Data Literacy Integration in Information Systems Undergraduate Education: Aligning with IS2020 Competency Model Requirements

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Abstract **– The impact of information in modern society is constantly growing. This requires new approaches to the collection, processing, and use of data. Data literacy becomes an important characteristic of professionals in the society, especially in the IT field, and university education must prepare current students for this challenge. This paper explores issues related to data literacy and how to be addressed in undergraduate Information Systems education, in particular, their alignment with the IS2020 Competency Model. It aims to provide a comprehensive view of incorporating data literacy skills into Information Systems curricula, ensuring that graduates possess the necessary competencies to work effectively in the data-driven world. The approaches suggested in the paper provide practical guidance on how this can be accomplished.**

Keywords **– Data literacy, information systems education, IS2020 competency model, data management.**

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1. Introduction

All organizations increasingly rely on data in order to run their business efficiently. Today, when organizations have access to more and more data, there is an increasing demand for employees who possess the abilities to work effectively with data.

The definition of data literacy (DL), provided by Gartner's Glossary, clarifies these abilities: "To read, write and communicate data in context, including an understanding of the data sources and constructs, analytical methods and techniques applied, and the ability to describe the use case application and resulting value" [1].

Data literacy in the big data era involves teaching critical skills for workforce participation. Increasing amounts of work are being undertaken in this direction.

In modern education, when working with data, both students and educators are faced with a number of challenges - on the one hand, rapidly evolving technologies, on the other, still limited educational resources. Recently, many initiatives were organized in this direction. To resolve them, leveraging industry partnerships for resources and constantly updating computing curricula to reflect new achievements should be used. For example, the Oceans of Data Institute's workshop brought together experts to explore how to develop data literacy in education, emphasizing analytical thinking and envisioning the role of a data-literate individual [2].

Undoubtedly, this applies to those working in the IT area to the greatest extent. Among them, specialists in the field of Information Systems (IS) have a distinctive place due to the special demands for working with data and information. Unlike computer scientists or software engineers, IS specialists prioritize business impact by leveraging technology to solve problems, emphasizing data literacy for actionable insights.

IS professionals enable decisions strategically and ethically, differing from other fields focused on system development. This requires high degrees of data literacy to be an integral part of IS undergraduate education.

This paper aims to identify methods for integrating data literacy into the education of IS undergraduate programs. More specifically, this research proposes approaches that align with the IS2020 Competency Model for Undergraduate Programs in Information Systems - the latest iteration of model curriculum work jointly developed by the ACM (Association for Computing Machinery) and the AIS (Association for Information Systems) with the participation of leading educators and professionals [3].

To explain the achievement of these goals, the paper proceeds as follows. Section 2 reveals the main components of the IS 2020 Competency model. The section Data Literacy provides a summary of definitions, explanations, knowledge, and skills concerning data literacy. In addition, some specifics of data literacy in the field of Information systems are outlined. In the next section, two approaches to integrating data literacy components into IS curricula and courses are proposed, both considering the specifics of IS 2020.

The Conclusion summarizes the key findings of the research and marks some immediate directions for future research.

2. IS2020 Competency Model

IS2020 - the latest IS curriculum highlights that both foundational knowledge and practical skills are important for the bachelor's IS students. It announces the competency-based educational framework for undergraduate Information Systems programs [4] in response to the increased interest of both industry and educational institutions in cultivating professional competencies [5].

IS2020 outlines a number of core competency areas in the education in the information systems field, but also leaves opportunities for the particular university programs to be supplemented with elective ones [6].

Furthermore, grouping designated competency areas, the curriculum announces six main competency realms in IS education, each of which is connected to specific learning outcomes:

- Foundations Competency Realm
- Data/Information Competency Realm
- Technology Competency Realm
- Development Competency Realm
- Organizational Domain Competency Realm
- IS Integration Competency Realm.

These 6 highlighted realms ensure that during their education, undergraduate students will develop a comprehensive set of skills and knowledge to effectively design, develop, implement, and manage information systems in various domains [7].

Foundations Competency Realm introduces major principles and concepts in the information systems area. Discussed are basic components of IS, information systems operations, the roles and responsibilities of IS professionals.

In this realm, DL concepts need to be included in order to expand students' understanding of the importance of data in the context of information systems and how these systems are used to collect, store, and retrieve data.

The Data/Information Competency Realm covers issues concerning how to organize, manage, and analyze data in order to effectively support business decisions. Data and information management, business analysis, and information visualization are among the issues discussed here.

Technology Competency Realm focuses on the technical aspects of information systems, including IT infrastructure, secure computing, and emerging technologies. It emphasizes the skills needed to design, implement, and maintain technology solutions.

