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Empowering Nurses Through Data Literacy and Data Science Literacy

Insights From a State-of-the-Art Literature Review

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IN THE DYNAMIC landscape of modern health care, where artificial intelligence (AI) and data-driven services are increasingly adopted, nurses find themselves at the forefront of a significant transformation. As frontline health care professionals, they stand at the intersection of escalating data availability and its growing significance. Through their extensive documentation, nurses generate vast amounts of data essential for health care innovations.[1] To provide quality patient care and improve health care outcomes, nurses must grasp the principles of data science and utilize data proficiently.[2,3] This necessitates comprehensive education designed to equip nurses with a nuanced understanding of both data literacy and data science literacy.

Data, within the data-information-knowledge-wisdom framework, refers to "discrete entities that are described without interpretation"[4(p.227)] often in the form of numbers or text that can be analyzed and interpreted to gain insights and make informed decisions. *Data science* is the field that deals with extracting knowledge

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Statement of Significance

What is known or assumed to be true about this topic?

1. The volume and complexity of data that health care professionals must understand and use is increasing exponentially, driven by the growing demands of data-driven health care to promote patient outcomes and address health equity.
2. There is a critical need for comprehensive education tailored to equip nurses with a nuanced understanding of both data literacy and data science literacy.

What this article adds:

1. A review of recent frameworks, models, training, and assessment tools for developing data literacy and data science literacy among nurses and other health care professionals.
2. Recommendations for action in educational and practice settings to enhance data literacy and data science literacy among nurses.

and insights from data through various scientific methods, algorithms, and systems.[5] *Literacy* is the ability to read and write, which refers to competence or knowledge in a specific area or field.[6] Data literacy commonly refers to knowledge about data and how to use it, whereas data science literacy refers to advanced skills and a deeper level of competence in using and extracting knowledge from the data.[7]

The evolution of data literacy and data science literacy reflects broad shifts in data interpretation and analysis skills, moving from basic understanding to more sophisticated methodologies. Initially, data literacy centered on fundamental skills, such as interpreting charts and graphs. However, with the advent of digital technology and the increasing complexity of data, the scope of data literacy has broadened to include critical assessments of data sources, understanding data collection methods, and interpreting complex datasets for decision-making.[8,9]

Data science literacy emerged alongside the growth of data science field.[10] The term "data science" was first proposed by Peter Naur in 1974 as an alternative name to computer science.[10] As data science became integral across industries, the need for professionals to understand data science tools and methodologies surged. This has led to an expansion of data science literacy beyond computation expertise, encompassing knowledge of algorithms, data management, ethical considerations, and the practical application of data-driven insights.[5] Educational institutions have responded by developing curricula that teach these advanced skills.

In health care, the concept of data literacy expanded over time to include the interpretation and analysis of clinical outcomes and patient-reported data. The growing emphasis on evidence-based, patient-centered care demands that health care providers are data-literate, ensuring informed clinical decisions based on accurate data interpretation. Additionally, data science methodologies in health care evolved to include complex tasks such as predictive modeling, natural language processing, and the development of decision support systems—tools instrumental for improving patient outcomes, personalizing treatment plans, and enhancing health care delivery.[11] Today, data literacy and data science literacy are recognized as essential competencies within health care, empowering professionals to leverage data effectively.

Despite the pivotal role of data literacy and data science literacy in nursing practice and research, significant ambiguity remains regarding the distinctions between these literacies. This ambiguity affects nursing professionals across roles, including students, nurses, nurse practitioners, nurse administrators, nursing faculty, nurse informaticists, and nurse scientists, leaving a gap in expectations for data science literacy training within the nursing field. This review synthesizes training efforts and frameworks related to health care data literacy and data

science literacy across academia, practice, and industry. This paper also aims to elucidate the distinctions between these literacies and offer insights into strategies for nurturing them within nursing education, practice, and research.

METHODS

Study design and search strategy

We conducted a state-of-the-art literature review, a methodology that addresses emerging trends and insights from the latest literature and identifies key areas that warrant further research.[11] This approach was chosen to capture the most recent and significant advancements in the rapidly evolving fields of data literacy and data science literacy in health care. Unlike systematic reviews, which focus on specific questions with strict inclusion criteria, a state-of-the-art review offers the flexibility to explore a broader range of topics, allowing for a thorough assessment of emerging insights and practices.[12,13] We followed a 6-step approach, which includes determining the research question, setting the timeframe, finalizing the research question to reflect the timeframe, developing a search strategy, and employing reflexivity in presenting the findings.[13] This process ensured that our review remains relevant and reflective of our topic in the data-driven health care landscape.

Systematic literature searches were conducted from October to November 2023 using PubMed, ProQuest, Scopus, CINAHL, and Google. The search strategy, initially developed using MeSH terms and keywords with Boolean operators in PubMed, was consistently applied across other databases. Key search terms included data science, data literacy, data competency, training, education, assessment, curriculum, clinical, practic*, healthcare occupations, and healthcare personnel. The search was limited to English-language literature published from August 2018 to August 2023. The initial search for articles on data literacy issues in academia yielded 330 unique articles after excluding 13 duplicates across databases. Similarly, the search for articles on data literacy issues in clinical practice identified 146 unique articles, excluding 15 duplicates. Additionally, Google searches revealed 5 reputable industry web resources.

