized as a fundamental competence for citizens. In addition, the government and public institutions are promoting policies and education to develop data-driven talent. A notable example is the collaboration between the Ministry of the Interior and Safety and the National Human Resources Development Institute to provide data competency training for public officials (Ministry of the Interior and Safety, 2021).

In the era of big data, the ability to handle data effectively has become an essential competency. Various educational programs aimed at developing these skills are being conducted across society. However, there is a significant lack of development in creating data literacy frameworks that can be utilized in national policies to identify the necessary competencies and set standards. In contrast, some countries have established national data literacy competency frameworks. These frameworks serve as benchmarks for developing educational curricula and policies aimed at enhancing data literacy competencies across various fields. Therefore, the purpose of this study is to analyze overseas data literacy competency frameworks developed under national initiatives, as well as literature related to data literacy competencies both domestically and internationally, to derive essential data literacy competencies.

To achieve the objectives of this study, the following research questions were formulated:

(1) What competencies constitute a data literacy framework according to previous studies?

(2) How can a data literacy competency framework be structured for utilization in national policies?

This approach aims to provide a structured basis for enhancing data literacy through informed educational and policy initiatives, reflecting both global standards and local needs.

1.1 Purpose and Research Procedure

The purpose of this study is to establish a data literacy competency framework to serve as a foundational resource for developing data literacy competencies. To address the research questions presented in Section 1.1, the research procedure was structured as shown in <Table 1>.

In the first step, the research background and research questions were identified. The second step involved analyzing data literacy frameworks from eight countries and twelve pieces of literature related to data literacy competencies, both domestically and internationally. The analysis criteria were based on the study by Kim and Berka (2022), titled “Comparative Analysis of Data Literacy Competency Frameworks,” which was presented at the 2022 Association for Library and Information Science Education (ALISE) conference. This study conducted an in-depth analysis of seven widely recognized data literacy competency frameworks, which have been frequently referenced in data literacy competency research, ensuring the reliability and currency of the findings.

In the third step, the data literacy competencies identified from the analysis of national and literature sources were synthesized. Finally, the study proposed a data literacy competency framework that could be utilized as a foundational resource in the domestic context.

Table 1. Research Procedure

Step	Description
Step 1	Identify research background and research questions
Step 2	Analyze data literacy frameworks from eight countries and twelve related literature sources
Step 3	Synthesize data literacy competencies from national and literature analyses
Step 4	Propose a data literacy competency framework for use as a foundational resource domestically

By following these research steps, the study aims to develop a comprehensive and applicable data literacy competency framework, facilitating the enhancement of data literacy competencies in various educational and policy contexts.

1.2 Theoretical background

1.2.1 Defining Data Literacy

As we entered the data society, many scholars at home and abroad recognized the importance of data literacy and conducted research, and as a result, it was confirmed that there were various opinions on the concept and definition of data literacy. The following <Table 2> summarizes eight documents dealing with various definitions of data literacy.

Table 2. Defining Data Literacy

Author(s)	Year	Definition Summary
Downes	2023	The ability to collect, manage, evaluate, and apply data.
Lee, Jung-Mi	2019	The ability to understand technical aspects of data and use data appropriately in context to interpret social issues objectively and insightfully.
Ongena	2023	The ability to identify, understand, use, reflect on, and communicate data to achieve organizational and social goals.
Han, Sang-Woo	2018	The ability to utilize technical elements and technology appropriately with humanistic thinking and logic, and to share and utilize produced data.
Choi, Kyung-Hee & Cho, Dong-Sung	2023	The ability to access, understand, critically evaluate, manage, analyze, present, and use data ethically.
Wolff et al.	2016	The ability to ask and answer real questions through the process of inquiry, considering the ethical use of data from large and small datasets.
Bae, Hwa-Soon	2019	The process of understanding, utilizing, and analyzing data to identify and solve various social issues.
Ridsdale et al.	2015	The ability to collect, manage, evaluate, and apply data in meaningful ways.

Most scholars have defined data literacy as follows. From concepts related to data collection, management, analysis, and processing, which are technical aspects of dealing with data, to concepts related to data collection, management, and processing, to using them in daily life and interpreting them critically to solve problems, and at the same time, it was expanded to a value and attitude concept that includes ethical use of data and the ability to make and communicate through data. In particular, in the case of Bae Hwa-soon (2019), who defined data literacy in relation to a specific field, data literacy was defined as civic education in social studies, and in the case of Han Sang-woo (2018), data literacy was redefined based on humanities.

1.2.2 previous research

This section analyzes the literature focusing on data literacy to describe the differences from this study. The following <Table 3> summarizes the list of eight domestic and foreign prior studies related to data literacy.

Table 3. List of prior studies

Author(s)	Year	Content and Implications
Jeong, Jae-Ri	2024	• Developed a data literacy competency framework for primary, middle, and high school students. • Four domains and eleven detailed competencies.
Burress et al.	2020	• Proposed data literacy competencies for university students and conducted a case study on undergraduate curriculum. • Ten detailed competencies.
Lee, Jung-Mi	2023	• Presented a framework for library data literacy education utilizing generative AI. • Seven components.
Han, Sang-Woo	2020	• Designed a 13-week data literacy model for humanities-based universities.
Kim, Seul-Gi & Kim, Tae-Young	2022	• Designed a big data analysis course for pre-service teachers and analyzed the impact on data literacy. • Three domains: knowledge, skills, values, and attitudes.
Pothier & Condon	2019	• Proposed seven data literacy competencies for business students.
Papamitsiou et al.	2021	• Developed an educational data literacy framework. • Six dimensions and twenty-one competencies.
Bae, Hwa-Soon	2019	• Presented the objectives, directions, and competencies for social studies data literacy education. • Three categories and twelve detailed elements.