The Development Competency Realm deals with different issues concerning the information system development life cycle, with a focus on systems analysis and design. Traditional and agile methodologies are introduced. Application development and programming for web, mobile, and other kinds of applications are studied.

The Organizational Domain Competency Realm involves understanding the Organizational context in which information systems operate. Here, competencies in IS management and strategy, digital innovation, and business process management are noticed.

The sixth realm - IS Integration Competency Realm emphasizes integrating information systems within an organization. It encompasses competencies in project management for information systems development, enabling students to gain practical experience in various project management tasks and activities.

Through systematically studying these 6 realms, students can gain an impressive set of knowledge, skills, and competencies that allow them to effectively manage data and design, develop, and maintain complex information systems.

3. Data Literacy

Various studies offer a more in-depth look at the definitions of data literacy and the competencies associated with this concept [8], [9].

There is no single definition of data literacy. A study notes that data literacy refers to “the ability to transform information into actionable instructional knowledge and practices by collecting, analyzing, and interpreting all types of data” [10]. The interpretations may vary depending on the context. A different study indicates that in the academic field, the focus is on technology, while in the public sphere, the focus is on human decision-making [11]. In [12], the authors examine different definitions and discuss some of the discrepancies between academic teachings and business expectations regarding data literacy, highlighting the need for alignment to address the talent shortage in organizations seeking data-literate people.

Several authors explore not only data literacy definitions but also the competencies and skills that need to be developed in different domains [13].

Over twenty key competencies and skills have been identified. These competencies can be categorized into several main groups [14]:

- Data fundamentals
- Data management skills
- Data analysis skills
- Data interpretation
- Data problem solving
- Communication skills
- Data culture
- Advanced skills.

The presented categories outline not only technical skills. Critical thinking and communication skills are also very important for the correct interpretation and use of data.

The first category covers basic concepts related to data, from its definition and sources to data quality issues. The next two categories focus on the technical and analytical aspects of data processing, such as processes of data collection, cleaning, and analysis.

The fourth category emphasizes the importance of accurate interpretation of data, based on the use of various modeling and analysis techniques, working with programming languages, algorithms, and specialized data processing tools. Additionally, there are data tools that facilitate data analysis, which are also included in this category.

The last significant categories concern ethical and privacy issues related to the data use and sharing [15].

Education plays a central role in the development of data literacy.

A number of studies have examined the implementation of data literacy in school or university education [16], [17], explored DL elements in educational programs [18], and have also paid attention to the development of DL skills by teachers themselves [19], [20].

In [21], the author focuses on the necessity of digital literacy in higher education in order to meet evolving job market demands. The paper explores integration challenges, such as resource limitations and varying student skills, while proposing strategies like curriculum changes and industry collaboration to enhance digital literacy for future workforce preparedness.

Still, there is a lack of specific research to address these issues in the field of computing disciplines such as computer science, information systems, software engineering, etc. This paper presents a method for addressing data literacy in Information Systems education.

3.1. Data Literacy in the IS Field

Information systems work with huge volumes of data that come from different sources and in different formats. It is essential that IS professionals understand the fundamentals of data, including concepts such as data sources, data structures, data flow, etc., in order to successfully design, develop, and manage these systems [22]. This requires a strong level of data literacy, enabling them to make informed decisions regarding the overall use of data. DL helps them analyze data to identify problems, understand patterns, and develop effective solutions in different business contexts.

The IS specialists often mediate between technical teams and various stakeholders. Possessing strong data literacy skills helps them convert complex data insights into practical business recommendations that can be easily understood and implemented by non-technical employees and users.

A common task for IS professionals is managing and integrating various information systems within a company. DL competencies are essential to ensuring that these systems operate effectively together, especially in terms of synchronizing and optimizing data flows. The emerging technologies also foster the need for DL skills, which are of great significance when working with artificial intelligence (AI) or applying machine learning methods (ML) – both heavily relying on data.

Usually, information system development goes through several phases: system analysis, system design, implementation, testing, deployment, and system maintenance.

Three main categories of data are taken into account in the development of IS:

- Data used in business analysis and determining the requirements for the functionality of the developed system,
- Data that the system will utilize for its own operation,
- Data that will be collected during the work of the already developed system and that will be used by the organization to improve its work.

This data undergoes various processing steps. Initially, data is collected by gathering raw data from various sources. In all three directions, this data should be integrated, summarized, and processed. These tasks involve the application of standardizing formats, cleaning the data - removing duplicates, resolving data conflicts, filling or replacing missing values, etc. When data comes from different sources, it should be integrated into a cohesive dataset. At this point, data transformation is usually applied to convert data into the appropriate format, and then the data is stored in the new data structure for later use.