Selection and review process

Figure 1 presents the literature selection process, adhering to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.[14] Included articles met the following criteria: (1) direct relevance to data literacy or data science literacy within the health care domain, (2) exploration of concepts, curricula, training, or assessment tools related to data literacy or data science literacy, and (3) publication in peer-reviewed journals, conference papers, books, reports, or materials. Article abstracts were initially screened by a pair of reviewers using Rayyan.[15] Following the abstract screening, 40 articles on data literacy issues in academia and 21 on data literacy issues in clinical practice were selected for full-text review.

In the first round of article reviews, pairs of reviewers conducted independent assessments. Subsequent rounds involved all reviewers working together until consensus on inclusion and exclusion criteria was reached. Ultimately, 22 articles (15 in academia and 7 in clinical practice) and 5 industry web resources were chosen for data extraction. Data were recorded in a Microsoft® Excel template, encompassing categories such as title, first author, year, study purpose, definitions of data/data science literacy, frameworks used, domains of data/data science literacy, content and duration of training programs, study settings, target audiences, assessment tools for data literacy and data science literacy, and outcomes.

The results are organized as follows: first, an overview of the reviewed articles and web resources is presented. The findings are then divided into 2 main sections: reviewed articles and web resources, reflecting the distinct nature of these sources. The reviewed articles section is further subdivided to highlight key findings, including

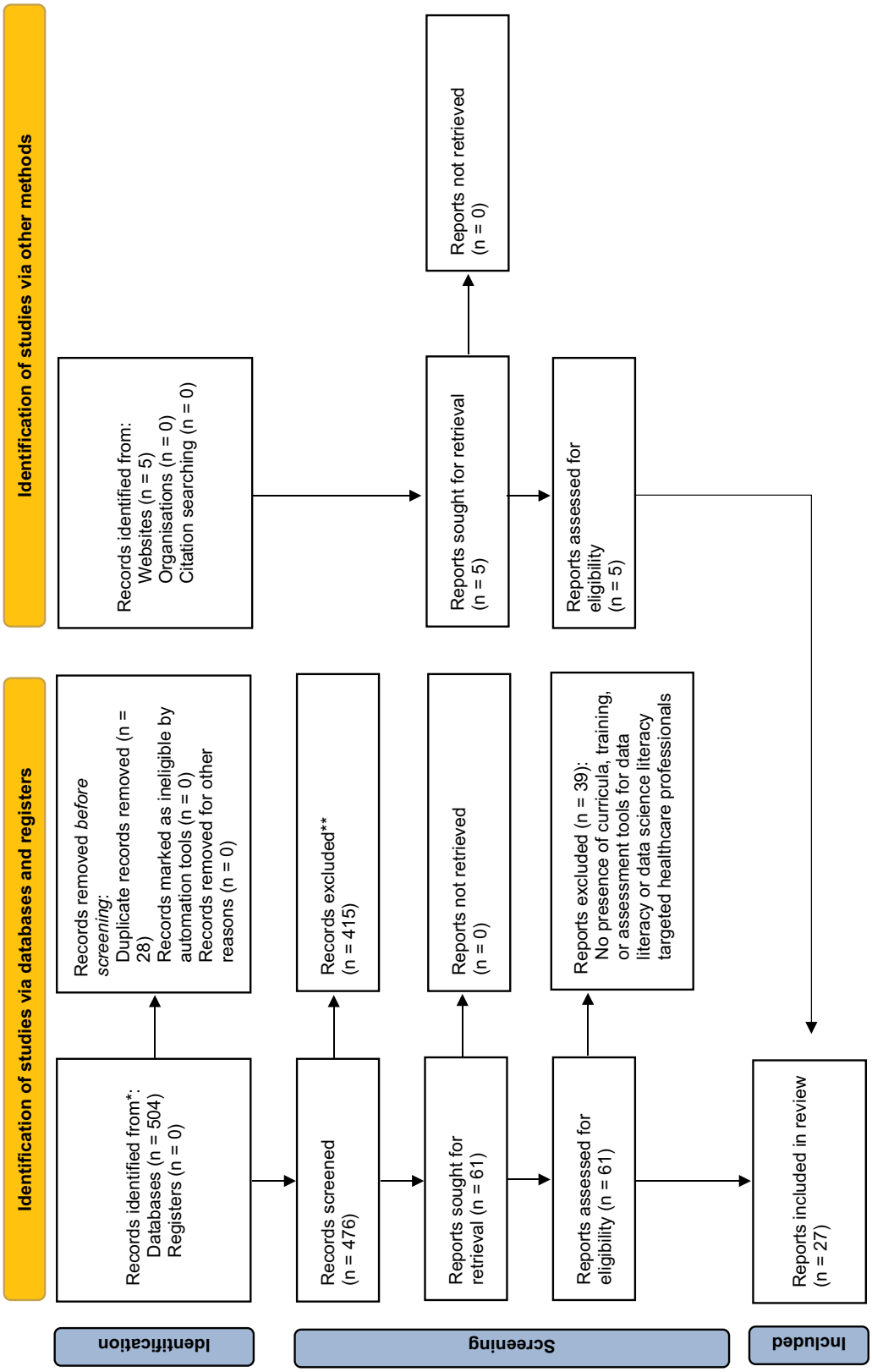

Figure 1. Selection process.

definitions of data literacy and data science literacy, components of frameworks, training content, and assessment tools. The web resource section summarizes all relevant insights from the 5 industry web resources.