The definition, necessity, and core competencies and components of data literacy re-established by scholars were proposed as a result of examining eight domestic and international prior studies on data literacy. In particular, many studies have designed an educational model by re-establishing the concept of data literacy and applying data literacy capabilities to the development of the curriculum. However, in Korea, no studies were found that analyzed the state-led data literacy framework proposed in this study. Therefore, in order to establish a framework for data literacy capabilities that will

be used for national policies, this study investigates and analyzes data literacy capabilities developed by the state abroad, and proposes a data literacy capability framework that will be used in national policies that synthesize the results by adding literature analysis that studied the components of data literacy capabilities at home and abroad.

2. Data Literacy Competency Framework Comparative Analysis Criteria

Kim and Berka (2022) is a project to explore the perception of data literacy in community colleges and identify basic data literacy and knowledge, and developed a data literacy framework by deeply analyzing seven competency frameworks to strengthen understanding of the concept of data literacy and show how necessary data literacy skills and knowledge should be characterized. In this study, based on the research of Kim and Berka (2022), which compared and analyzed various data literacy frameworks that have been recently studied, the data literacy competencies of each country are classified and categorized into similar concepts and used as basic data for the framework of data literacy competency components that have not yet been systematized in Korea. Kim and Berka (2022) established a new data literacy framework by comparing and analyzing seven data literacy competency frameworks that have been trusted by various scholars to derive a total of 15 competencies. In the framework of Calzada Prado and Marzal (2013), the first of the seven data literacy competency frameworks, five core competencies derived from various information literacy standard frameworks were presented. Second, Carlson and Johnston (2014)'s framework included 12 competencies reflecting the data life cycle, and the third, Ridsdale et al. (2015), designed a framework for data literacy education that includes 22 competencies and examples of knowledge and tasks mapped to each. Fourth, Wolff et al. (2016)'s framework contains seven basic competencies built around the Problem, Planning, Data, Analysis, and Conclusion Exploration Process (PPDAC). Fifth, Grillenberger, and Romeike (2018) developed a framework to support computer science education, including four process competencies and four content competencies. Sixth, the framework of Sternkopf and Mueller (2018) includes 12 competencies and four levels of proficiency in each competency, developed for use by NGOs (non-governmental organizations). Finally, the framework of Data To The People (2020) presented 15 competencies targeting business and industry (Kim & Berka, 2022).

The following <Table 4> shows the data literacy competencies derived by Kim and Berka (2022) by comparing and analyzing seven data literacy competency frameworks.

Table 4. Data literacy capabilities of Kim & Berka (2022)

Competency	Description
Data Awareness	• Understanding the concepts and definitions of data; knowledge of different data types and formats.
Data Searching	• Searching for, identifying, and accessing data from various sources.
Data Collection	• Gathering and aggregating data for specific purposes.

Competency	Description
Data Cleaning	• Using appropriate methods and tools to correct and remove corrupted, misformatted, duplicate, and incomplete data from datasets.
Data Analysis	• Applying statistical techniques and tools to summarize data and identify patterns; extracting relevant information from datasets.
Data Modeling	• Applying advanced analytical and statistical techniques and tools to build accurate and valid modeling solutions.
Data Visualization	• Creating meaningful tables, charts, and graphics to visually represent data.
Data Interpretation	• Reading and understanding tables, charts, and graphs to identify points of interest.
Data Storytelling	• Communicating data insights through compelling stories tailored to specific audiences.
Data Quality Assessment	• Critically evaluating data to determine if it meets the required quality for specific purposes and if it is suitable for the intended use.
Data Organization	• Organizing and distributing data with file naming conventions, directory organization, and version control.
Data Documentation	• Enhancing findability and accessibility of data through comprehensive metadata.
Data Storage	• Implementing backup procedures and using physical and cyber resources and facilities for effective preservation and storage of data.
Data Ethics	• Recognizing legal and ethical issues; acquiring, using, and sharing data in an ethical manner.
Evidence-Based Decision Making	• Using interpreted data to make rational and informed decisions.

Kim and Berka (2022) derived a total of 15 data literacy competencies as shown in <Table 4> by analyzing similar or commonly presented competencies in seven data literacy competencies. The 15 competencies derived as components of data literacy competencies are data recognition, data search, data collection, data organization, data analysis, data modeling, data visualization, data interpretation, data storytelling, data quality evaluation, data composition, data documentation, data storage, data ethics, and data evidence-based decision-making competencies.

Data recognition is about knowing what data is, the various types and formats of data, and understanding the use of data concepts and definitions. Data retrieval refers to data retrieval, identification, retrieval, and access from various sources, and data collection refers to collecting and combining primary or secondary data for specific purposes. Data cleaning refers to the correction or removal of corrupted, missformed, duplicated, or incomplete data within a data set using appropriate methods and tools. Data analysis is the use of analysis or statistical techniques and tools to provide summaries and patterns, and to extract executable relevant information from a given data set. Data modeling is the application of advanced analysis or statistical techniques and tools (e.g., machine learning, data mining) to build accurate and valid modeling solutions. Data visualization is the visualization of data by creating meaningful tables, charts, and graphics, and data interpretation refers to the reading and understanding of tables, charts, and graphs, and the identification of information of interest. Data storytelling is the delivery of customized data insights to specific targets through persuasive stories. Data quality assessment is the critical assessment of data to determine whether

it meets the quality required for a particular purpose and whether it is the type and quantity appropriate to support the intended purpose. Data composition refers to the organization and distribution of data between files, including file naming conventions, and includes directory organization and version management. Data documentation refers to the enhancement of searchability and accessibility by reinforcing metadata, and data storage refers to the application of storage method backup procedures for data including physical and cyber resources and facilities for effective preservation and storage of data. Data ethics refers to the acquisition, use, and sharing of data in an ethical manner, including recognizing legal and ethical issues (e.g., prejudice, privacy, security, reliability, copyright), and finally, evidence-based decision-making refers to the use of data to judge the interpretation of processed and analyzed data and to make reasonable decisions.