Data analysis can now be conducted, allowing valuable insights from data to be extracted. These insights can be appropriately visualized to present the findings in a more understandable way using charts, graphs, and other visual aids. To communicate findings to stakeholders, data reports are generated, and dashboards are produced.

When the newly developed information system starts to work with real users, the standard data processing activities are performed. In addition, some activities concerning data archiving and disposal are implemented.

To handle these activities, a set of data literacy competencies and skills is required for IS professionals.

3.2. The Role of Education Leveraging Data Literacy in the IS Field

Education plays a central role in the development of data literacy among information systems professionals, and bachelor's programs in information systems are extremely important in this context. A well-designed program can effectively support the acquisition of DL skills and competencies in each of the main groups listed in the previous section.

Data fundamentals: An undergraduate program in IS should provide fundamental knowledge and skills in understanding and processing data. The program should provide at an appropriate level basic concepts such as: definitions of data and its different types (structured, unstructured, etc.), collecting and integrating data sources, fundamentals of data quality, including methods for data cleaning and validating.

This basic knowledge gives students the necessary foundation on which to build more complex skills in data processing.

Technical and analytical skills: Bachelor's programs usually include courses in programming, algorithms, data structures, data modelling, data analysis, etc., that are essential for information systems professionals. In such courses, students learn how to model, design, and manage databases using models and algorithms for analyzing and processing data, including big data. These courses allow students to acquire the ability to utilize different data processing languages and tools (SQL, Python, R, etc.).

Through these courses, students will be able to obtain not only technical abilities that are important for the daily work of information systems, but also analytical skills for making decisions based on their data.

Preparing for new technologies and trends: Information Systems programs should also pay attention to emerging technologies and trends concerning different sides of data dealing, such as machine learning, data mining, big data analytics, artificial intelligence, IoT, etc. Students should prepare for their future job positions by obtaining skills to work with the latest data processing and analysis technologies.

Solving practical problems: A particular aspect of IS bachelor's programs is their orientation to prepare students to solve real-world problems. Providing many teams and individual projects and case studies, these programs give students the opportunity to apply their theoretical knowledge in practice. Students learn how to identify and solve data problems in the context of existing information systems. Students also learn how to optimize data collection and processing, how to deal with incorrect or incomplete data, and how to address ethical and legal issues related to data.

Ethics and responsibility: Ethical issues regarding the use of data are increasingly important in the current digital age. Undergraduate programs should prepare IS students to resolve the ethical challenges that may arise when collecting, processing, analyzing, and visualizing data.

It is also possible to cover topics concerning overall transparency and accountability in data processing, especially the protection of personal data, and to explain the role of compliance with laws and regulations, such as GDPR (General Data Protection Regulation) and other data protection legislation.

Interpretive and communication skills: It is important, in addition to the technical and analytical knowledge, IS undergraduate programs to offer students education in communication skills. Students should be able to interpret data and present results clearly and understandably, not only to technical staff but also to managers and other stakeholders who may not have a deep knowledge of the data.

These topics are of particular significance within information systems, as effectively utilizing data often requires skills in communicating results and recommendations that lead to informed business decisions.

Building a data culture: Information systems education should help students build data culture that recognizes and understands the value of data and how to use it to make informed and reasoned decisions in their future careers.

4. Integrating Data Literacy in IS Education

The above-presented discussion outlines the importance of data literacy for education in the field of Information Systems. Despite the growing value of data literacy in this and other educational fields, the integration of these competencies into curricula is still a challenge [23]. In this section, two possible approaches to integrate data literacy components into the current IS undergraduate curricula are proposed.

Overall, two major integration strategies can be followed for this purpose: top-down and bottom-up.

The first strategy is based on a mapping of data literacy components to the high-level concepts of IS curricula, such as IS realms.

The bottom-up strategy is based on thoroughly analyzing the content of different IS2020 courses and identifying ways of including elements of data literacy in each of them. Following this strategy, the integration could start with several mandatory courses and incorporate suitable DL elements into them. After that or in parallel, DL elements can be added to the elective ones depending on the distinct curriculum.

Next, both approaches are discussed in more detail.

4.1. Mapping Data Literacy to the Six IS2020 Competency Realms

To address the implementation of this strategy, a possible mapping is explored that ensures data literacy is comprehensively integrated across all IS2020 competency realms, preparing IS graduates for the complexities of the data-driven world.

