BMJ Open

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Journal:	*BMJ Open*
Manuscript ID	bmjopen-2022-061124
Article Type:	Original research
Date Submitted by the Author:	28-Jan-2022
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Keywords:	Health informatics < BIOTECHNOLOGY & BIOINFORMATICS, HEALTH SERVICES ADMINISTRATION & MANAGEMENT, Quality in health care < HEALTH SERVICES ADMINISTRATION & MANAGEMENT

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Identifying Requisite Learning Health System Competencies: A Scoping Review

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Word count: 4,063

Keywords: Learning Health Systems, Competencies, Quality Improvement

Abstract

Objectives

Learning health systems (LHS) integrate knowledge and practice through cycles of continuous quality improvement and learning to increase healthcare quality. LHS have been conceptualized through multiple frameworks and models. Our aim is to identify and describe the requisite individual competencies and system competencies described in existing literature in relation to operationalizing LHS.

Methods

A scoping review was conducted with descriptive and thematic analysis to identify and map competencies of LHS for individuals/patients, health system workers, and systems. Articles until April 2020 were included based on a systematic literature search and selection process. Themes were developed utilizing a consensus process until agreement was reached among team members.

Results

Eighty-nine articles were included with most studies conducted in the United States. The largest number of publications represented competencies at the system level, followed by health system worker competencies. Themes identified at the individual/patient level were knowledge and skills to understand and share information with an established system and the ability to interact with the technology used to collect data. Themes at the health system worker level were skills in evidence-based practice, leadership and teamwork skills, analytical and technological skills required to use a "digital ecosystem," data-science knowledge and skill, and self-reflective capacity. Researchers embedded within LHS require a specific set of competencies. Themes identified at the system level were data, infrastructure, and standardization; integration of data

and workflow; and culture and climate supporting ongoing learning. Researchers drafted a framework to represent interaction among levels of identified competencies.

Conclusion

The identified individual stakeholder competencies within LHS and the system capabilities of LHS provide a solid base for the further development and evaluation of LHS. International collaboration for stimulating LHS will assist in further establishing the knowledge base for LHS.

Strengths & Limitations of Scoping Review

- Review of 13 years-worth of publications relating to learning health system competencies
- Identification of requisite competencies across multiple levels of analysis
- Development of framework representing interaction among levels of analysis
- Review does not include articles from 2021

INTRODUCTION

Since first proposed by Etheridge in 2007 as a system to "quickly develop new evidence for daily medical practice and policy," thereby "increasing the value of health care" (p. 107), the learning health system concept (LHS) has been conceptualized through multiple frameworks and models.[1] The LHS concept has spread globally, with publications focusing on process models, micro to meso to macro system levels of analysis, infrastructure requirements to achieve such systems, the values underlying the cultural shift required to achieve such systems, and case studies exploring the application of the concept within healthcare.[2-3] For further development and implementation of LHS it is important to identify requirements for establishing an infrastructure for cycles of continuous quality improvement and learning, including competent key players within a LHS.

Menear and colleagues recently provided a framework for LHS which suggests that in order to encourage learning and improvement within a system, four main components are required--core values, pillars and accelerators, processes, and outcomes.[3] The conceptual framework explicates the need for change to occur within each level of the system (micro, meso, macro) and within the geographical areas for which the system acts (regional, national, and international) and provides details on the components of the pillars and processes needed to lead to outcomes defined previously as the quadruple aim to optimize healthcare. However, the framework does not delineate the competencies and skills necessary for the individuals within a system, the system itself, or networked systems (either on a national or international scale) that would result in an effective and efficient LHS.

Recent literature has begun to investigate requisite competencies and skills needed to build LHS. Forrest presented a core set of 33 competencies for researchers embedded in LHS

categorized in seven domains that included (1) systems science, (2) research questions and standards of scientific evidence, (3) research methods, (4) informatics, (5) ethics of research and implementation in health systems, (6) improvement and implementation science, and (7) engagement.[4] However, further identification of the personal competencies (knowledge, skills, and attitudes) required of other stakeholders within LHS remain in question. Although we have conceptual frameworks to rely on that identify general areas of knowledge, skill, and abilities mostly at a system and theoretical level, there is little research identifying the specific competencies required by the individuals within the LHS and how they develop and guide the processes needed to develop and assess appropriate outcomes.

Finally, there has been a significant increase in available literature that should be integrated into our current understanding of LHS competencies. This scoping review aims to identify and describe the requisite individual competencies (knowledge, skills, and attitudes) and system competencies (capacities, characteristics, and capabilities) described in existing literature in relation to operationalizing LHS.

METHODS

Given our interest in identifying and mapping the characteristics of LHS for individuals and systems, we elected a scoping review to answer our research question. In conducting the review, we utilized Arksey and O'Malley's five-stage process of performing a scoping review: identifying the research question; identifying relevant studies; selecting studies; charting data; and collating, summarizing and reporting findings.[5] The Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist guided the writing of the study report.[6] This checklist can be found in Appendix 3. The following research question guided this scoping review: "How has existing literature

described requisite individual competencies and system competencies for operationalizing LHS?"

Identifying Relevant Studies

We conducted a scoping review using both MESH and free-text terms "learning health system*" OR "learning healthcare system*" OR "learning health care system*") AND ("competence*" OR "standard" OR "proficienc*" OR "capacities" OR "characteristics" OR "capabilities" OR "knowledge" OR "skills" OR "attitudes." Searches were limited to English language studies and the period between January 2007 and April 2020. Databases searched included PubMed, CINAHL, and Scopus. Publications were excluded if they were book chapters, commentaries, editorials, or conference proceedings. Further, if an article did not describe LHS competencies, it was also excluded.