3. Country-specific data literacy competency framework

The following <Table 5> summarizes the data literacy competency framework of eight countries.

Table 5. Data Literacy Competency Framework in 8 Countries

Country	Title
Netherlands	Data Literacy for Improving Government Performance: A Competency-Based Approach and Multidimensional Operationalization
United Kingdom	Data Literacy and the UK Government
New Zealand	Competency Framework
European Union	DALI Data Literacy Framework
Germany	Future Competencies: Data Literacy Framework
Canada	Data Competency Framework of the Canadian Government
United States	Comprehensive Elements of Data Literacy
Australia	APS Data Competency Framework (Version 1)

In this study, cases of 8 countries that developed a data literacy competency framework led by the government were analyzed. The frameworks referenced for the development of the data literacy framework in this study are diverse, such as the general public, K-12 students, and public service workers. This is to develop a framework that can be applied universally regardless of the field. The target countries are the Netherlands, New Zealand, Germany, the United States, the United Kingdom, the European Union, Canada, and Australia. Among them, the Netherlands, New Zealand, Canada, and Australia have established a data literacy competency framework for national officials, and Germany, the United Kingdom, and the European Union have established a framework for data literacy competencies that ordinary citizens will cultivate. In the case of the United States, a framework for data literacy competencies required for educators in education has been established.

3.1 Netherlands

Ongena (2022) analyzed the relationship between data literacy and government performance through a research report related to ‘a competency-based approach and multidimensional operation of data literacy to improve Dutch government performance’. It was verified using survey data of 120 Dutch government agencies, and as a result, data literacy was found to have an important effect on the internal performance of the government. Therefore, by deriving components related to data literacy competency and establishing a framework, it was intended to promote data literacy competencies of employees handling data in government agencies. The following <Table 6> shows the Dutch data literacy competency framework.

Table 6. Dutch Data Literacy Competency Framework

Category	Competency
Data Identification	• Search
Data Identification	• Collection
Data Communication	• Visualization
Data Communication	• Presentation
Data Understanding	• Cleaning
Data Reflective Thinking	• Evaluation
Data Reflective Thinking	• Assessment
Data Usage	• Embedding
Data Usage	• Ethics
Data Usage	• Definition
Data Usage	• Verification

Data literacy competencies were presented as a total of 11 competencies according to five categories as shown in <Table 6>. First, the ‘data identification’ area requires the ‘searching and collecting’ competency, and the ‘data understanding’ area requires the ability to analyze, refine, or recover data. In ‘data use’, accurate and goal-oriented questions are required to create value by appropriately defining questions about data and to find meaningful answers. In ‘data communication’, competencies in ‘visualization and expression’ are required. Finally, ‘data reflective reflection’ includes ‘evaluation and ethics’ competencies, which are related to the question of what data literacy means in relation to data (Pangrazio & Selwyn, 2019).

3.2 New Zealand

The New Zealand government announced the Data Literacy Competency Framework in 2020, and the following <Table 7> represents 25 data literacy competency components.

Table 7. New Zealand Data Literacy Competency Framework

Competency
1. Data Coding and Classification
2. Data Integration
3. Data Processing Methodology
4. Contribution to the Production of Data Results, Products, or Services
5. Exploratory Data Analysis
6. Business Intelligence Data Analysis
7. Statistical Data Analysis
8. Professional Data Analysis
9. Identification and Understanding of Data Availability
10. Data Collection Methodology
11. Contribution to Data Access Design
12. Contribution to Sourcing and Utilization of Administrative Data
13. Understanding of Data Collection Process Design
14. Data Description and Summary
15. Understanding and Applying Data Editing Methods
16. Use of Data Quality Assurance Measures
17. Data Identification and Evaluation
18. Improvement of Data Processes/Systems/Products
19. Identification of Research Questions
20. Data Governance Guidelines
21. Evaluation of Data Assets
22. Utilization of Statistical Concepts and Methodologies
23. Support for Data Use and Reuse
24. Adoption of Data Information Management Concepts
25. Data Visualization

The characteristic of the data competency framework announced by the New Zealand government is that competencies are formed according to the data life cycle. There are a total of 25 competencies, each with guidelines for data literacy education.

3.3 German

The German data literacy framework was developed in 2019 and provides guidelines for developing data literacy capabilities in each field. The following <Table 8> summarizes the German data literacy framework.

Table 8. German Data Literacy Framework

Competency Area	Sub-Competency
Establishing Data Culture	• Identifying Data Application Cases
Establishing Data Culture	• Designating Data Use
Data Evaluation	• Data Analysis
Data Evaluation	• Data Visualization
Data Evaluation	• Utilizing Coordinate Data
Data Evaluation	• Expressing Data in Language
Data Evaluation	• Data Description and Summary
Data Provision	• Model Data Application
Planning	• Interpreting Linguistic Expression
Result Interpretation	• Ensuring Data Protection/Security Compliance
Result Interpretation	• Visualization Interpretation
Result Interpretation	• Data Analysis Interpretation
Collection	• Identifying Data Sources
Collection	• Data Integration
Collection	• Identifying Data
Data Interpretation	• Data Verification
Preparation	• Data Refinement
Preparation	• Data-Driven Actions
Operation	• Impact Assessment
Operation	• Data Refinement
Operation	• Data-Driven Actions

Germany's data literacy framework consists of six competencies: data culture settlement, data provision, data evaluation, result interpretation, data interpretation, and action, each with 18 sub-competency elements.