Following the specifics of the different realms, it is possible to introduce data literacy concepts at an appropriate level in each of the realms.

In the focus of the Foundations Competency Realm, it is appropriate to introduce the basic concepts of DL to build an understanding of the basic principles concerning data collection, management, and use. Students can become familiar with the history and evolution of data processing and understand their impact on IS development.

The Data/Information Competency Realm should focus on Data and Information Management and Governance. The alignment with data literacy can be achieved in 3 directions:

- Data Management - introduction of basic techniques for organizing, storing, and retrieving data.
- Data Governance – discussing major issues concerning data quality, data security, and compliance with legal standards.
- Data Analysis - application of statistical and analytical tools and methods for interpreting data.

Effective database design techniques, including data modeling, normalization, indexing, etc., should be the main emphasis of a database management course. Students should learn how to create and manage databases that can efficiently handle large volumes_of data while ensuring data integrity and security.

In the Technology Competency Realm, issues concerning IT infrastructure and emerging technologies should be matched to data literacy. It is important for students to obtain a good level of utilizing programming languages like SQL, Python, R, and specialized tools such as Tableau and Power BI.

To efficiently work with large datasets, students need to understand how to deal with distributed computing platforms. This involves understanding and utilizing technologies like MapReduce, Hadoop, and Spark, major NoSQL solutions, as well as effectively leveraging cloud-based solutions for scalable data storage and processing.

Data Literacy elements concerning Systems Development and Project Management should be aligned in the Development Competency Realm. All issues concerning different data-related project handling should be discussed. This includes project planning, execution, monitoring, and evaluation. Here, specifically for the field issues of data integration, such as combining data from different sources and ensuring interoperability, could be considered.

Understanding the distinctive characteristics of the subject area is crucial for the successful development of a new information system. Therefore, in the Organizational Competency Realm, using DL skills to understand specific data in various organizational domains, such as finance, healthcare, education, and others, is very important. With the support of the appropriate analytical tools, strategic decision-making could be enhanced. Here is the place to ensure the ethical use of data in accordance with organizational rules, procedures, and boundaries.

In the sixth realm - IS Integration Realm, elements of data literacy can be included across different disciplines to enhance the role of IS integration in both education and practice. It will ensure that different systems work efficiently together, exchange data, and support implementing data analytics to assist in making strategic and operational decisions within organizations. Including data literacy across different disciplines will enhance the understanding of IS integration.

By aligning these skills, competencies, and tools with the IS2020 competency model realms, students can ensure developing the necessary capabilities to manage data effectively.

4.2. Introducing Data Literacy Concepts through Courses in the IS2020 Undergraduate Program

The IS2020 Curriculum Guidelines provide recommendations for developing undergraduate information systems programs that can be used in many directions. As this document focuses on core topics and skills that should be covered in information systems education programs, it can also be used to encompass how elements of data literacy, which encompasses the ability to understand, interpret, and use data effectively. It can be integrated into a variety of courses already taught within such a program.

Several examples of the most common courses present how this can be realized in practice.

In the first year, in the course Introduction to Information Systems, a specific module could be added that explains basic data concepts about how data is collected, stored, and processed, as well as fundamental principles of data governance. Students can be introduced to basic data collection technologies (databases, data warehouses, etc.) and how that data can be analyzed, visualized, and interpreted.

This will expand students' understanding of the importance of data in the context of information systems and how these systems are used to collect, store, and retrieve data.

Database Management Systems is a core course in which students learn about the evolution and the fundamentals of databases. Using models and techniques for database design, such as ER modeling and normalization, students can be taught how to design systems with an emphasis on good data structuring to ensure their accuracy and usability. Besides discussing different data models - hierarchical, network, relational, object-relational, etc., a focus on the intelligent collection and usage of data in the real world, including issues such as data integrity, data access, data ethics, and the importance of data quality, should be provided. Students should understand not only how to manage data in databases, but also how to assess data quality in the context of business and societal needs.

The Systems Analysis and Design Course is another fundamental course of the program. It is the place where students understand how to design information systems that are capable of managing and processing data effectively. This course focuses on requirements. When gathering and analyzing requirements for information systems design, students should learn how to identify data collection and processing needs.

Working with specific examples of business requirements that require data structuring and analysis (for example, from real-world industry cases) can help students see how to relate data requirements to design solutions. Methods for validating data quality can be included, as well as how to define attributes and relationships for storing data in the system, and how to ensure high data quality.

The Project Management Course in the Information Systems program provides the understanding of the concepts of project management activities and the appropriate project management techniques for information systems development.