Study Selection

The initial search yielded 655 articles. After removal of duplicates and non-English language articles, a total of 304 articles underwent title and abstract review. Removal of editorials, commentaries, book chapters, and conference proceedings, left 168 articles that were uploaded into Covidence to undergo full-text review. Sixty-one articles were excluded based on pre-defined exclusion criteria. One-hundred and seven articles were included for the data extraction portion of this review. Given our goal to identify published *individual* and *system* level competencies, articles were organized into 'patient,' 'health system worker,' and 'system' level competencies. System level competencies included both organizational and inter-organizational (networks of organizations or national and international systems) levels. An additional 18 articles were excluded at this final stage, as they did not discuss specific competencies related to LHS. This resulted in the final inclusion of 89 articles in this scoping

review as listed in the references section, as well as Appendix 1. Figure 1 depicts the search decision flowchart during the scoping review.

Figure 1. Search Strategy (insert figure 1)

Titles and abstracts were screened by a team of four reviewers, split into two teams of two (PM and KH; JM and PVDW). The teams reviewed the articles using the agreed upon inclusion and exclusion criteria. Disagreements between reviewers were resolved by consensus and the reasons for exclusion were noted.

Charting the Data & Analytic Strategy

Data extraction was conducted in the same two person teams as article selection. The articles were divided between the two teams; each team read the full text of articles assigned prior to data extraction. Appendix 2 presents the data extraction template the team created to guide data extraction including article identifiers, such as author, year of publication, originating discipline, and article type. Data was extracted by the members of the two person teams individually and verified through team discussions. In addition to the identifying data extracted for each article, the researchers focused on extracting the individual and system level competencies identified within each article. They further subdivided the level of individual competencies into two broad groups of stakeholders: individuals or patients as recipients of healthcare and individuals working within the healthcare system.

We began with a descriptive analysis summarizing the characteristics of the studies (designs, methods), level of analysis (individual/patient, health system worker, system) and study locations. To address the aim of the review, the two person teams summarized the major findings of each study. Summary statements were then organized into individual/patient, health system worker, and system level. Finally, a thematic analysis was conducted, by developing

themes within each level utilizing a consensus process and several rounds of discussion until agreement was reached among team members.

Patient and Public Involvement

There were no patients involved in this research.

RESULTS

Descriptive analysis

Most of the studies were performed in the United States and the United Kingdom with different European countries contributing a few relevant articles. In addition, there was a growing level of interest in LHS from 2013 onward, as shown in Figure 2.

Figure 2. Frequency of Articles Published Per Year (insert figure 2)

During our assessment of the originating country of the articles, we noted the increased interest in LHS from North America and Western Europe, with a lack of publications coming from the Asia-Pacific region, as shown in Figure 3.

Figure 3. Distribution of Articles Published by Country (insert figure 3)

This scoping review considered requisite competencies by level of analysis; correspondingly, Figure 4 presents the frequency of publication by level of analysis. In our frequency analysis we isolated those articles that focused solely on one level of analysis and those that represented combined levels of analysis or addressed competencies at more than one level. As indicated by the figure, the largest number of publications represented competencies at

the systems level alone. The next highest level of articles related to those indicating both system and health system worker competencies.

Figure 4. Publication Frequency by Level of Analysis (insert figure 4)

Thematic analysis

Individual/Patient Level

Three articles were identified in the scoping review that addressed individual/patient level competencies for engaging in LHS. Two articles addressed the knowledge and skills of individuals/patients required to access and understand health related information and to understand and share information with an established system, including the need for explicit directions and instructions for sharing.[7-8] Fore and colleagues emphasized the importance of a patient's ability to interact with the technology used to collect data. One article addressed the ability of patients to partner with physicians on research.[9]

Health System Worker Level

Of 89 articles reviewed, 21 addressed competencies required of healthcare system workers working in an LHS. Themes identified within this literature related to skills required of health system workers were skills in evidence-based practice, leadership and teamwork skills, analytical and technological skills required to use a "digital ecosystem," data-science knowledge and skill, and self-reflective capacity. Ten articles addressed practitioner related competencies, with early work done in the field of nursing.[10-19]

Early work emphasized skills in evidence-based practice.[10,17] These skills included the ability to use of guidelines and quality improvement programs for evidence-based practice, the ability to use electronic health record data to assess quality and provide quality care, and the

ability to use practice guidelines and clinical decision support (CDS) for evidence-based practice.[10,17] Newhouse further discussed the ability to model these skills in practice.[17] Subsequent publications focused on the analytical and technological skills (computer and information technology) required to use a "digital ecosystem" and the data science knowledge and skills required to access and make-sense of the data from EHR systems.[12,16,18-19] Early work in the field of nursing highlighted the requirement for leadership skills to move data into clinical practice by fostering an appreciation of data and information.[10] Several subsequent articles focused on other leadership skills required of practitioners in LHS, such as skills in collaboration and teamwork, motivation and engagement, and self-reflective capacity.[14-16,18,20]

Three articles focused on competencies required of researchers embedded in learning health systems.[4,21-22] Reid et al.'s work proposed researchers partner with stakeholders across the health system (leaders, managers, analysts and clinicians) on all phases of a learning cycle,[21] requiring skills in analyzing health services delivery systems for problems and synthesizing evidence related to solutions; applying solutions appropriate to the content and assisting with key system modifications or redesigns; assigning with executing, spreading, and evaluating implemented changes; identifying required adjustments; and disseminating findings beyond the organization. With regard to producing and conducting evidence reviews, specify that researchers must be able to develop a review scope and identify key questions important to multiple stakeholders and subsequently engage a variety of stakeholders in the review process.[22] As noted in our introduction, Forrest et al. identified seven domains comprising 33 competencies for researchers embedded in LHS.[4] These domains address general competencies required of researchers embedded within any health system (application of appropriate research

methods and standards of scientific evidence and ethical conduct of research): however, these domains have been interpreted from the lens of applying the competencies to investigate learning health systems.[4] For example, the definition of the domain of "Research Questions and Standards of Scientific Evidence" is defined as "to ask meaningful questions relevant to health systems stakeholders and evaluate usefulness of scientific evidence and insights) (p. 2623).[4] The domains also extend to unique requirements of researchers embedded in LHS not always associated with other embedded researchers (knowledge and application of systems science, informatics, improvement science, and implementation science).[4]