3.4 United States

In 2021, the United States developed a framework by jointly defining four key elements and three support structures in cooperation with the National Center for Systemic Improvement (NCSI), the National Center on Educational Outcomes (NCEO), the Indivisible with Disabilities Education

Act (IDEA) and the IDEA Data Center (CIID) to build educators' data literacy capabilities in the field of education. The following <Table 9> shows the data literacy competency framework in the United States.

Table 9. U.S. Education Data Literacy Competency Framework

Essential Competency	Content
Data Exploration	• Purpose and reasons for data
Data Exploration	• Identifying the right questions and the right data to answer them (including existing data)
Data Usage	• Data analysis and interpretation, visualization, and sharing, decision making, etc.
Data Management	• Data identification and collection
Data Management	• Selection, collection, quality, access, and storage of data sources, tools
Data Management	• Processes such as input, submission, access, including the use of data systems
Reflection and Improvement	• Identifying inefficiencies across elements and collaborating with stakeholders to define improvement strategies
Reflection and Improvement	• Expanding successful strategies and processes
Reflection and Improvement	• Professional development, system documentation, etc.
Reflection and Improvement	• Stakeholder engagement

Data literacy capabilities in the United States are presented as four essential capabilities for data exploration, data management, data use, reflection, and improvement, and these capabilities come in three support structures: professional learning, infrastructure, and stakeholder participation.

3.5 United Kingdom

The UK considered data competency as one of the 'National Data Strategy (NDS)' and came up with related policies and initiatives to improve data literacy, mentioning the importance of data technology for a 'data-driven economy and data-rich life' and basic data literacy for everyone. In particular, in 2020, the framework for data competency was announced through the Open Data Institute's 'Data Skills Framework'. The following <Table 10> represents the UK ODI data competency framework.

Table 10. UK ODI Data Competency Framework

Category	Competency
Data Introduction	• Data Classification
Data Introduction	• Enhancing Data Usability
Data Introduction	• Creating Data Value
Data Ethics	• Data Security and Risk Management

Category	Competency
Data Standardization	• Data Integration
Data Standardization	• Data Cleaning
Data Business	• Service Design
Data Business	• Sustainability
Data Business	• Data Policy
Data Interaction	• Data Creation
Data Interaction	• Data Visualization
Data Interaction	• Data Analysis
Data Interaction	• Data Statistics

ODI's data competency framework is a tool for users who need data literacy for an effective balance of data competencies, and is a guide to cultivate those competencies and identify current competencies. Competencies related to data introduction, standardization, and data interaction are practical competencies, and data ethics and business-related competencies are critical and strategic competencies related to data use capabilities.

3.6 European Union

The European Union announced the 'Data Literacy Framework for Citizenship' through the DALI Project, which was conducted to foster data literacy among citizens. The following <Table 11> summarizes DALI's data literacy framework.

Table 11. DALI Data Literacy Framework

Category	Sub-component	Content
Data Understanding	Knowledge	• What is data and how is it created?
Data Understanding	Knowledge	• Where can data be found?
Data Understanding	Knowledge	• What can be done with data?
Data Understanding	Knowledge	• Can you engage with data?
Data Understanding	Awareness	• Knowing about the existence of data
Data Understanding	Awareness	• Conceptualizing and explaining what data represents
Data Understanding	Awareness	• Understanding the meaning of data
Data Understanding	Critical Thinking	• Knowing that data has value
Data Understanding	Critical Thinking	• Recognizing how and why data is used
Data Understanding	Critical Thinking	• Understanding the impact of data usage
Data-Based Action	Data Collection	• Collecting data using external devices or apps
Data-Based Action	Data Collection	• Searching and collecting active data from repositories, apps, and internet portals

Category	Sub-component	Content
Data-Based Action	Data Collection	• Using specialized software for data creation, storage, collection, and analysis
Data Management	Data Management	• Creating, editing, and storing data in simple file formats (.txt or .xls)
Data Management	Data Management	• Managing data collected from apps and internet portals
Data Management	Data Management	• Managing data from various sources using specific software
Data Sharing	Data Sharing	• Sharing and transmitting existing datasets with ethical considerations
Data Sharing	Data Sharing	• Sharing self-created data with others
Data Sharing	Data Sharing	• Anonymizing and combining datasets (external and self-generated) and sharing in public repositories
Policy and Regulation	Policy and Regulation	• Understanding how society shapes data use (policy-making)
Policy and Regulation	Policy and Regulation	• Applying policies and regulations to one's own data activities
Policy and Regulation	Policy and Regulation	• Having a say in policies
Decision Making	Decision Making	• Understanding the potential for personal data use
Decision Making	Decision Making	• Participating in decision-making: using data for actions and individual decisions
Decision Making	Decision Making	• Leading data-driven decision-making
Data Activism	Data Activism	• Understanding data activism movements and how they can change stakeholder data use
Data Activism	Data Activism	• Participating, signing, or endorsing data activity initiatives started by others
Data Activism	Data Activism	• Impacting society: engaging, initiating, or leading data activism
Data Advocacy	Data Advocacy	• Understanding the potential and applications of data
Data Advocacy	Data Advocacy	• Raising collective awareness about data use
Data Advocacy	Data Advocacy	• Actively advocating for peers and stakeholders to use data to enact change

The DALI data literacy framework consists of four key components and 10 sub-components, including data literacy capabilities, data-based action, data participation, and ethics and privacy underlying each capability.