RESULTS

Overview of the reviewed articles and web resources

In articles describing academic programs for data science literacy, we found 2 quantitative survey studies,[16,17] 2 quantitative program/course evaluations,[18,19] 5 reviews,[20-24] and 2 opinion articles.[25,26]Additionally, 3 articles presented frameworks for developing data science literacy programs.[27-29] One article described a data science curriculum model for a Doctor of Philosophy (PhD) nursing program.[30] In the realm of clinical practice, 7 articles were found, including 1 randomized interventional study,[31] 1 scoping review,[32] 2 cross-sectional studies,[33,34] 2 commentaries,[35,36] and 1 quasi-experimental study.[37] We also extracted relevant web resources from 5 industry websites: datacamp.com,[38] qlik.com,[39] quanthub.com,[40] tableau.com,[41] and healthcatalyst.com.[42]

Reviewed articles

Definitions of data literacy and data science literacy

None of the reviewed articles provided the distinction between data literacy and data science literacy. Furthermore, few articles provided refined definitions of data literacy, with some emphasizing health care–related literacies such as data and information literacy,[25] nursing informatics (NI) competencies,[31,32] public health informatics competencies,[33] digital information literacy,[34] and genomic literacy.[35]

In the context of data literacy for nurses, 2 articles described NI competency as encompassing the nurses' knowledge, skills, and attitudes to collect, store, retrieve, process, and use information in nursing care, ranging from simple clinical skills to complex application-based knowledge.[31,32] Further research was recommended to reach a consensus on core domains of NI competency and its assessment tools through a scoping review of 52 relevant articles.[32] Bergren and Maughan[25] emphasized that data literacy involves accessing, manipulating, evaluating, communicating, sharing, presenting, preserving, and applying data information in care delivery, advocating for data literacy training in school nurses.

Public health informatics competencies encompassed identifying appropriate sources of data and information to assess community health, collecting valid data, participating in quality improvement processes for agency programs and services, and identifying evidence-based approaches to address public health issues.[33] Digital information literacy was defined as the set of knowledge, skills, attitudes, abilities, strategies, and awareness required when using information and communications technology and digital media.[34] Genomic literacy emphasizes understanding the complex interactions of polygenic inheritance and the chronicity of disease, which is required for community health care workers to deliver precision health care.[35]

Also, there was a lack of articles that explicitly defined data science literacy, while several discussed the various definitions and scope of data science itself.[20,22,24,26,29] For example, Foster and Tasnim[20] defined data science as the systematic study of the organization and use of digital data to accelerate discovery, improve critical decision-making processes, and enable a data-driven economy. Moore et al[22] defined data science as the integration of statistical and computational techniques with domain knowledge to gain insights from big data, addressing prespecified questions and discovering novel hypotheses in an unbiased manner. Tolsgaard et al[24] stated that data science aims to utilize statistics, AI, and machine learning (ML) to extract knowledge from data, employ database management to organize, manage, and store data, and apply systems engineering to provide the computational infrastructure needed for complex data analyses. Dreisbach and Koleck[29] defined

genomic nursing data science as the intersection of biology, statistics, computer science, and nursing domain expertise.

While data science has been commonly described as an interdisciplinary field,[24,26,27,29] Loftus et al[26] emphasized that it incorporates 3 realms: mathematics and statistics, domain knowledge, and computer science. Rather than defining data science literacy, Shea et al[30] asserted 6 data science constructs for PhD nursing students: domain, ethics, theory, technical, analytics, and dissemination. Awad et al[16] described data science skills ranging from data collection, labeling, and analysis to complex computational techniques such as ML.

Various terms such as data intelligence,[18] digital capability,[28] AI literacy,[36] and statistical literacy (SL), and scientific reasoning and argumentation (SRA)[37] have been introduced, emphasizing the transformation of data into value and covering principles such as data governance, basic statistics, data visualization, and their impact on clinical processes. For instance, Gutierrez-Aguado et al[18] used the term data intelligence to describe the transformation of data into information, information into knowledge, and knowledge into value. Davies et al[28] defined digital capabilities as ranging from basic digital literacy to advanced skills with data and analytic methods. Wiljer and Hakim[36] described AI literacy in health care as implementing ML approaches to emulate clinical decision-making, track patient health, deploy advanced analytics to sift through large data sets for clinical efficiencies, and use natural language processing to conduct surveillance and predict outbreaks. Schmidt et al[37] differentiated SRA, the competence of comprehending and applying scientific working methods and their results to solve problems, from SL, defined as the ability to explain and critically evaluate statistical numbers.