System Level

Most articles in this review (64 of 89) addressed requisite system level competencies for LHS. Articles within this review noted that a mature LHS would have the capability to use diverse and integrated data for multiple purposes, namely developing clinical decision supports for patents and clinicians to make good evidence based decisions;[23-28] supporting quality improvement and continuous learning within and among systems;[23-25,27,29-37] supporting ethically sound research that is integrated into practice and enhances knowledge;[23,25,33,35-36,38-39] and, developing sound and evidence-based healthcare and social policy.[28,30,40-44]

The thematic analysis resulted in three themes reflecting major areas of competence that would allow the system to address the multiple purposes required in a mature LHS. The themes include: (1) data, infrastructure, and standardization; (2) integration of data and workflow; and (3) culture and climate supporting ongoing learning.

Data, Infrastructure, and Standardization

Several articles emphasized that systems need the capability to provide access to real-time, secure data with integrated data infrastructures and EHR interoperability that captures

patient care experiences digitally and is accessible from multiple locations and harmonized at the system level.[31,43-48] Other authors suggest that systems need the capability to access big data from multiple sources including national clinical trials databases, population-based data, and national and international databases.[24-25,28,31,49-50] Data sharing across access points within the system was a commonly recognized required capacity.[14-16,19,21,25,28,32-33,40-49,51-52] Usable and flexible data sharing among local stakeholders (clinicians, researchers and patients) was emphasized with special emphasis on the ability to share data across silos and networks without regulatory and institutional barriers.[39,42-43,45,52] Several authors recommended national level systems for monitoring data access and transfer across different settings.[22,50]

Numerous articles suggested specific technological capabilities required for data access and management in a mature LHS.[12,18,24-26,31-32,39,41-43,50-56] A sound technological infrastructure (at the organizational and inter-organizational levels) is required to support health data collection, access, interoperability, and exchange.[31,42-43,54-55] The infrastructure should ensure that data are easily available for many uses and purposes and supplied "to the right person at the right time".[19,25,26,32,39,40,41,42,43,57,58,59] Technological systems must have the capacity to manage information from clinical entities to facilitate research within practice settings and be flexible to allow for local tailoring.[25,39,42] Computational tools should allow quick, real-time analysis, providing stakeholders the ability to visualize data to support important clinical decisions.[12] One study recommended the need for real time natural language processing capabilities, so that data from patient narratives could be easily used as a data source.[55] Another indicated that the system must develop and support "citizen-centered smart and mobile devices" in order to monitor progress and care.[24] Finally, the system should be

able to assist in promoting public health by providing surveillance of health concerns that could inform public policy.[42]

Fifteen articles discussed capabilities for data standardization and governance in LHS.[14-15,20,24,29,31-32,39-42,51,60-62] Trustworthy and high-quality data that is evidence based, ethically sound, and interchangeable were essential factors.[20,31,32,39,61] Standards must be transparent and apply good governance practices to ensure trustworthiness.[20,60] One study suggested that the adoption of internationally recognized standards (i.e. Fast Healthcare Interoperability Resources - FHIR) would ensure standardization of all systems supporting efficient clinical decision making.[42] Data should be available for use by individual stakeholders (clinicians, researchers, patients) in a manner that maintains privacy and confidentiality and incorporates appropriate levels of consent in order to assist in making clinical decisions.[19,40-43,57]

Integration of data and workflow

To support the multiple and varied uses of data within a "digital ecosystem" data must be integrated into workflow.[12,15,18,21,24-25,38-39] Such integration would facilitate collaborative design on program evaluation among researchers and stakeholders and increase the potential for timely evaluation and feedback .[25,38] It would increase the capacity to manage information-intense workflows.[39] Ultimately, such a digital ecosystem would increase capacity for clinical decision-making,[23-28] particularly when data is aggregated at the appropriate learning unit level or point of care and decision-supports are based upon real-time data mining.[21,24,26]

Culture and climate of supportive learning

An important competency suggested by some authors is the need to create a culture and climate supportive of learning.[12,17,21-23,25-26,29,33,37,40,47,51,53,63-67] A learning culture is supported through system competencies and allows for reflection and a practicing mindful organization.[26,68] It necessarily requires a culture of transparency and effective communication supporting a "learning climate".[25,63] Several articles noted that enabling a learning culture requires the capability to build trust, respect, and affective commitment within the organization .[66-68] Establishing trust by engaging patients and the public is important,[66] with one article suggesting organizational "ambassadors" for this purpose.[67] Moreover, leadership capacity is required to promote a learning culture and climate.[47] Organizational leadership must provide performance metrics and rewards aligned to the "value" placed on learning and continuous improvement.[17,23,47] Leadership capability is also required to motivate the workforce to engage in evidence-based practice and to take ownership of local processes for implementation.[23]

Interactions among individuals and engagement of individuals with the LHS system are required for ongoing learning and quality improvement. Capability for engagement and collaboration was emphasized in 13 articles within the review;[21-23,26,29,33,37,40,51,53,63-65], a LHS system must support engagement from all key stakeholders with a particular focus on engagement of patients and family members with the system.[26,33,51,53] It should also enable and promote collaboration across stakeholders.[22-23,29,37,53,63-64] Two articles noted collaboration as a necessary outcome of establishing shared goals within the system.[29,37] Others focused on the capacity for interprofessional collaboration within a LHS specifically noting collaboration among organizational leaders and researchers to establish the scope of problems and research methods,[22-23,63] collaboration within multidisciplinary teams for high

quality patient care,[26] and collaboration with policy experts embedded within the system.[65] One article emphasized the capacity for inter-organizational collaboration for rapid synthesis and conversion of data to portable formats (e.g. tools and guidelines).[64]

Finally, a LHS system should have the capacity to train and educate the workforce to maximize participation and potential for ongoing learning and quality improvement.[12,23,68] An organization must be able to train frontline workers to deliver evidence-based practice and a data-science workforce to engage with a digital ecosystem.[23,69]

Results from our analysis suggest an interacting framework of themes for requisite competencies for individuals/patients, health system workers, and systems across levels of analysis. Figure 5 presents the graphic we developed based upon analysis in this review.