3.7 Canada

The data literacy framework announced by the Canadian government in 2022 was designed to support the strengthening of data literacy capabilities of public officials. The framework was developed to establish a common understanding of the basic, intermediate and advanced data capabilities needed across the federal government, and catalogued a series of knowledge and skills throughout the data life cycle required to make evidence-based decisions. The following <Table 12> below summarizes the Canadian government's data literacy framework.

Table 12. Canadian Government's Data Literacy Framework

Category	Competency
Data Concepts and Culture	• Data, Digital, and Organizational Awareness
	• Data Ethics and Privacy
	• Evidence-Based Decision Making
Data Governance, Collection, and Management	• Data Governance, Management, and Standards
	• Data Collection
	• Data Quality, Value, and Trust
	• Access, Security, and Interoperability
Analysis and Evaluation	• Questioning and Problem Formulation
	• Data Analysis
	• Storytelling and Visualization
	• Outcome Evaluation
Data Systems and Architecture	• Data Architecture
	• Data Systems

The Canadian government's data literacy framework includes four categories and 13 capabilities: data concept and culture, data governance, collection and management, analysis and evaluation, data systems and architecture, each of which plays a central role in the data lifecycle.

3.8 Australia

In 2021, the Australian government established the 'APS Data Capability Framework' for the purpose of developing data literacy capabilities of members of the Australian Public Service (APS). The following <Table 13> summarizes the Australian government's 'APS Data Capability Framework'.

Table 13. Australian APS Data Competency Framework

Category Term	Competency
VAL	• Evaluate organizational data as an asset
COM	• Data communication
IMP	• Improvement and innovation (for data)
GOV	• Data governance
AVL	• Identify data availability
ACC	• Facilitate data access
SRC	• Sourcing and use of administrative data
COL	• Data collection
SMX	• Subject matter expertise
RSC	• Identify research questions

Category Term	Competency
OUT	• Data output, products, or services
MTH	• Data collection methodology
QUL	• Data quality
SCM	• Statistical concepts and methodologies
MGT	• Data and information management
CLS	• Data classification
INT	• Data integration
EDT	• Data editing
MET	• Metadata
USE	• Data usability and reusability
PRC	• Data processing methodology
EXP	• Exploratory data analysis
VIS	• Data visualization
STS	• Statistical data analysis
SPC	• Professional data analysis
BUS	• Business intelligence data analysis

Australia's 'APS Data Competency Framework' briefly describes a total of 26 data competencies and defines brief terms for each category of competencies.

3.9 Mapping country-specific data literacy frameworks

The following <Table 14> maps the data literacy competency framework of the eight countries examined earlier according to the standards of Kim and Berka's (2022) data literacy competency framework.

<Data Literacy Competency Description Level Legend>

● Complete description of the item (1 point)
◐ Incomplete description of the item (0.5 points)
○ No description exists for the item (0 point)

Table 14. Data literacy competency framework mapping in 8 countries

Competency	Netherlands	New Zealand	Germany	United States	United Kingdom	European Union	Canada	Australia	Total
Data Awareness	●	●	●	●	●	●	●	●	8
Data Search	●	●	●	●	●	●	●	●	8
Data Collection	●	●	●	●	●	●	●	●	8
Data Cleaning	●	●	●	◐	●	●	●	◐	7

Competency	Netherlands	New Zealand	Germany	United States	United Kingdom	European Union	Canada	Australia	Total
Data Analysis	●	●	●	●	●	●	●	●	8
Data Modeling	●	●	●	●	●	○	◐	◐	6
Data Visualization	●	●	●	●	●	●	●	●	8
Data Interpretation	●	●	●	●	●	●	●	●	8
Storytelling	●	●	○	●	●	●	●	◐	6.5
Data Quality Assessment	●	●	●	●	●	●	●	●	8
Data Organization	●	●	◐	●	●	●	●	◐	7
Data Documentation	●	◐	●	●	◐	○	○	●	5
Data Storage	◐	●	○	●	●	●	◐	●	6
Data Ethics	●	◐	●	●	●	●	●	◐	7
Evidence-Based Decision Making	●	●	●	●	●	●	●	◐	7.5

The results of analyzing the data literacy competency components of the country-specific framework are as follows. Data literacy data recognition, search, collection, analysis, visualization, interpretation, and quality evaluation have been adopted in all eight countries, and data purification, modeling, storytelling and composition, data storage, data ethics, and evidence-based decision-making capabilities are important in most countries. In the case of data documentation capabilities, it was analyzed as the lowest data literacy capabilities recognized by five countries.

4. Data literacy competency literature

The following <Table 15> summarizes the contents of 12 documents related to the data literacy competency components studied within the last 10 years. The documents to be analyzed are intended to derive more detailed and reliable results for data literacy competency by adding four documents along with the preceding studies in <Table 2>.