Data literacy and data science literacy frameworks

Table 1 presents a comprehensive view of various frameworks and their components related to data literacy and data science literacy, illustrating the interdisciplinary nature of the field. For the data literacy framework, relevant frameworks identified include: NI competency[32] and the European Commission Digital Competency Framework.[34] Regarding data science literacy frameworks, we identified the Data Intelligence Model,[18] Graduate-level Health Data Science Curriculum Model,[27] an extension of the Health and Care Digital Capabilities Framework,[28] genomic nursing data science lifecycle,[29] Data Science Curriculum Organizing Model (DSCOM),[30] and SRA.[37] Some articles did not present a specific name for their framework but outlined domains of data science literacy along with their definitions of data science.[16,24,26] While each framework included unique components specific to their approach, they commonly emphasized data analysis, computational techniques (AI, ML), and domain knowledge. Ethics was also included in some frameworks.[18,28,30]

Data literacy and data science literacy training

Only 1 article provided detailed information on data literacy training specifically designed for critical care nurses.[31] This program, encompassing computer skills, information sourcing, and practical application exercises, was delivered as a 3-day, 8-hour workshop over 3 weeks across 18 critical care units.

In contrast, data science training programs were the focus of a greater number of articles. While some articles presented the actual training content for data science literacy,[16,18,19,21,30] most proposed essential content for data science training programs or curricula targeting a diverse group of health care professionals. A comprehensive description of these data science training programs, including the target audience and training duration, is provided in Table 2. Three articles focused exclusively on nurses and nursing students, proposing data science content for nursing curricula at

Table 1. Data Literacy and Data Science Literacy Frameworks and Components

First Author (Article)	Framework Name	Framework Components
Data Literacy		
Bergren[25]	Data Literacy Framework	Accessing; manipulating; evaluating; communicating; sharing; presenting; preserving; applying data
Kleib[32]	Nursing Informatics Competency	Common to beginning and experienced nurses—computer skills (administration; data access; education; monitoring; basic desktop software); informatics knowledge (data; impact). Unique to beginning nurses: computer skills (communication; decision support; documentation; systems). Unique to experienced nurses—computer skills (quality improvement; research); informatics knowledge (research); informatics skills (evaluation; role; system maintenance)
Shiferaw[34]	European Commission Digital Competency	Information processing; content creating; communication; safety; problem solving.
Data Science Literacy		
Awad[16]	Data science (no specific)	Data analysis; artificial Intelligence; machine learning
Beyene[27]	Health Data Science Curriculum Model	Domain knowledge; computer science; statistics/mathematics
Davies[28]	Extended Health and Care Digital Capabilities	Digital implementation; digital health for patients and public; ethical, legal, and regulatory considerations; human factors; health data management; artificial intelligence
Dreisbach[29]	Genomic Nursing Data Science Life Cycle	Developing a research question; collecting/obtaining omics and phenotype data; wrangling/preprocessing; analyzing/interpreting; translating/implementing findings
Foster[20]	Data science (no specific)	Data cleansing; cluster analysis; natural language processing; data visualization
Gutierrez-Aguado[18]	Data Intelligence Model	Data science; artificial intelligence; epidemiology; public health services; health information systems; global health; ethics; new technologies
Loftus[26]	Data science (no specific)	Mathematics/statistics; domain knowledge; computer science
Schmidt[37]	Scientific Reasoning and Argumentation	Problem identification; questioning; hypothesis generation; construction and redesign of artifacts; evidence generation; evidence evaluation; drawing conclusions; communicating; scrutinizing scientific reasoning and results
Shea[30]	Data Science Curriculum Organizing Model	Domain (expertise, meaning, cohesion, applications); ethics (privacy, safety, intent, mining); theory (representation, organization, interpretation); technical (learning & execution of models, capture, process); analytics (transforming, learning, predictive); dissemination (exploration, visualization, communication, insights)
Tolsgaard[24]	Data science (no specific)	Artificial intelligence; machine learning; natural language processing

Note. Data science (no specific) means that while data science is mentioned, there is no specific framework or named reference.