Figure 5. LHS Competency Framework (insert figure 5)

DISCUSSION

This scoping review described requisite competencies at patient, health system worker, and system level in relation to operationalizing LHS. Themes identified at the individual/patient level were knowledge and skills to understand and share information with an established system, and the ability to interact with the technology used to collect data. Themes at the health system worker level were skills in evidence-based practice, leadership, self-reflection, and teamwork and analytical and technological skills required to use a "digital ecosystem." Researchers within LHS require a specific set of competencies. Themes identified at the system level were data, infrastructure, and standardization; integration of data and workflow; and culture and climate supporting ongoing learning. A framework of competencies across levels of analysis was drafted representing their interactions.

The scoping review identified that the current literature on LHS competencies has been steadily growing since 2013. As the concept of LHS is relatively new and closely associated to healthcare policy initiatives (Quadruple Aim), it is not surprising that there is growing interest. We also identified that a large majority of the work is being performed in the United States, United Kingdom, and Canada while a few studies have been identified from other parts of the world.

Although this finding may be due to the search terms we used and the differences in global research foci this finding may prove important for the future growth of LHS. An underlying premise of developing mature LHS is the need for national and international collaboration with data exchange, process sharing, and outcome standardization. For mature LHS to evolve, competent individuals and systems that effectively communicate globally is required. Further study of the global needs individual and system competencies is needed.

In this scoping review we identified individual competencies of patients/individuals, healthcare workers, and system capabilities published in the literature and considered requisite to operationalizing LHS. Regarding individual level competencies, very few articles, described competencies at the patient level. Those published related to the patient's capacity to access the system, to understand and share health related information, to interact with the technology used to collect data, and to partner with healthcare workers. Additional researcher is required to identify competencies required of patients to interact with and contribute to LHS.

At the LHS worker level, the need for skills in evidence-based practice and the ability to model these skills in practice was identified, as well as the use of data and information to evaluate quality of practice and to inform quality improvement initiatives. Competencies of researchers embedded in LHS have been described in detail reflecting seven domains; two of

those domains were reinforced by other articles reviewed. The seven competency domains for researchers in LHS described by Forrest et al. provide a comprehensive framework for the further development of individual knowledge, skills, and attitude of researchers.[4] Greenberg-Worisek subsequently identified the domains from this work as competencies required of healthcare providers working in LHS.[11] However, this author did not consider the alignment between the competencies identified by Forrest et al. and the skills and knowledge required by practitioners beyond identification of the domains.[4] Further research should explore which of the specific competencies as identified by Forrest et al. should be developed for practitioners working in LHS and should also focus on the competencies of patients in the LHS.[4]

Leadership plays a pivotal role in supporting the development of a learning culture and climate in LHS, and leaders at clinical, operational, and strategic level are deemed important for creating and supporting requisite individual and system capabilities including stimulating a culture and climate of supportive learning. Yet, questions remain regarding how to be build individual level competencies within stakeholders in the system to support a culture and climate supportive of learning. The use of champions and leadership support are well established strategies in the field of quality improvement and implementation science. However, additional research is required to distinguish the unique leadership capabilities required in relation to the complexity of the "system" (i.e., group within an organization, organization, inter-organizational network, national system, international network).

Understanding individual competency level requirements to act within a LHS is vital to the successful development and implementation of LHS. Further research should investigate individual competencies for acting within a LHS to inform important stakeholders like

educational systems and industry-based training entities and policymakers to reach the Quadruple Aim of healthcare.

The preponderance of the included articles described system level capabilities for which we identified three main themes: (1) data, infrastructure, and standardization; (2) the integration of data and workflow; and (3) the culture and climate supporting ongoing learning. However, within the literature related to systems competencies, the meaning of "system" varied from being related to referring to units within organizations, to organizations, to intra-organizational groups, inter-organizational networks, national networks, and international networks. While this review did not seek to analyze system level competencies according to degree of size or complexity associated with respective levels of "systems," analysis did suggest that as the organization of the respective "systems" became more complex, so did the establishment of requisite competencies within those systems (i.e., data standardization, data sharing, data governance).

Our scoping review expands on previous efforts to establish frameworks that model how a LHS best functions. This scoping review demonstrates the importance of alignment of competencies and capabilities across different levels--comprehensive of the system and all the system stakeholders. Our analysis indicates that system competencies for a LHS are fairly well identified. Yet, further development is necessary to effectively integrate those competencies with those required of individual stakeholders within the system.

The need for the further development of LHS has been recognized through several international initiatives. Core values have been described, a research agenda was established, [70] and the current knowledge on LHS was synthesized in a recent scoping review.[71] Despite the high potential of LHS, their development and implementation are a challenge, and many organizations are seeking support in becoming a LHS. Exemplars of outcomes from

establishment of LHS are required. In addition, guidance and tools for developing and implementing a LHS are needed to support the enactment of LHS within and across organizations.

Our scoping review has several limitations. Many studies included in this review are based on preliminary analyses of LHS which limits the ability for robust data synthesis. In addition, quantitative evaluations of LHS are scarce and causal inferences about necessary competencies and capabilities cannot be reliably constructed. However, the scoping review approach is congruent with the current developmental phase of LHS and allows for the identification of knowledge gaps and future directions for research, policy, and practice.

In conclusion, the identified individual competencies of stakeholders within LHS as well as the system capabilities of LHS provide a solid base for the further development and evaluation of LHS. International collaboration for stimulating LHS will assist in further establishing the knowledge base for LHS.

CONFLICTS OF INTEREST

The authors report no conflicts of interest for this study.