Table 15. Data Literacy Competency Literature Organization

Author(Year)	Paper Title
Jeong, Jae-Ri (2024)	• Development of a Systematic Competency Framework for Data Literacy Enhancement
Lee, Jae-Yoon (2020)	• A New Perspective on the Composition of Sub-Competencies in Data Literacy
Lee, Jung-Mi (2023)	• A Study on Data Literacy Education in Libraries in the Era of ChatGPT and Generative AI
Han, Sang-Woo (2020)	• A Study on the Design of a Humanities-Based Data Literacy Model
Kim, Seul-Gi & Kim, Tae-Young (2022)	• Development and Application of a Big Data Analysis Course to Enhance Pre-Service Teachers' Data Literacy Competencies

Author(Year)	Paper Title
Pangrazio, L., & Selwyn, N. (2019)	• Personal Data Literacy: A Critical Approach to Understanding Personal Digital Data
Papamitsiou et al. (2021)	• Towards an Educational Data Literacy Framework: Profiling the New Competencies of Online and Blended Course Designers and e-Tutors
Pothier & Condon (2019)	• Exploring Data Literacy through Librarian-Faculty Learning Communities: A Case Study
Song, Yu-Kyung et al. (2021)	• Development of a Data-Based Discussion Class Model and Teaching Strategies for Enhancing Data Literacy
Bae, Hwa-Soon (2019)	• Social Studies Educational Implications of Data Literacy
Burress et al. (2020)	• Exploring data literacy through the librarian-teaching learning community: a case study
Maybee & Zilinski (2015)	• Data-Based Learning: The Next Step in Data Literacy Frameworks for Higher Education

Jeong Jae-ri (2024) presented four areas and 11 detailed competencies: basic understanding of data, collection and management, data analysis activities, and result utilization, and Jeong-mi Lee (2023) presented seven components: understanding data, data generation, data collection, data verification, data management, data use and sharing, and data ethics. Seul-ki Kim and Tae-young Kim (2022) composed competencies by three areas of knowledge, function, values, and attitudes. Papamitsiou et al. (2021) presented 21 competencies in six dimensions related to data collection, management, analysis, data understanding and interpretation, application, and ethics. Yoo-kyung Song et al. (2021) presented six detailed items according to two areas of statistical analysis ability and communication ability, and Burress et al. (2020) presented a total of 10 detailed competencies over three stages: general undergraduate education, undergraduate research, and graduate student research. In the case of Jae-yoon Lee (2020), six core competencies in data literacy were presented, and Han Sang-woo (2020) presented competencies through the 13th week of education model on humanities data literacy competencies. Pangrazio and Selwyn (2019) presented five data literacy competencies, including data identification, understanding, reflection, use, and strategy. Pothier and Condon (2019) presented seven data literacy competencies, and Bae Hwa-soon (2019) presented each detailed element by categorizing data literacy competencies in the dimension of civic education centered on social studies into three. Maybee and Zilinsk (2015) presented “data informed learning” for data literacy education in higher education and designed a data literacy framework to solve the shortcomings related to general technology-based models by allowing students to learn how to use data in the context of academic learning. The competencies presented by each researcher were applied to the following <Table 16> below and synthesized. The <Table 16> maps 12 documents on data literacy competency by dividing the level of description of the concept of competency into three according to the criteria of Kim and Berka’s (2022) data literacy competency. In <Table 16>, 1 point was given when the description of the competency described in the preceding study is detailed. The degree of perfect technology was judged based on the preceding research that was judged to be a detailed technology, and 0.5 points were given for insufficient technology. If there was no content described, no points were assigned. Two researchers conducting a joint study decided on the level of judgment criteria for each competency under consultation.

<Data Literacy Competency Description Level Legend>

● Complete description of the item (1 point)

◐ Incomplete description of the item (0.5 points)

○ No description exists for the item (0 point)

Table 16. Data literacy competency literature mapping

Competency	Jeong Jae-ri (2024)	Lee Jung-mi (2023)	Kim Seul-ki and Kim Tae-young (2022)	Papamitsiou et al. (2021)	Song Yoo-kyung et al. (2021)	Burress et al. (2020)	Jaeyoon Lee (2020)	Han Sang-woo (2020)	Pangrazio, L. & Selwyn, N. (2019)	Pothier & Condon (2019)	Bae Hwa-soon (2019)	Maybee & Zilinski (2015)	Score
Data Awareness	●	●	●	●	●	●	◐	●	●	●	●	●	11.5
Data Search	●	●	●	●	●	●	●	●	●	●	●	●	12
Data Collection	●	●	●	●	●	●	●	●	●	●	●	●	12
Data Cleaning	○	◐	●	◐	◐	◐	●	●	◐	●	◐	◐	7.5
Data Analysis	●	●	●	●	●	●	●	●	●	●	●	●	12
Data Modeling	◐	◐	◐	◐	◐	●	●	●	●	●	◐	◐	8.5
Data Visualization	●	●	●	●	●	●	●	●	●	●	●	●	12
Data Interpretation	●	●	●	●	●	●	●	●	●	●	●	●	12
Storytelling	◐	◐	◐	◐	○	●	●	●	◐	◐	●	◐	7.5
Data Quality Assessment	○	○	○	○	●	●	○	●	●	●	○	●	6.5
Data Organization	◐	◐	●	○	◐	◐	●	●	◐	●	◐	●	7
Data Documentation	◐	◐	◐	○	○	◐	◐	●	◐	◐	○	●	5.5
Data Storage	○	●	●	◐	○	◐	◐	●	◐	●	◐	●	7.5
Data Ethics	●	●	●	●	●	●	●	●	●	●	●	●	12
Evidence-Based Decision Making	●	●	●	●	●	●	●	●	●	●	●	●	12

The results of analyzing the data literacy competency components by literature in <Table 16> are as follows. Data literacy data recognition, search, collection, analysis, visualization, interpretation, ethics, and evidence-based decision-making capabilities have been adopted in all 12 literatures, and data purification, modeling, storytelling, quality evaluation, data composition and storage capabilities are recognized as important in about 7 documents. Finally, less than 6 documents with 50% data documentation were analyzed as data literacy capabilities. It can be seen that this shows the lowest importance as in the competency analysis of the data literacy framework by country

discussed earlier.

The following <Table 17> summarizes the analysis of the importance of data literacy competencies by 8 countries and 12 competencies by literature. The example of the country-specific legend in <Table 14> is expressed as N1-N8 from the Netherlands to Australia, and the example of the legend by literature in <Table 16> is set as A1-A12 from Jeong Jae-ri (2024) to Maybee & Zilinski (2015).