Table 2. Data Science Literacy Training

First Author (Article)	Training Content	Target Audience (Training Duration)
Awad[16]	Current curricular topics covered across universities identified via survey: cloud services (Amazon Web Services, Google Cloud); database management (SQL); scripting (BASH/SHELL); data visualization (Tableau, Excel); version control (Git); statistical programming languages (R, Python); utilization of ML libraries; AI application to health disparities research	Biomedical undergraduates, postdoctoral and early-stage and senior faculty (N/A)
Beyene[27]	Proposed graduate curriculum for health data science program: regression modeling strategies; health informatics; data science/ML; advanced algorithm analysis; infectious disease modeling; data science practicum; fundamentals of health research methods; computational statistics; ethics and scientific writing in health research; data visualization; exploratory analysis; mathematical statistics; big data analytics; introduction to R/Python; research thesis	Graduate students in Africa (graduate program)
Davies[28]	Proposed post-graduate certificate of data science program content coverage: clinical data engineering; math, stats, and ML; data visualization and communication; human factors and digital transformation	Health care professionals (N/A)
Dreisbach[29]	Proposed training content for genomic nursing research: creating research question amenable to data science solutions; data wrangling; data preprocessing; data analysis with computer programming knowledge and ability to use data editing software; statistical knowledge; skills in analysis for supervised and unsupervised methods	Students, nurses, nurse scientists (N/A)
Foster[20]	Proposed curriculum for graduate nursing education: quantitative research methods including ML, AI and advanced mathematical techniques; advanced programming techniques with various statistical packages (eg, Stata, SAS, and R); integration of data security content into ethics courses; data cleansing; cluster analysis; NLP; data visualization; mock predictive analyses with data manipulated into reports and graphs; appraisal of data quality in datasets using health on the Net Foundation Standards	MSN, PhD, DNP students (N/A)
Gutierrez-Aguado[18]	Seven learning modules and workshops: basic concepts of epidemiology in public health; health data management and modeling: dynamic models; health information systems; intelligence and visualization of health data; AI application in health: identification of numerical patterns, texts, and images; workshop: SIR model—Python: concepts and applications; workshop: ML and epidemiological patterns	Peruvians with a high academic level or professional degree/ research profile (5 months)

(*continues*)

Table 2. Data Science Literacy Training (*Continued*)

First Author (Article)	Training Content	Target Audience (Training Duration)
Heredia-Negron[19]	Current course: Part 1: theoretical concepts of AI, ML, health disparities, and data sources; Part 2: developing skills in R and Python; Part 3: implementation of predictive ML models, presentations, lectures, demonstrative videos, and reading materials in English and Spanish	Graduate, undergraduate, early-stage investigators, university staff (15-week course)
Hersh[21]	Current curricula for biomedical and health informatics: overview of biomedical data science; overview of biostatistics, ML, and AI; critical assessment of ML literature; introduction to data sources and programming languages; data preparation; data exploration; using code libraries or visual programming tools for ML algorithms (k-nearest neighbor, logistic regression, decision trees, random forest, support vector machines, and neural networks); model implementation; ethical considerations	Biomedical Informatics graduate students (varied by program—certificate, Masters, PhD)
Loftus[26]	Proposed training for surgeons: mathematics/statistics; domain knowledge; computer science	Surgeons (varied by program—residency, Masters, PhD)
Moore[22]	Proposed curriculum for personalized/precision medicine: data management and integration including database experience; statistical analysis including basic concepts and methods in probability and inference; data science including computer programming and methods; AI including AI fundamentals, ML, NLP; biomedical domain knowledge and motivation for using big data	Biomedical students (during graduate courses)
Shea[30]	Curriculum including advanced statistics for health sciences, health care informatics theory and practice, theory development and evaluation, quantitative methods and qualitative methods in nursing research	PhD nursing students (throughout PhD program)
Wiljer[36]	Recommended AI education: data governance principles; basic statistics and algorithmic decision-making; data visualization and storytelling capabilities; understanding of the impact on clinical processes	Broad health care professionals (N/A)

Abbreviations: AI, artificial intelligence; DNP, doctor of nursing practice; ML, machine learning; MSN, master of science in nursing; NLP, natural language processing; N/A, not available; PhD, doctor of philosophy; SIR model, susceptible, infectious, recovered model; SQL, structured query language.

the master's, Doctor of Nursing Practice (DNP), and PhD levels,[20] genomic nursing education,[29] and PhD nursing curricula using the DSCOM.[30] Expanding the scope, experts shared data science course outlines designed for undergraduate and graduate biomedical students,[16,22,27] faculty,[16,19,27] multidisciplinary professionals,[18] biomedical researchers,[19] physicians and medical students,[24] surgeons,[26] and general health care professionals.[28] An interdisciplinary approach to data science education was

advocated, emphasizing the consideration of context with ML-driven solutions.[24] Common curricular elements included mathematics, statistics, and computer science[16,19,26,27,29,30] while fewer articles presented curricula integrating ethics[19,28,30] or domain knowledge.[26,29,30]

Various training modalities were described, including traditional academic coursework,[16,19,26,27,29,30] professional training at undergraduate or postgraduate levels outside the mandatory curriculum,[18,19] workshops/seminars, train-the-trainer programs,[16] case studies, hands-on activities,[28] and informal online offerings and social events such as hackathons.[29] Some authors highlighted the need for data science short courses and workshops for faculty members, but the exact content was not specified.[27] Few articles explicitly described the duration of the training.

While specific training outcomes were not explicitly detailed, a wide range of objectives was found. These objectives aimed to prepare trainees (eg, clinicians, students, and faculty) to proficiently apply fundamental data science concepts to health and biomedicine,[18] navigate large electronic health record (EHR) databases using data analytics to advance clinical and population health,[20] and engage in data-informed public health decision-making.[27] Additionally, the described programs aimed to nurture data scientists and leaders in scientific projects,[22] clinical implementation projects,[26] and omics research,[29] as well as nurse scientists who can teach, enhance clinical knowledge, and conduct research by utilizing the wealth of available data.[30]

Data science literacy assessment tools

There was a notable absence of data literacy and data science literacy assessment tools. Relevant assessment tools identified included the AI competency survey,[17] the NI Competency Assessment Tool,[31] the Public health informatics competencies,[33] the Digital Competency Tool,[34] and SL and SRA[37] (see Supplemental Digital Content 1, available at: http://links.lww.com/ANS/A92).