AUTHOR CONTRIBUTION

The authors confirm contribution to the paper as follows: Study conception and design: PM; data collection: PM, JP, KH, JM, PVDW; analysis and interpretation of results: PM, KH, JM, PVDW; draft manuscript preparation: PM, JP, KH, JM, PVDW. All authors reviewed the results and approved the final version of the manuscript.

ACKNOWLEDGEMENTS

None

FUNDING

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

DATA SHARING

No additional data available.

ETHICS STATEMENT

Review by an ethics committee or internal review board was not required for this study as it did not involve human subjects research.

FIGURE LEGEND

Figure 1. Search Strategy

Figure 2. Frequency of Articles Published Per Year

Figure 3. Distribution of Articles Published by Country

Figure 4. Publication Frequency by Level of Analysis

Figure 5. LHS Competency Framework

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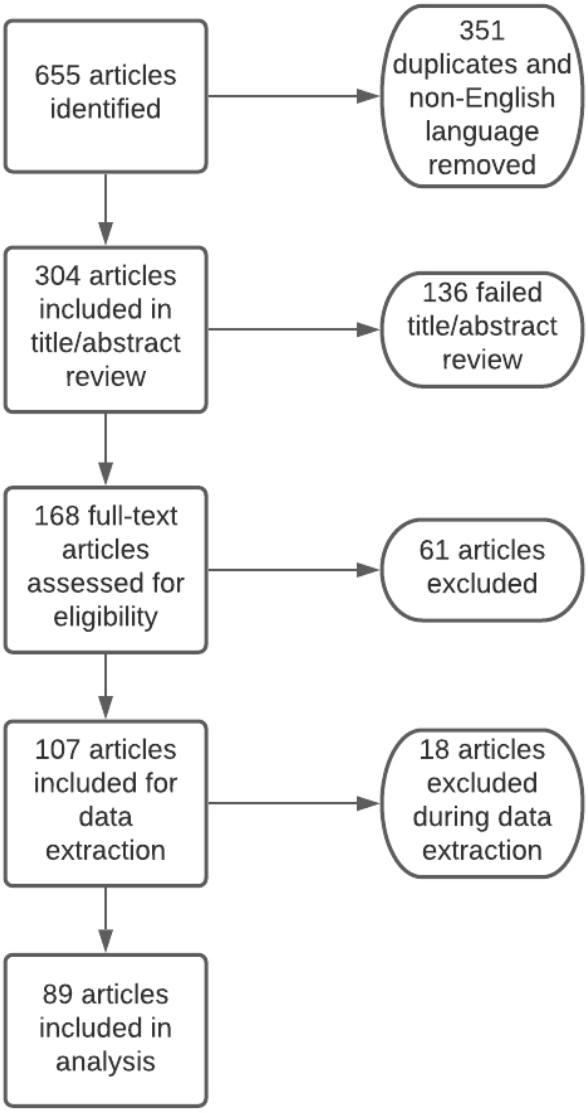

Figure 1. Search Strategy

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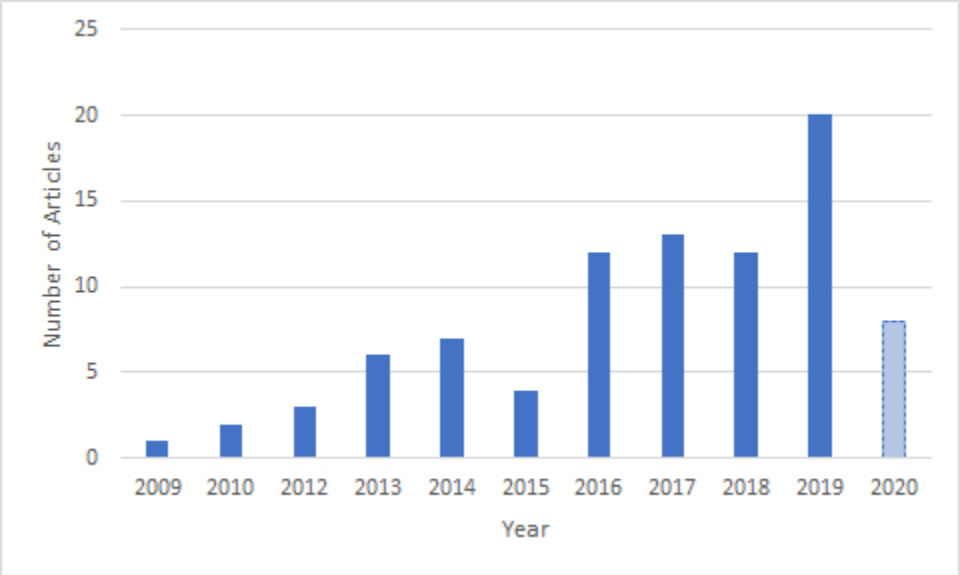

Figure 2. Frequency of articles published per year

320x192mm (38 x 38 DPI)