<Data Literacy Capability Data Legend>

Order of Country in <Table>: N1 - N8 (Country)

In the order of literature in <Table>: A1 - A12 (Thesis)

Table 17. Comprehensive Data Literacy Capabilities

Competency	N1	N2	N3	N4	N5	N6	N7	N8	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	계(점수)
Data Awareness	●	●	●	●	●	●	●	●	●	●	●	●	●	●	◐	●	●	●	●	●	19.5
Data Search	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	20
Data Collection	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	20
Data Cleaning	●	●	●	◐	●	●	●	◐	○	◐	●	◐	◐	◐	●	●	◐	●	◐	◐	14.5
Data Analysis	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	20
Data Modeling	●	●	●	●	●	○	◐	◐	◐	◐	◐	◐	◐	●	●	●	●	●	◐	◐	14.5
Data Visualization	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	20
Data Interpretation	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	20
Storytelling	●	●	○	●	●	●	●	◐	◐	◐	◐	◐	○	●	●	●	◐	◐	●	◐	14
Data Quality Assessment	●	●	●	●	●	●	●	●	○	○	○	○	●	●	●	●	●	●	○	●	14.5
Data Organization	●	●	◐	●	●	●	●	◐	◐	◐	●	○	◐	◐	●	●	◐	●	◐	●	14
Data Documentation	●	◐	●	●	◐	○	○	●	◐	◐	◐	○	○	◐	◐	●	◐	◐	○	●	10.5
Data Storage	◐	●	○	●	●	●	◐	●	○	●	●	◐	○	◐	◐	●	◐	●	◐	●	13.5
Data Ethics	●	◐	●	●	●	●	●	◐	●	●	●	●	●	●	●	●	●	●	●	●	19
Evidence-Based Decision Making	●	●	●	●	●	●	●	◐	●	●	●	●	●	●	●	●	●	●	●	●	19.5

When analyzing the comprehensive data literacy capabilities by country and literature in <Table 17>, data recognition, search, collection, analysis, visualization, and interpretation capabilities were important in all 20 cases, and data purification, modeling, storytelling, quality evaluation, data composition and storage, data ethics, and evidence-based decision-making capabilities were analyzed as the next most important capabilities. In the case of data documentation capabilities, about 50% of 20 cases are important.

5. Proposed Data Literacy Competency Framework

In this chapter, based on the results summarized in Chapter 3, similar competencies are categorized to present competencies and detailed elements. When analyzing the data literacy competency framework by country and data literacy competencies by literature, competencies that were not covered by Kim and Berka (2022), which were the criteria for the framework, were presented, so I would like to add and reconstruct the data literacy competency framework of this study. The following <Table 18> shows the data literacy competency component framework proposed in this study.

Table 18. Propose data literacy competency components

Category	Competency	Sub-component
1. Data Understanding and Ethics	1.1 Data Awareness and Understanding	• Understanding data concepts, roles, definitions, etc. • Understanding a data culture • Understanding a data value • Identifying problems through data • Understanding a data overview • Understanding a data citizenship • Awareness/understanding of key data terms, standards, policies, documents, etc. • Understanding complex data, statistics, and analysis concepts • Defining and implementing strategies for the development of talent and infrastructure needed to enhance data literacy
	1.2 Data Ethics	• Acquiring a privacy protection • Acquiring a legal and ethical use: copyright and ownership • Acquiring a data reuse • Understanding and complying with ethics, privacy, legal standards • Applying processes and procedures to ensure an ethical approach to data • Designing and implementing processes and procedures to ensure an ethical approach to data
2. Data Collection and Management	2.1 Data Access	• Acquiring a data exploration and search skill • Acquiring a data access skill • Understanding and using data search methods • Improving information access, search, and use through metadata, database indexing, information analysis, and management
	2.2 Data Collection	• Collecting data for specific purposes • Collection methodologies and processes • Identifying and acquiring data • Understanding data collection roles and recognizing data collection methods and tools • Supporting the resolution of data collection issues (e.g., sampling issues, missing data, errors, inconsistencies) • Evaluating and validating data collection methods and tools
	2.3 Data Preprocessing	• Understanding data types • Data cleaning, organizing, preprocessing • Understanding a guidelines for data types and preprocessing • Sharing processes related to data preprocessing • Evaluating data preprocessing and ensuring quality
	2.4 Data Storage and Preservation	• Acquiring a data storage, preservation, and storage • Awareness of data storage and preservation • Implementing governance systems for data storage and preservation • Developing an evaluation system for selecting data storage