Web resources

Data literacy definitions and frameworks

The 5 industry web resources[38-42] primarily focused on enhancing data literacy for various organizations and personnel, with only 1 explicitly targeting health care professionals[42] (see Supplemental Digital Content 2, available at: http://links.lww.com/ANS/A93). Across these resources, data literacy definitions commonly emphasized the importance of communicating data and findings or insights derived from data, as well as the practical application of data skills in various contexts. Analytical skills were also highlighted for deriving meaningful insights from data and making data-driven decisions.

Various data literacy frameworks were presented, focusing on data skills in different categories. Among these web resources, one differentiated data science skills from data literacy, with core data science skills categorized into 3 areas: math/statistics, programming/coding, and business/domain skills.[40] Some web resources highlight frameworks to build data literacy initiatives. For example, Qlik[39] offers a 6-step data literacy adoption framework. Tableau[43] provides a guide called Tableau Blueprint to help organizations enhance their data utilization for impactful outcomes. Healthcatalyst[42] presents the 9-level Health Catalyst Analytics Adoption Model to assess and support progress toward data-driven health care organizations.

Data literacy assessment tools and training

Industry web resources offer various data literacy assessment tools to evaluate individual and organizational data literacy levels (see Supplemental Digital Content 3, available at: http://links.lww.com/ANS/A94). At the individual level, DataCamp's Signal™ Assessment[44] and Qlik's Skills Assessment[45] assess a wide array of data-related competencies. DataCamp Signal™ Assessment,[44] in particular, aligns with the competency model for data scientists, distinguishing

proficiency levels (Associate—Level 1, Professional—Level 2). Based on the assessment and competency level, these tools determine different personas, such as data scientist, data analyst, and data engineer, as well as data guru, data apprentice, data newcomer, and data avoider. Quanthub's Data Science Skill Assessment[46] provides data skills taxonomies that cover dozens of predefined roles during the defining skills steps. In Tableau's Blueprint Assessment,[43] depending on a specific stakeholder's role and responsibility within an organization (eg, frontline manager, mid-level leader, and executive leader), the individual is routed to particular assessment sections. By pinpointing strengths and areas for improvement, these tools empower individuals to tailor their learning and development efforts to enhance their data literacy skills effectively.

At the organizational level, DataCamp Data Maturity Assessment[47] and Qlik Corporate Data Literacy Score Assessment[39] offer invaluable insights into the overall data literacy and maturity levels within an organization. These assessments enable leaders to identify opportunities for enhancing data literacy initiatives and fostering a data-driven culture. Moreover, they serve as strategic tools for aligning organizational priorities with the evolving demands of the data-driven landscape.

The training content varies for each data literacy program, personalizing the learning experience for individuals. The duration of training programs ranges from a few weeks to several months. Some offer flexible schedules for independent learning. The delivery format is similar, with many programs using a blended approach that combines online resources such as hands-on virtual labs, YouTube, TedTalks, podcasts, interactive courses, and in-person classroom sessions.

DISCUSSION

Nurses in the 21st century are expected to be data literate, possessing the skills to manage data in the increasingly data-rich environments of health care.[25] Nurses are often required to interact with complex and diverse data systems, including EHR data, clinical registry data, wearable health data, patient-reported outcome data, and others. Furthermore, to support initiatives focused on social determinants of health and health equity, it is explicitly recommended that nursing expertise be integrated into designing, generating, analyzing, and applying data using diverse digital platforms, AI, and other innovative technologies.[48,49]

This literature review has identified frameworks, training, and assessments that could be applied to structure curriculum or training programs to promote nurses' data literacy and data science literacy. However, we found a lack of consensus on the definitions of data literacy and data science literacy. Furthermore, none of the articles or web resources clearly distinguish between the two. This review also highlighted a shortage of resources tailored to health care professionals and content specifically directed to the nursing profession, implying a significant need for focused attention and actions to appropriately educate and train nurses.

Few health care articles offered detailed data literacy definitions and frameworks; however, a common thread among these descriptions is their emphasis on the knowledge, skills, and abilities required to effectively interact with and utilize data in various contexts. While few industry web resources specifically define data literacy for health care professionals, their definitions commonly emphasize the ability to understand, read, write, work with, and analyze data. They also stress the importance of communicating data and insights derived from data, as well as making data-driven decisions.

Based on the commonality of data literacy definitions and frameworks reviewed, we propose a redefined concept of data literacy for nurses: Data literacy for nurses encompasses the knowledge, skills, attitudes, and abilities necessary to effectively utilize data, including the ability to access, evaluate, manipulate, communicate, and apply data for decision-making and problem-solving in

nursing practice. It involves understanding data sources, interpreting data meaningfully, and using data ethically and reflectively in nursing care contexts.