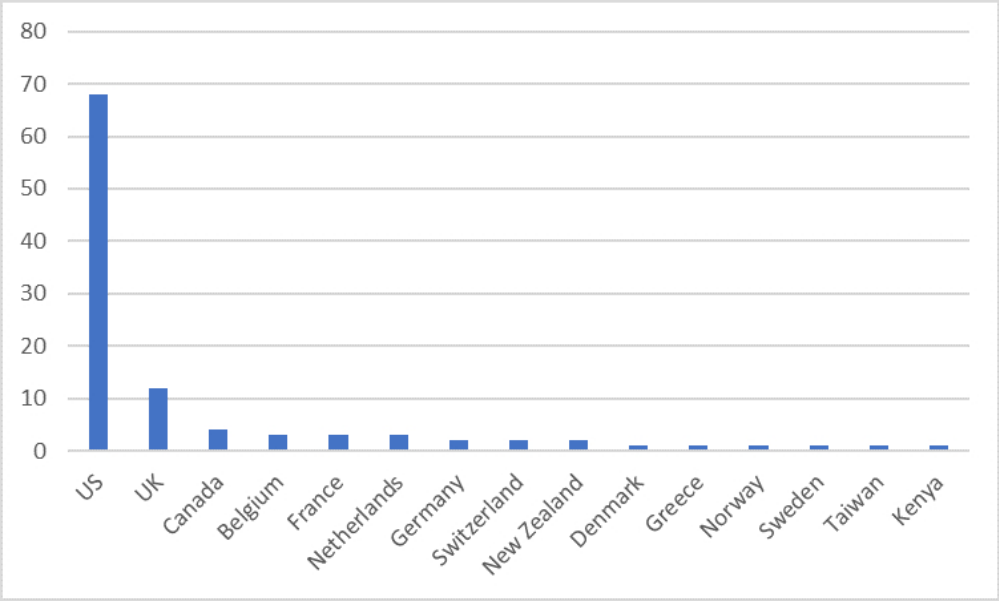

Figure 3. Distribution of articles published by country

502x302mm (38 x 38 DPI)

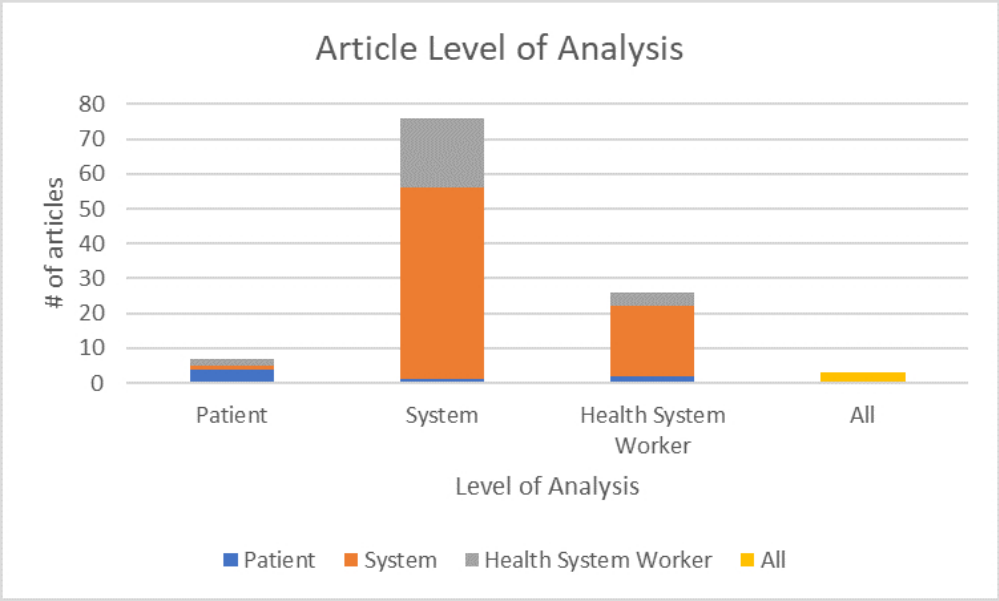

Figure 4. Publication frequency by level of analysis

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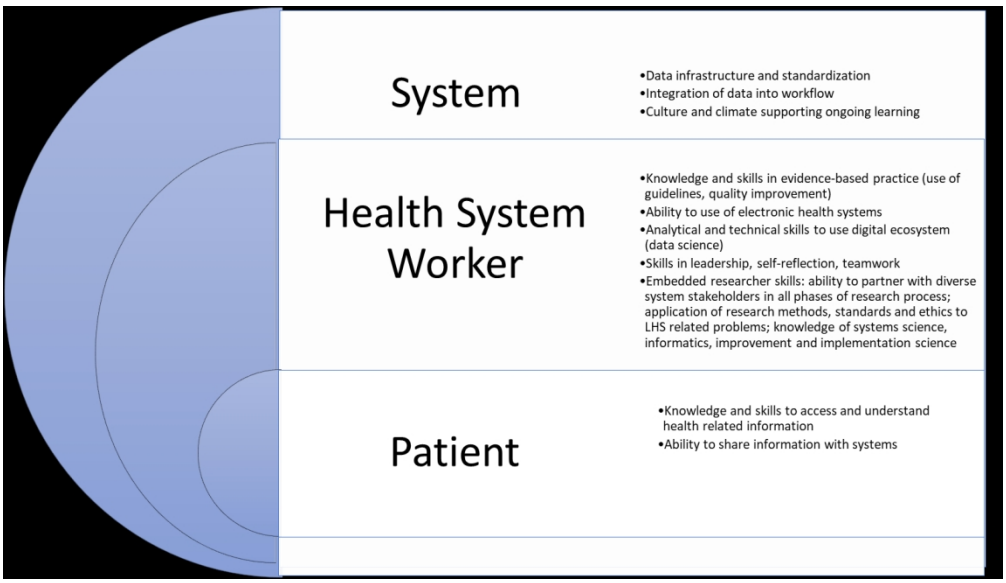

Figure 5. LHS Competency framework

1094x626mm (38 x 38 DPI)

Appendix 1: Additional Supporting References

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Appendix 2: Data Points

- Authors
- Publication Title
- Originating Discipline
- Article Type (consensus, empirical, framework, review, perspective)
- Level of Analysis (patient, health system worker, system)
- Publication Year
- Study Location (country)
- Study Type
- Intervention Type, if any
- Duration of intervention, if any
- Study Population
- Study Aims
- Methodology Overview
- Outcomes & Measures
- Results
- Patient Level Competencies Described
- Health System Worker Level Competencies Described
- System Level Competencies Described
- Contribution of Article to Understanding of Objectives
- Reviewer Notes

Appendix 2: **Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist**

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
TITLE			
Title	1	Identify the report as a scoping review.	1; Title Page
ABSTRACT			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	2-3
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	4-5
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	5-6
METHODS			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	Review protocol exists; is not registered
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	6
Information sources*	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	6
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	6
Selection of sources of evidence†	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	6-8
Data charting process‡	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	7-8
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	Appendix 2
Critical appraisal of individual sources of evidence§	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe	n/a

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
		the methods used and how this information was used in any data synthesis (if appropriate).	
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	8-16
RESULTS			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	7
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	8-16
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	n/a
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	8-16
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	8-16
DISCUSSION			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	17-21
Limitations	20	Discuss the limitations of the scoping review process.	21
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	21
FUNDING			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	19

JBI = Joanna Briggs Institute; PRISMA-ScR = Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews.

