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Data Literacy Assessment - Measuring Data Literacy Competencies to Leverage Data-Driven Organizations

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Abstract

In today's rapidly evolving data-driven landscape, the ability to understand, analyze, and interpret data is more important than ever. With an ever-increasing amount of data being generated and collected at an unprecedented rate, both individuals and organizations are forced to develop a high level of data literacy. Data literacy, as the ability to work with, analyze, understand, use, and argue with data, is therefore the key not to drown in data. A detailed data literacy assessment can provide companies with a significant advantage and push their daily and data-related activities to a mature level. A literature review of existing data literacy frameworks with their competencies underscore the need for a flexible and adaptable approach to data literacy that considers the diverse needs and contexts of different stakeholders. While there is no one-size-fits-all assessment, the frameworks outlined in this review provide a useful starting point for developing a common language and set of data literacy skills. The purpose of this paper is to put an accent on the importance of data literacy by introducing an assessment of competencies applicable in different industry sectors that can sustainably support companies to make them realize the need for data literacy and for leveraging their skills. The competencies as part of a data literacy framework as a whole will be applied and validated in different industry sectors for continuous improvement in future research.

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1. Introduction

Today's world is changing rapidly in terms of digital transformation and new technologies, and people are constantly surrounded by these data created [1]. Data is the starting point for knowledge and as digitalization and datafication will permanently change our work and life in the upcoming centuries, it can create the basis for evidence-based and better decisions.

With the ever-increasing amount of data being generated and collected at an unprecedented rate, both individuals and organizations are forced to develop a high level of data literacy. Data literacy includes the skills to collect, manage, evaluate, and apply data in a critical way [2]. Becoming data literate means understanding that different data sources can have

different applications and need corresponding evaluation and analysis methods. It is about being aware of the value that working with data has. Moreover, depending on individual roles, an organization's industry, and its focus, becoming data literate encompasses a different skill set for each role, so developing into a data-literate organization has multiple advantages (e.g., *Evidence-based decision making, Increased efficiency, Improved data communication, Fostering data culture to empower, Scaling the organization, Staying ahead of the competition*). While many of those advantages are no secret to most companies and organizations, the way toward transforming into a data-literate company is scattered with many challenges.

To stay ahead in this data-centric age, it is necessary to be well-versed in various data-related concepts, such as methods

of data collection, data storage, data analysis techniques, and data visualization. A solid understanding of these principles enables professionals to gain meaningful insights from large data sets and derive valuable knowledge [3]. A detailed data literacy assessment can give companies a significant advantage and push their daily and data-related activities to a mature level. Multiple factors come into consideration from the culture, the vision, and strategy to the processes, tools, and technology when talking about data literacy skills. The main ambition of the framework proposed in this article is to help organizations improve their data literacy skills related to master data, meaning all data describing the key business entities on which an organization's activities are based, such as business partners, products, or employees [4].

Therefore, this study aims to answer the following research question: *Which competencies should be part of a holistic data literacy framework which is applicable in all industries helping organizations making better data-based decisions?*

To answer this research question, a literature review has been performed. After reviewing relevant academic publications, an overview of the data literacy frameworks with their focus capabilities is provided. Moreover, an introduction of the capability map of a holistic data literacy framework applicable in all industry sectors to support organizations to make them realize the need of data literacy and to leverage their skills is included.

This paper proceeds as follows. Chapter 2 defines the terms data literacy and gives a concise overview of the current research status and methodology. Chapter 3 presents our findings and gaps of the existing literature. In Chapter 4, the competencies of a data literacy framework for closing the research gap are proposed. This is followed by a discussion of the proposed competencies and its limitations and an outlook on possible future research. Chapter 6 concludes our paper.

2. Methodology

This work considers capabilities which need to be measured to make value out of the advantages of data-literate organizations. Therefore, four data management experts started with a design thinking approach to figure out the needs of an organizations and its individuals. Based on this baseline, the prototype for a data literacy approach will be presented in this paper with the focus on the derived assessment of competencies.

To get an understanding of existing frameworks, a list of the competencies related to data literacy has been created. A literature analysis was undertaken using Google Scholar, Research Gate, ACM, as well as Springer and Emerald publications using the search terms “data literacy framework” and “data literacy assessment”. As this research was conducted by four data management consultants, two groups were formed, each group examining half of the papers found (i.e., Group 1: Paper 1 – 1-13; Group 2: Paper 14-26). After checking for public availability, 23 articles (English and German) were then analyzed in a second step by the other group using predefined criteria: a) focus on which industry and group; b) focus on data literacy definition or methodology and competencies; c) focus

on which competencies. In addition, four frameworks published by industry have also been analyzed.