Category	Competency	Sub-component
	2.5 Data Documentation	• Understanding metadata and documentation • Collecting and recognizing metadata • Writing metadata
	2.6 Data Organization	• Understanding file naming conventions, organizing and distributing data between files • Understanding directory organization, version control • Understanding data organization methods • Applying data organization methods to organize data • Implementing data organization methods and working in various fields
3. Data Analysis and Evaluation	3.1 Data Analysis	• Summarizing or identifying patterns using analysis techniques and tools • Extracting information from data • Considering the use of open-source and freely available tools for data analysis • Sharing data and analysis results publicly • Performing data exploration such as data mining, web scraping using advanced tools and techniques
	3.2 Data Visualization and Presentation	• Visualizing and presenting data using tables, graphs, charts, etc. • Accurate and useful data presentation in tables and graphics • Ensuring data representation is directly connected to questions • Evaluating the accuracy and false representation in storytelling and visualization
	3.3 Data Interpretation	• Reading, understanding, critically interpreting, and drawing conclusions from visualized data • Understanding analyzed data • Criticizing analyzed data • Drawing conclusions from analyzed data
	3.4 Data Modeling	• Applying advanced analysis and statistical techniques and tools to build accurate and valid modeling solutions (e.g., machine learning, data mining) • Understanding appropriate data processing tools • Analyzing data with appropriate processing tools • Enabling data modeling
	3.5 Data Source Evaluation	• Critically evaluating data sources • Understanding the importance of data sources • Complying with standards for data sources • Critically evaluating data sources
	3.6 Data Quality Assessment	• Understanding policies for evaluating data quality • Ensuring and improving data quality by complying with data standards • Ensuring and evaluating data quality and interoperability
4. Data Utilization	4.1 Data Sharing and Citation	• Awareness of data sharing and citation • Establishing governance systems for data sharing and citation • Proposing evaluation and dissemination strategies for data sharing and citation
	4.2 Evidence-Based Decision Making	• Using knowledge and information collected through data • Searching for data needed for decision making and evaluating the suitability of such data • Integrating subjects ethically and methodologically to evaluate if data is suitable for decision making
	4.3 Data Communication	• Data communication and participation • Effectively communicating with various stakeholders during data production processes • Effectively conveying the relationship between data and context • Using innovative approaches to improve the process of summarizing data into meaningful explanations

Category	Competency	Sub-component
	4.4 Data Storytelling	• Storytelling: reconstructing meaning based on data, explaining and conveying data • Accurate and useful data presentation in tables and graphics • Ensuring data representation is directly connected to questions • Evaluating the accuracy and false representation in storytelling and visualization
	4.5 Reflective Thinking	• Identifying inefficiencies across elements and collaborating with stakeholders to define improvement strategies • Expanding successful strategies and processes • Professional development, system documentation, and stakeholder engagement • Recognizing issues related to data utilization • Defining and implementing strategies to improve issues related to data utilization • Deriving successful strategies for data utilization through stakeholder engagement
5. Data Governance and Systems	5.1 Data Architecture and Systems	• Understanding data management tools such as data catalogs, data warehouses • Considering the entire system lifecycle when developing or deploying architecture • Building and sharing expertise needed to analyze enterprise-level solutions for operating advanced analytical models such as AI
	5.2 Data Policy	• Understanding how society shapes data usage (policy making) • Understanding how society shapes data usage (policy making) • Applying policies and regulations to one's own data activities • Having a say in policies
	5.3 Data Outputs	• Data outputs, products, or services • Providing usable items and services related to data • Understanding and applying appropriate processing methods for used data • Recognizing and understanding steps involved in generating data outputs, products, or services and decisions made at each step • Generating data output products and providing data services following established processes and systems • Providing expertise for developing new products or data services to meet changing requirements
	5.4 Data Security	• Governance and systems for data security • Awareness of policies, guidelines, and regulations related to data security and storage • Applying approved security enhancement tools such as data anonymization and de-identification • Improving information access, search, and use through metadata, database indexing, information analysis, and management

There are five categories: data understanding and ethics, data collection and management, data analysis and evaluation, data utilization, data governance, and systems, and 23 detailed elements were presented by subdividing the capabilities of each category. First, data understanding and ethics include data recognition and understanding, data ethics, and data collection and management require data access, data collection, data preprocessing, data storage and preservation, data documentation, and data composition capabilities. Data analysis and evaluation capabilities were derived from data analysis, data visualization and representation, data analysis, data modeling, data source evaluation,

and data quality evaluation capabilities. Data utilization requires data sharing and citation, evidence-based decision-making, data communication, data storytelling, and reflective reflection capabilities, and data architecture and data systems, data policy, data results, and data security capabilities were derived from data governance and systems.

6. Conclusion

Data literacy capabilities and education are required throughout society, ranging from data-handling technology, data-based decision-making, problem-solving, and ethical data use, as we enter the big data era called data flood. The purpose of this study is to derive the components of competency by analyzing cases of foreign countries and various data literacy competency-related literature on the competencies required to cultivate data literacy, and based on this, a data literacy framework that can be used in national policy is proposed. The derived data literacy framework consists of five categories and 23 competencies, and the contents are as follows.

(1) Data understanding and ethics require an understanding of data recognition and understanding, data concepts and roles according to data ethics capabilities.
(2) Data collection and management includes data access, data collection, data preprocessing, data storage and preservation, data documentation, and data composition capabilities, and corresponding capabilities such as data access, identification, and data type identification are required.
(3) Data analysis and evaluation include data analysis, data visualization and representation, data interpretation, data modeling, data source evaluation, and data quality evaluation. In order to develop these competencies, it is necessary to extract information on data using analysis tools, visualize it with tables or graphs, draw critical interpretations and conclusions through this, and evaluate data quality.
(4) Data utilization includes data sharing and citation, evidence-based decision-making, data communication, data storytelling, and reflective reflection capabilities, and ethical data sharing and citation, data evidence-based decision-making and communication are required to cultivate them.
(5) Data governance and systems include data architecture and data systems, data policies, data results, and data security capabilities, which require systematic and policy training on appropriate processing and methods for data.

This study proposed a data literacy competency framework as basic data to strengthen the data literacy competency to be used in national policy, but it has the following limitations. Discussions are limited because the importance was calculated by quantifying scores according to the frequency of appearance of the competencies of eight countries, expert review of the derived results, and the possibility of field application have not been verified. Therefore, follow-up studies are needed to supplement these points through expert review of the capabilities presented in the future and on-site demand surveys and evaluations. Nevertheless, this study is meaningful in that it proposes

a framework for the capabilities of data literacy necessary for anyone to live in the data era and can be used as basic data for national policy.

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