In the realm of data science literacy, while this literature review revealed a lack of explicit definitions of data science literacy in health care articles and industry web resources, several data science curricula or training models for health care professionals were identified.[18,27-30,37] Additionally, some articles did not present a clearly named framework but outlined key domains of data science along with their definitions.[16,20,24,26,36] Despite the absence of a standardized definition, these frameworks and definitions commonly described data science as an interdisciplinary field, emphasizing data analysis, computational techniques (eg, AI, ML), and domain knowledge, with some also incorporating ethical considerations.[18,19,27,28,30] The findings of our review reinforce and enrich the definition of data science by the National Institutes of Health Strategic Plan For Data Science[50(p.1)] as an "interdisciplinary field of inquiry in which quantitative and analytical approaches, processes, and systems are developed and used to extract knowledge and insights from increasingly large and/or complex sets of data."

Therefore, we suggest the following definition for nursing data science literacy: Nursing data science literacy encompasses the knowledge, skills, attitudes, and abilities necessary for nurses to effectively utilize advanced data science principles and techniques in their practice. It goes beyond basic data literacy by focusing on the application of statistical and computational methods, such as AI/ML, to extract meaningful insights from complex health care datasets. Nursing data science literacy includes understanding the lifecycle of data science projects, from data collection and preprocessing to model development and evaluation. It also involves the ability to critically evaluate data sources and methodologies, communicate findings effectively to health care teams and patients, demonstrate ethical use of data, and use data-driven insights to improve patient care outcomes and inform evidence-based nursing practice.

Along with these definitions and frameworks of data literacy and data science literacy for nursing, adequate training is critical. There is a noted shortage of nurse scientists trained in data science[30] and data science implementations in nursing.[3] Although the American Nurse Association (ANA) has established an Innovation Advisory Committee for data science, augmented intelligence, and artificial intelligence,[51] building these competencies is still not a priority for the majority of nursing programs in the United States. Current nursing curricula are insufficient to prepare nurses to leverage the abundant data evolution and data science opportunities for accelerating scientific advances in nursing.[20]

Our review identified only 3 articles proposing data science content for nursing programs and professional training. These included nursing curricula for MSN, DNP, and PhD students,[20] genomic nursing education,[27] and PhD nursing curricula using the DSCOM.[30] Their programs encompassed various aspects of data analysis, such as including data wrangling, data preprocessing, statistical analysis, advanced programming techniques, data visualization, and data quality appraisal. From the remaining articles in our review, we found similar and additional content and resources beneficial for nurses. However, the diversity in content posed challenges in suggesting a definitive set of data literacy and data science literacy training materials. Nonetheless, for training programs to enhance nurses' data literacy and data science literacy, it is important to integrate the principles of data lifecycle, data science lifecycle, data integrity, domain knowledge, regulations, and ethics into their curriculum and training.

The data lifecycle, although there is no single fixed definition, generally refers to the sequence of stages through which data is created, acquired, cleaned, stored, used, maintained, shared, published, archived, and ultimately preserved or destroyed.[52,53]

The industry-based data literacy training programs we reviewed also included these aspects of the data lifecycle. Data integrity refers to the completeness, accuracy, consistency, and validity of data throughout its lifecycle. Therefore, data literacy training programs in nursing should be designed to enhance nurses' abilities to generate, find, manage, organize, store, and share data, as well as to evaluate the completeness, accuracy, consistency, and validity of data. These programs need to cover the legal, ethical, and security requirements. Nursing knowledge and nursing-sensitive data considerations must be comprehensively integrated into data literacy training programs.

The data science lifecycle extends beyond the data lifecycle by emphasizing the generation of scientific findings and includes computational skills and technologies, inferential methodology, documentation of research and metadata creation, reproducibility, governance, and intellectual property considerations within the scope of data science.[52] Various stages of the data science life cycle have been presented; however, it commonly includes the following sequences: posing a question; collecting, cleaning, and storing data; developing tools and algorithms; performing exploratory analysis and visualization; making inferences and predictions; making decisions; and communicating results.[54]

Nursing data science literacy curricula or training programs can utilize the steps of the data science lifecycle as a pedagogical sequence. Training programs should focus on developing data scientists who can proceed through the following steps: planning; data acquisition; data exploration; hypothesis generation; data cleaning, merging, and organization; feature selection; model estimation and statistical inference; simulation and cross-validation; visualization; publication and artifact archiving.[52] However, the extent to which and how computational skills are integrated into nursing curriculum or training needs further discussion. Nursing programs can leverage existing resources across disciplines to support their data science curriculum and research agenda. Industry-based data literacy training programs can be additional valuable tools for enhancing nurses' data literacy; however, given they do not encompass nursing domain knowledge, careful consideration of relevance to nursing, program quality, and implementation strategies is necessary.