3. Literature Analysis Results

3.1. Academic Literature

Due to the great potential and novelty of challenges linked to data, there is a great research interest in making the best out of data skills. However, in the past years from 2015 to 2023, the focus of research has been mainly on digital transformation in general. Some newly published papers still focus on assessments and frameworks, that further promote the whole process of digital transformation, while a specific data literacy framework is often disregarded in this research area. Indeed, the topic is getting more and more attention across multiple industries and areas of interest. There are three main questions that arise when exploring the existing literature: Who are the main stakeholder groups or industries covered in the literature? Which data literacy frameworks have been published? Which competencies have been captured?

Groups and industries: Firstly, the goal was to identify the main target groups or industries in the previous research analyzed. Most of the authors focus on data literacy education in the context of data-related activities. Indeed, many of the articles and papers target students, teachers, and academic libraries. By targeting this group, the goal is often to assist the research community and librarians at data management and technology driven research [5, 6], make recommendations of specific improvement of the university data management policies [7] or improve the way students are educated on data related topics for their future professional life [8]. By this last aspect, the authors want to rise the concern that it is important for students to be able to answer questions using data, to interpret information, and using data to solve problems and communicate solutions [9].

Some articles deviate from the education sector and put their attention on journalism [10] or the public sector [11]. Data literacy is one of the skills required for the future of the profession [10]. Moreover, in the same spirit as private companies, the public sector is aware of the tendency of building a culture of data-informed decision making and service provision and developing an effective working relationship between data specialists and non-specialists [11].

Finally, the few articles which elaborate on data literacy for private companies express the need to develop data literacy in organizations and applicable to a wide range of industries [12].

Content: In terms of content, just a small number of articles develop entire data literacy frameworks. Most of them are limited to the definition of data literacy, and the competencies and skills that need to be developed. These competencies and skills can be applied in various fields to effectively work with data, derive meaningful insights and improve data-decision making [13, 14]. Some also develop methodologies for teaching data literacy in order to reach a certain level of a data literacy indicator evaluating the skills of reading and talking about them [15]. By developing methodologies to evaluate and assess the required data literacy skills, some articles pushed the topic further. Most of the skills assessment methodologies

found, take the form of questionnaires or self-assessment scales. People realize the need for employees to have access to data and the skills to interpret them, enabling these people to track their work progress, make data-driven decisions, and improve their performance but without mentioning a specific framework to help the organization grow in that direction [16]. The following Table 1 shows the classification of articles by the data literacy aspects they address most.

Table 1. Literature review results classification

<i>Competencies</i>	<i>References</i>
Data fundamentals/ data concepts	[15],[3],[17],[18],[19],[20],[21],[22]
Data interpretation	[12],[8],[10],[11],[21],[23],[24]
Data visualization	[5],[9],[10],[11],[12],[14],[14],[19],[21]
Data privacy and ethics	[15],[8],[9],[11],[12],[16],[17],[25],[18],[19],[21],[23]
Data governance	[9],[16],[19],[24]
Data-driven decision making	[15],[12],[8],[9],[11],[12],[14],[16],[17],[25],[18],[20],[21],[22],[23],[24]
Bias evaluation	[9],[14],[16],[18],[20]
Data collection	[2],[3],[6],[8],[9],[10],[11],[12],[14],[16],[17],[25],[19],[20],[21],[23],[24]
Data analysis	[2],[15],[3],[6],[8],[9],[11],[12],[14],[16],[17],[25],[19],[20],[21],[22],[23],[24]
Data management skills	[2],[3],[5],[7],[11],[12],[14],[16],[17],[25],[19],[20],[21],[23],[24]27-03-2024 16:17:00
Data sharing/ Communication	[2],[15],[3],[12],[5],[6],[8],[9],[10],[11],[12],[16],[17],[19],[20],[21],[23]
Data quality	[2],[3],[9],[10],[11],[12],[14],[16],[17],[19],[20],[21],[24]
Data storage and access	[2],[3],[11],[16],[19]
Data modelling and cleansing	[2],[15],[3],[11],[16],[17],[19],[20],[21]
Data tools	[2],[3],[14],[16],[17],[19],[20],[21],[23]
Discipline-specific expertise	[2],[17],[23]
Information literacy	[2],[3],[12],[17],[19],[23]
Statistical literacy	[2],[3],[9],[14],[17],[19],[23]
Computational skills	[2],[3],[12],[14],[17],[19],[23]
Critical thinking	[2],[3],[11],[12],[14],[17],[25],[19],[20],[21],[23]
Digital literacy	[2],[14],[17],[19],[23]
Problem identification and solving	[2],[11],[14],[19],[20],[21]
Data culture	[2],[15],[11],[21],[22]

3.2. Industry Literature

In addition to the review of research papers, four industrial data literacy frameworks have been examined. In the following, the main focus of these frameworks and their capabilities will be summarized.