* Where *sources of evidence* (see second footnote) are compiled from, such as bibliographic databases, social media platforms, and Web sites.

† A more inclusive/heterogeneous term used to account for the different types of evidence or data sources (e.g., quantitative and/or qualitative research, expert opinion, and policy documents) that may be eligible in a scoping review as opposed to only studies. This is not to be confused with *information sources* (see first footnote).

‡ The frameworks by Arksey and O'Malley (6) and Levac and colleagues (7) and the JBI guidance (4, 5) refer to the process of data extraction in a scoping review as data charting.

§ The process of systematically examining research evidence to assess its validity, results, and relevance before using it to inform a decision. This term is used for items 12 and 19 instead of "risk of bias" (which is more applicable to systematic reviews of interventions) to include and acknowledge the various sources of evidence that may be used in a scoping review (e.g., quantitative and/or qualitative research, expert opinion, and policy document).

From: Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMAScR): Checklist and Explanation. Ann Intern Med. 2018;169:467–473. doi: 10.7326/M18-0850.

BMJ Open

Identifying Requisite Learning Health System Competencies: A Scoping Review

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2022-061124.R1
Article Type:	Original research
Date Submitted by the Author:	25-Apr-2022
Complete List of Authors:	McDonald, Paige; The George Washington University, Department of Clinical Research and Leadership Phillips, Jessica; The George Washington University, Department of Clinical Research and Leadership Harwood, Kenneth; Marymount University Maring, Joyce; The George Washington University, Department of Health, Human Function van der Wees, Philip; Radboudumc, Rehabilitation and IQ Healthcare; The George Washington University School of Medicine and Health Sciences, Clinical Research and Leadership
Primary Subject Heading:	Health services research
Secondary Subject Heading:	Health informatics, Health policy
Keywords:	Health informatics < BIOTECHNOLOGY & BIOINFORMATICS, HEALTH SERVICES ADMINISTRATION & MANAGEMENT, Quality in health care < HEALTH SERVICES ADMINISTRATION & MANAGEMENT

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Identifying Requisite Learning Health System Competencies: A Scoping Review

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Word count: 4,571

Keywords: Learning Health Systems, Competencies, Quality Improvement

Abstract

Objectives

Learning health systems (LHS) integrate knowledge and practice through cycles of continuous quality improvement and learning to increase healthcare quality. LHS have been conceptualized through multiple frameworks and models. Our aim is to identify and describe the requisite individual competencies (knowledge, skills, and attitudes) and system competencies (capacities, characteristics, and capabilities) described in existing literature in relation to operationalizing LHS.

Methods

A scoping review was conducted with descriptive and thematic analysis to identify and map competencies of LHS for individuals/patients, health system workers, and systems. Articles until April 2020 were included based on a systematic literature search and selection process. Themes were developed utilizing a consensus process until agreement was reached among team members.

Results

Eighty-nine articles were included with most studies conducted in the United States (68 articles). The largest number of publications represented competencies at the system level, followed by health system worker competencies. Themes identified at the individual/patient level were knowledge and skills to understand and share information with an established system and the ability to interact with the technology used to collect data. Themes at the health system worker level were skills in evidence-based practice, leadership and teamwork skills, analytical and technological skills required to use a "digital ecosystem," data-science knowledge and skill, and self-reflective capacity. Researchers embedded within LHS require a specific set of

competencies. Themes identified at the system level were data, infrastructure, and standardization; integration of data and workflow; and culture and climate supporting ongoing learning.

Conclusion

The identified individual stakeholder competencies within LHS and the system capabilities of LHS provide a solid base for the further development and evaluation of LHS. International collaboration for stimulating LHS will assist in further establishing the knowledge base for LHS.

Strengths & Limitations of Scoping Review

- Review of 13 years-worth of publications relating to learning health system competencies
- Identification of requisite competencies across multiple levels of analysis
- Review includes only articles published in English and published between January 2007 and April 2020
- The following publications were excluded from this review: book chapters, commentaries, editorials, or conference proceedings

INTRODUCTION

Since first proposed by Etheridge in 2007 as a system to "quickly develop new evidence for daily medical practice and policy," thereby "increasing the value of health care" (p. 107), the learning health system concept (LHS) has been conceptualized through multiple frameworks and models.[1] The LHS concept has spread globally, with publications focusing on process models, micro to meso to macro system levels of analysis, infrastructure requirements to achieve such systems, the values underlying the cultural shift required to achieve such systems, and case studies exploring the application of the concept within healthcare.[2-3] However, there is a paucity of evidence indicating the effectiveness of LHS across levels of analysis. Moreover, there is a need for increased understanding of the requisite competencies and capabilities across levels of a system that promote learning and continuous quality improvement.