Domain expertise is indispensable in data science to ensure that questions posed of data are reasonable and to guide the interpretation of results. Critical choices are made in the selection and/or transformation of variables, appropriateness of methods to answer specific questions, and subsequently, how to best communicate and interpret findings using effective visualization techniques.[22] Crucially, curricula and training programs should prepare nurses to be equipped to ask the right questions of data and have a generalized knowledge of how data science methods can be applied. It is recommended that DNP and PhD students co-learn fundamental health care data science and work with interdisciplinary data science teams of experts, including nurse practitioners, clinical nurse specialists, and nurse informaticists, to shape questions and facilitate meaningful discovery from data.[20]

Training should be tailored to individual goals through knowledge and needs assessment. In conducting our review, it was anticipated that psychometrically sound instruments for assessing the knowledge and skills of health care professionals and nurses in data science educational and training courses could be identified. However, assessment instruments were scarce overall, and few tools have been tested for psychometric properties. The absence of comprehensive assessment tools for data literacy and data science literacy in health care areas highlights a critical gap in developing appropriate training programs for nurses, evaluating program effectiveness, and identifying areas for improvement. Therefore, it is evident that psychometric studies of measures of data

science literacy for use in curricula and training programs are needed.

Our review found that industry data literacy training programs have developed and used assessment tools, with personas reflecting different levels of data literacy, and provided training based on these assessments in an individual or organizational level. Although none has clearly focused on the nursing profession, they can serve as valuable resources and examples for nurses to build their own assessment tools and evaluations regarding data literacy. Dynamic and adaptive data literacy assessments, incorporating practical applications, case studies, updates in health care information systems, ethical considerations, global standards, and real-world clinical nursing scenarios, can provide robust feedback to nurses at different levels. Integrating these assessment and feedback mechanisms in training modules would contribute to a positive user experience, guide nurses toward areas of improvement, and maximize learning, fostering a comprehensive and effective learning environment.

Recommendations for nursing

To foster a culture of data-driven nursing care, integrating data literacy and data science literacy into nursing education and practice is essential.[25] This training enhances clinical nurses' ability to recognize patterns and trends, which can help identify early signs of deterioration and critical values, leading to timely interventions and improved patient outcomes. Predictive algorithms, such as those using machine learning, have demonstrated superior accuracy in assessing risks such as pressure injuries, improving clinical outcomes and operational efficiency.[55]

Nursing education programs should prioritize incorporating data literacy assessments to evaluate students' knowledge and skills and provide targeted training. Training modules can be tailored to address data issues specific to different nursing specializations. For instance, pediatric nurse could receive training on analyzing growth charts, vaccination records, and developmental milestones to identify deviations and manage growth disorders or delayed milestones.[56] Public health nurses might be trained to analyze demographic data, use Geographic Information Systems to map health disparities, and design targeted interventions.[57]

Incorporating data literacy concepts into the National Council Licensure Examination for registered nurses (NCLEX-RN) exam and other nursing certification exams can further verify new nurses' data literacy. The NCLEX-RN could include questions that test candidates' ability to interpret data from EHRs, such as identifying trends in lab results or make clinical decisions based on patient-reported outcomes.

Nursing leaders should advocate for integrating data literacy into practice standards and allocate resources to support ongoing training for practicing nurses.[58] EHR and data acumen vendors need to offer learning resources to introduce their proprietary data programming and support nurses' data literacy and data science literacy within institutions and health care systems using their software. Effective implementation of data literacy and data science literacy training programs requires organizational commitment, planning, infrastructure support, and ongoing training to maintain skills and adapt to new technologies. It is recommended to provide nurses and students with an integrated computational platform where they can work with data, conduct analyses, and evaluate results to support their learning process and apply knowledge and skills to enhance nursing care.

National nursing organizations can offer online resources to build data literacy across different specialties. For instance, the National Association of School Nurses provide "data literacy training and resources" on its website.[59] Well-trained nurses can identify patterns and trends in patient data, enhance clinical decision-making in complex health care situations, address gaps in care, and ultimately improve the quality of care.

LIMITATION OF THIS REVIEW

Although we conducted a comprehensive search and multiple rounds of independent and paired reviews to minimize selection bias, there is still a possibility that some relevant articles and industry web resources were missed. The diversity within the limited information of data literacy and data science literacy training and assessment tools posed challenges in suggesting a definitive set of data literacy and data science literacy training materials for nursing. Additionally, our search was limited to English-language literature published from 2018 to 2023. As the growing demands of data-driven health care to promote patient outcomes and address health equity, more attention to data literacy and data science literacy training may have been developed since then. Therefore, further review and discussion are warranted to promote data literacy and data science literacy among nurses.

CONCLUSION

This state-of-the-art review reveals diverse frameworks and models aimed at structuring data literacy and data science literacy. However, the observed variations and the lack of comprehensive frameworks and assessment tools specific to these literacies indicate a critical need for future development. Our review identified a notable deficiency in data literacy and data science literacy training and assessments within nursing practice and education, emphasizing the urgent need for their integration into nursing curricula and ongoing professional development initiatives. Future research and development efforts should focus on filling these gaps to better equip nurses and other health care professionals with the literacies to navigate the complexities of data utilization and data science principles in health care.

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