One of the best-known data literacy frameworks is the one developed by Gartner. According to Gartner, data literacy

includes the ability to read, write, and communicate data in context, with an understanding of data sources and constructs, analytical methods and techniques applied, and the ability to describe the use case application and resulting business value or outcome. This framework emphasizes the importance of understanding the context in which data is used and the ability to communicate effectively with stakeholders [22].

The Open Data Institute (ODI) has developed a framework that consists of three levels of data literacy: awareness, skills, and leadership [20, 26]. The awareness level includes understanding the value of data and how it can be used to inform decision-making. The skills level includes the ability to work with data, including data analysis, visualization, and interpretation. The leadership level includes the ability to lead data-driven projects and initiatives, including data strategy, governance, and ethics. This framework emphasizes the importance of developing data literacy at all levels of an organization, from entry-level employees to senior leaders.

An additional notable framework for data literacy is presented by the European Data Science Academy (EDSA) proposed in 2017 [20]. The EDSA framework defines data literacy as "the ability to read, understand, create, and communicate data as information" and identifies six key competencies: data awareness, data analysis, data design, data ethics, data management, and data visualization. The framework is designed to be used as a self-assessment tool for individuals to evaluate their own data literacy skills.

The Data Literacy Project, a collaboration between Qlik and the Cognizant Center for the Future of Work, proposes a framework that highlights the importance of data literacy in the workplace and identifies four key components: data understanding, data analytics, data management, and data storytelling. The framework is designed to help companies establish a culture of data literacy and empower employees to make data-driven decisions [12].

Overall, these reference frameworks can be used by individuals and organizations to assess their own data literacy skills and develop strategies to improve those skills. Through all the literature review results, we see that each author selects their own criteria to define data literacy and develops their own means of assessing the degree of data literacy of the group they are interested in. Nevertheless, the existing data literacy frameworks highlight the need for a flexible and adaptable approach to data literacy that considers the diverse needs and contexts of different stakeholders.

3.3 Insights

The following insights could be obtained: First, it can be stated that no framework includes all different competencies in one skillset approach.

Second, there is a need to develop the topic to apply it to the corporate world. In the digital and data-oriented world which organizations operate in, all employees need to have the required knowledge and data literacy skill set required for their function. To reach that goal, it can be considered how to transfer findings from the analyzed articles to the companies and gather the existing ones.

Moreover, there is a lack of details and granularity in the existing data literacy frameworks. There is a need to go further in the process of evaluating the skills that make people and organizations able to handle data adequately, and being good data literates. Reaching the stage of a data literacy in an organization is a journey along which it is necessary to analyze the current situation. Therefore, a methodology going from the clear elaboration of definitions and objectives to a complete roadmap to ensure developmental longevity is needed.

For all these reasons, these finding should be considered by developing a data literacy framework which includes a data literacy assessment as an essential ingredient to support industrial organizations to overcome many challenges encountered in today's corporate world. Industrial organizations will have to develop the skills of the future but above all must do so in a sustainable and guided way.

4. Data Literacy Approach

The proposed data literacy approach (cf. Figure 1) wants to tackle the aforementioned individual and organizational needs, with a focus on master data-related topics. It addresses the aspects data security, data privacy, data transparency, data availability, data sustainability, data quality and data visibility. The whole approach can be performed within one up to two months, depending on the individual organization and size.

To start the 5-step-approach, a clear scope including stakeholder management needs to be defined, and an overview of the customer as-is situation must be derived (step 1). This includes identifying key stakeholders, performing a pre-study of current customer situation, engaging project road shows, adaptation to a customer designed assessment method and the definition of relevant data roles and data literacy levels within the organization.



Figure 1. Data Literacy Approach

After building the basis, a data literacy assessment should provide the status of the organization regarding derived competencies which are important in the context of a data-literate organization. This assessment constitutes the core of the whole approach since it gives the direction for the following steps 3 up to 5 in which milestones and the way forward out of the assessment results must be created. The data literacy assessment of the organization is performed via surveys and dedicated interviews to conduct later a change impact analysis (CIA) and a training need analysis (TNA). Step 3 includes the evaluation and possible adaptation due to assessment results. In step 4, a specific training concept can be enabled before realization and transforming it in step 5 to the organization. This includes defined data personas and learning paths templates and KPIs to sustainably monitor improvement of data literacy skillsets. Creating a training syllabus, training plan and set up training communications along all milestones.