Besides understanding and gaining basic knowledge and practical project management skills in the area of project scope, time and cost management, quality and risk management, human resource management, etc., within this course, students can be taught how to plan and organize the processes for collecting, storing, and analyzing data during the implementation of projects. This concerns not only the technological side of the project development, but also important organizational aspects such as defining data needs of the particular company and choosing adequate methods, technologies, and tools for data collection, processing, and visualization.

Students should appreciate the importance of data quality at each level and be able to identify and resolve different problems related to the accuracy and completeness of data in order to ensure an effective decision-making process.

Risk management is an integral part of all project management frameworks, so this course may also discuss risks that are associated with data, e.g., outdated, incomplete, or incorrect data, as well as possible strategies for managing these risks throughout the project implementation. This will help students to develop skills to manage data and processes for their collection and processing in the context of information systems projects, understanding the importance of data quality and reliability for project success.

Further, data literacy can be successfully integrated in some more technologically oriented courses – for example, in a course presenting Web Technologies for Information Systems Development.

In such a course, students can learn how to build web systems that collect data from different sources, how to deal with the challenges associated with diverse data formats, how to ensure data compatibility, and which technologies to implement.

Students should be able to use advanced data visualization methods and tools in web applications to present information in a way that is easily understandable by customers and users. In addition to collecting and processing data, students should deal with the various aspects of data security in web applications - encryption, authentication, and confidentiality.

Emphasizing data literacy in such a course will help students obtain skills to integrate and process data in web applications, while ensuring that the data is safe, accurate, and effectively visualized.

In addition to technological courses, more business-oriented courses, such as an E-Business course, for example, could focus on basic principles for collecting and using data for business analytics - sales, marketing, user behavior data, etc. This course can explain the metrics for e-business evaluation, the understanding of e-business key performance indicators (KPIs), such as user traffic, conversion, etc, or how to use data to personalize customer experience on online platforms.

In this course, students can learn how to analyze user data and predict behavioral trends using statistical and analytical methods, how to perform data analysis in order to optimize business processes, marketing strategies, or customer services, and how to utilize metrics and analytical tools to evaluate the effectiveness of e-business models.

Another ground course focused on ethical and legal issues concerning data processing could incorporate elements of data literacy, explaining the ethical and legal aspects of data usage, confidentiality, and the social and ethical consequences of data manipulation. Students need to understand how data-driven decisions may affect people and the societal influence of information. Students should also explore the legal and ethical issues related to data in order to better realize their professional responsibility.

Incorporating data literacy in such a course on Ethics and Legal Issues in Data will encompass knowledge of ethical issues related to data privacy, security, and responsible use. It will ensure that students are aware of legal regulations and ethical norms when handling data.

Data literacy can be integrated into the above-mentioned or similar courses in various ways, with each discipline offering different opportunities for applying data skills. From information systems design and analysis to project management and web technologies, all of these topics can benefit from a focus on effectively gathering, analyzing, and interpreting data.

Incorporating these elements will help students understand not only how to handle data but also how to leverage their data to benefit themselves.

5. Conclusion

Strong knowledge and skills in the overall processing and management of data are needed today for successfully developing and maintaining the numerous information systems in modern companies. The education of IS students should provide them with high levels of data literacy in order for future IS specialists to handle this.

The article discusses the latest IS2020 undergraduate curriculum and how elements of data literacy can be incorporated when utilizing it for a specific IS program. Two approaches are proposed for embedding data literacy elements.

The first one adheres to the IS competency model realms. This approach ensures that data literacy is systematically aligned to the established IS 2020 competency realms, ensuring coherence and curricular integrity.

The second one points to the number of courses in IS programs, where data literacy elements can be consequently incorporated. Identifying specific courses within IS programs where data literacy components can be naturally and progressively embedded, this approach allows flexible and context-sensitive implementation.

The essential contribution of the suggested approaches is their close connection to the *IS 2020* Competency Model, which ensures integrity and systematicity.

The first approach relies on a comprehensive and in-depth integration of data literacy components into the educational curriculum. Nevertheless, this demands considerable time and cooperation.

The second approach is more easily applicable to practice, enabling one to begin with several courses and expand on what has been accomplished at each new level.

The two approaches can be used separately or in combination, depending on the structure and the goals of the particular university program. Also, because of their modularity, the approaches could be easily adopted for other computing programs such as Computer Science, Software Engineering, Information Technology, etc.

In the future, the progress of data literacy competencies development will be followed and continued by addressing them in the education of information systems programs. Further research will be conducted to assess how suggested approaches impact students' DL competencies and their aligning with industry expectations.

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