4.1 Assessment of Competencies

A data literacy maturity assessment containing 23 competencies in eight groups which can be applied independently from each other on individual customer requirements is conducted by including analyzed competencies from research as well as further competencies addressing organizational and individual requirements. Figure 2 shows the competency map of the assessment.

The scope of the assessment focuses on small data, more precisely on master data. Thanks to its modular architecture, the proposed approach supports adding data literacy related aspects on all architecture levels (domain-level, sub-domains, and questions). Experience from comparable frameworks (e.g., SPICE, CMMI) tells us that the more precise and fine-grained the evaluation framework, the more focused and target-oriented the improvement strategy can be.

All competencies of the map are measured against levels starting from 1 to 6. In addition, each capability is getting a relevance status signaling the organization's priority which is given after an evaluation together with the organization's people. The levels follow the ISO 33000 standard [27]. For all competencies a questionnaire has been derived to figure out the level of maturity. Each level also has its own definition so that the degree of maturity can easily be derived by experts. At this stage, the framework is meant to be used for experienced experts. Nevertheless, the guidance should help experts with lower experience levels to also be able to perform the approach. Moreover, this assessment approach is also applicable to a general strategy data management assessment model introduced by Pörtner et al. 2022 [28].

Eight different groups, named data foundations, data management skills, data analysis skills, data interpretation, data problem solving, communication skills, data culture and advanced skills try not just to capture technical skills, but also a critical thinking skill. To be truly data literate, individuals shall not only be able to work with data, but also to question, analyze, and interpret it in a meaningful way. Moreover, data literacy is not only an individual skill but also an organizational and societal skill. Organizations need to develop a culture of data literacy to take full advantage of data-driven decision making. This requires not only training employees in data literacy, but also creating an environment that values data and encourages experimentation and innovation.

In the following, each group with its competencies is described to get an understanding of what is necessary to measure.

Data foundations include questions about existing data concepts and the way in which data is collected within the organization and which data sources are used. Especially in the age of increasing fake news, the dimension of data foundations forms a decisive basis for data quality.

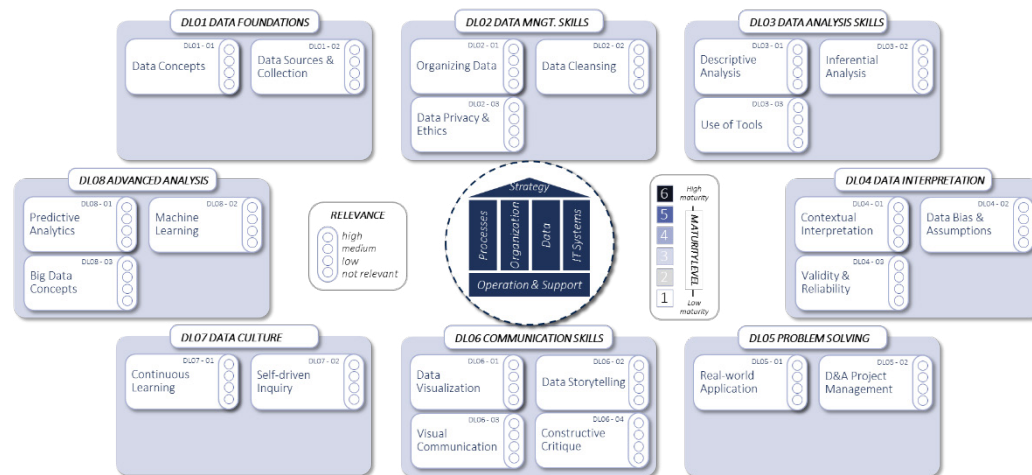


Figure 2. Competency Map

Data management skills go one step further and look at the organization of data, how data is cleansed. This also includes the question of how to deal with data privacy. This also includes the topic of data ownership and governance. **Data analysis** describes the technical, analytical handling of data. It is important which analysis tools are used. In addition, a distinction must be made between purely descriptive analyses and predictions made with data in the company. It is crucial to understand whether the focus is purely on describing the visible characteristics of a dataset or whether the organization is already extracting value from its data. Based on the topic of data analysis, **data interpretation** is an important component to be investigated, as existing data must also be interpreted correctly in order to prevent false statements. The aspect of data bias and assumptions also plays a role here, also in connection with validity and reliability of the data. Following on from the technical analysis skills, the dimension of **problem-solving** is to be added. It is questionable whether analyzed, interpreted data can also be used in everyday organizational life and in data and analytics projects. The competencies around **communication** focus on the critical skill of individuals and an organization. This is about how data is critically questioned, visualized, and communicated. Data storytelling plays a decisive role to be able to classify data into the overall concept. Even if a company is data-driven and has high data literacy skills, it is important to create an environment that values data and encourages experimentation and innovation. Therefore, it is of great importance to establish a **data culture** that is continuously evolving. In connection with this, **advanced skills** are also needed to be able to use innovative solutions within the organization for one's own progress and efficiency. These include, for example, predictive analyses or machine learning applications.

5. Discussion and Evaluation

The proposed data literacy framework approach with its data literacy assessment attempts to close the gaps and to address the stakeholder needs by tackling the advantages of data literate organizations. The analyzed frameworks focus on data literacy education with a user group of students, teachers and academic libraries or private companies. Mostly, the frameworks focus

on giving a data literacy definition by not going more into detail in methodology and approach steps. The proposed framework shifts the perspective more to provide a practical holistic approach for small data enriched with more competency details. 23 competencies in eight groups are derived to get a clear picture of the organization's scope to enable organizations people better to make *evidence-based decisions* by also *improving the data communication* and *fostering a data culture*. This can be guaranteed through the step of enabling a training and monitoring concept. Moreover, the grow of an organization and its data can be handled through the training and the skills provided. Nominated data personas learn to fulfill the requirements of their roles. *Increased efficiency* and *staying ahead of the competition* can be realized by measuring the status within the data literacy assessment and building up a customer-specific roadmap to become a data-literate organization. To make value out of the advantages, organizational as well as needs from the employee have been considered by creating the framework design. How to tackle *data security* and *data privacy* correctly will be part of the trainings and governance structure which is build up within the organization. Therefore, employee and respective data personas also learn to provide *data transparency* which is linked to provide better *data availability* and higher *data quality* within the organization. Used data can then be made visible and provided to make value out of it for further activities and decisions (*data visibility* and *data sustainability*).

This work has several limitations: First, its practical validation is only in a very early phase since its deployment in practice requires adequate partnerships. The evaluation of the framework will be performed based on interviews/ experiments with decision makers and subject experts in five different industry sectors (automotive, aviation, consumer goods/manufacturers, pharma and media). The effectiveness in terms of understandability, feasibility (interview time, target profiles etc.), completeness (through interview questions) on several hierarchy levels in the different sectors will be evaluated by experts as well as the understandability, completeness, and satisfaction level of the interviewed people after each interview will be collected. It is yet unknown how the sampling of data literacy based on selected stakeholder interviews allows to make conclusions on the data literacy levels of one or several organizational units.

Second, the feasibility of the proposed data literacy framework still needs to be verified. Due to its modular architecture, the framework can be adapted easily. The biggest customization need from our experiences arises from different data types. The impact of this, however, is not on the top-level framework architecture. Here, the challenge is to find out the customization needs depending on the different data types.

Third, the scalability of the data literacy framework for different sized organizations in multiple industry sectors is based on a theoretical consideration only at this stage. There is no criterium evaluated that depends on specific industries or sizes. As the data literacy levels may vary across organizational units, the actual scalability requires an application of the framework to several units. Future research needs to be done to see if the proposed framework needs to be tailored more precise for evaluating data literacy for different data types.

Forth, this work did not yet investigate the skills required by assessors or consultants to perform the approach in practice. Therefore, level descriptions as guidance should help to derive a measuring scheme and make it more transparent. For the current evaluation cycle of the framework, interviewees have a higher experience level of knowledge in the area of data management, meaning that they have more than three up to ten years of experiences in this domain.

6. Conclusion and Outlook

Data literacy is a critical skill for individuals and organizations in today's data-driven world. While individual solutions for developing data literacy are required, the frameworks, and resources we examined provide a useful starting point for developing a common language and set of skills around data literacy. By investing in data literacy, individuals and organizations can unlock the full potential of data and make more informed decisions. We have proposed a data literacy approach including an assessment of competencies that provides the enabling basis for data-driven organizations applicable in all industry sectors. The essential unique contribution in the whole data literacy approach lies in covering the requirements of an organization by first measuring their maturity related to small data and providing a customer-specific roadmap. In our future work, we aim at building up more precise data literacy level definitions and validating our approach with pilot partners from industry in the context of data management. From an education perspective, we will investigate how designers can be trained and empowered to be able to consider the proposed solution concept.

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