Conceptualizations of LHS have increased in their specificity over time. Initially, the Institute of Medicine (IOM) envisioned learning health systems (LHS) as "systems where science, informatics, incentives, and culture are aligned for continuous improvement and innovation with best practices seamlessly embedded in the delivery process and new knowledge captured as an integral by-product of the delivery experience" (page ix).[4] Friedman and colleagues further specified the conceptualization by defining each component word. "Learning" refers to the "capability for continuous improvement through the collection and analysis of data, creating new knowledge, and the application of the new knowledge to influence practice" (page 1).[5] "Health" is defined as both an "end-goal" or "universally recognized benefit to humanity" as also a "domain of human endeavor".[5] Finally, according to Friedman et al. a "system consists of component parts acting in unison to achieve goals not attainable by any subset of the components" (page 1).[5] Correspondingly, self-monitoring and improving performance through

continuous cycles of learning-supported by people, policy, and processes-transforms health systems into LHS.[5-6]

Menear and colleagues recently provided a framework for LHS which suggests that in order to encourage learning and improvement within a system, four main components are required--core values, pillars and accelerators, processes, and outcomes.[3] The conceptual framework explicates the need for change to occur within each level of the system (micro, meso, macro) and within the geographical areas for which the system acts (regional, national, and international) and provides details on the components of the pillars and processes needed to lead to outcomes defined previously as the quadruple aim to optimize healthcare. However, the framework does not delineate the competencies and skills necessary for the individuals within a system, capabilities of the system itself, or capabilities of networked systems (either on a national or international scale) that would result in an effective and efficient LHS.

Recent literature has begun to investigate requisite competencies and skills needed to build LHS. Forrest presented a core set of 33 competencies for researchers embedded in LHS categorized in seven domains that included (1) systems science, (2) research questions and standards of scientific evidence, (3) research methods, (4) informatics, (5) ethics of research and implementation in health systems, (6) improvement and implementation science, and (7) engagement.[7] However, further identification of the personal competencies (knowledge, skills, and attitudes) required of other stakeholders within LHS remain in question. Although we have conceptual frameworks to rely on that identify general areas of knowledge, skill, and abilities mostly at a system and theoretical level, there is little research identifying the specific competencies required by the individuals within the LHS and how they develop and guide the processes needed to develop and assess appropriate outcomes.

Finally, there has been a significant increase in available literature that should be integrated into our current understanding of LHS competencies. Prior literature indicates that stakeholders within LHS require specific knowledge and abilities to engage in continuous cycles of learning and that systems require specific capabilities, capacities and characteristics to support said cycles. Correspondingly, this scoping review aims to identify and describe the requisite individual competencies (knowledge, skills, and attitudes) and system competencies (capacities, characteristics, and capabilities) described in existing literature in relation to operationalizing LHS.

METHODS

Given our interest in identifying and mapping the characteristics of LHS for individuals and systems, we elected a scoping review to answer our research question. In conducting the review, we utilized Arksey and O'Malley's five-stage process of performing a scoping review: identifying the research question; identifying relevant studies; selecting studies; charting data; and collating, summarizing and reporting findings.[8] The Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist guided the writing of the study report.[9] This checklist can be found in Appendix 1. The following research question guided this scoping review: "How has existing literature described requisite individual competencies and system competencies for operationalizing LHS?"

Identifying Relevant Studies

We conducted a scoping review using both MESH and free-text terms "learning health system*" OR "learning healthcare system*" OR "learning health care system*") AND ("competence*" OR "standard" OR "proficienc*" OR "capacities" OR "characteristics" OR

"capabilities" OR "knowledge" OR "skills" OR "attitudes." Searches were limited to English language studies and the period between January 2007 and April 2020. Databases searched included PubMed, CINAHL, and Scopus. Publications were excluded if they were book chapters, commentaries, editorials, or conference proceedings. Further, if an article did not describe LHS competencies, it was also excluded.

Titles and abstracts were screened by a team of four reviewers, split into two teams of two (PM and KH; JM and PVDW). The teams reviewed the articles using the agreed upon inclusion and exclusion criteria. Disagreements between reviewers were resolved by consensus and the reasons for exclusion were noted.

Charting the Data & Analytic Strategy

Data extraction was conducted in the same two person teams as article selection. The articles were divided between the two teams; each team read the full text of articles assigned prior to data extraction. Appendix 2 presents the data extraction template the team created to guide data extraction including article identifiers, such as author, year of publication, originating discipline, and article type. Data was extracted by the members of the two person teams individually and verified through team discussions. In addition to the identifying data extracted for each article, the researchers focused on extracting the individual and system level competencies identified within each article. They further subdivided the level of individual competencies into two broad groups of stakeholders: individuals or patients as recipients of healthcare and individuals working within the healthcare system.

We began with a descriptive analysis summarizing the number (count) of articles published per year, level of analysis (individual/patient, health system worker, system), and number of articles by study location. To address the aim of the review, the two person teams

summarized the major findings of each study. Summary statements were then organized into individual/patient, health system worker, and system level. Finally, a thematic analysis was conducted, by developing themes within each level utilizing a consensus process and several rounds of discussion until agreement was reached among team members.[10]

Patient and Public Involvement

There were no patients involved in this research.

RESULTS

Study Selection

The initial search yielded 655 articles. After removal of duplicates and non-English language articles, a total of 304 articles underwent title and abstract review. Removal of editorials, commentaries, book chapters, and conference proceedings, left 168 articles that were uploaded into Covidence to undergo full-text review. Sixty-one articles were excluded based on predefined exclusion criteria. One-hundred and seven articles were included for the data extraction portion of this review. Given our goal to identify published *individual* and *system* level competencies, articles were organized into 'patient,' 'health system worker,' and 'system' level competencies. System level competencies included both organizational and inter-organizational (networks of organizations or national and international systems) levels. An additional 18 articles were excluded at this final stage, as they did not discuss specific competencies related to LHS. This resulted in the final inclusion of 89 articles in this scoping review. Figure 1 depicts the search decision flowchart during the scoping review.

Figure 1. Search Results (insert figure 1)

Descriptive analysis

Most of the studies were performed in the United States and the United Kingdom with different European countries contributing a few relevant articles. In addition, there was a growing level of interest in LHS from 2013 onward, as shown in Figure 2.

Figure 2. Number of Articles Published Per Year (insert figure 2)

During our assessment of the originating country of the articles, we noted the increased interest in LHS from North America and Western Europe, with a lack of publications coming from the Asia-Pacific region, as shown in Figure 3.

Figure 3. Number of Articles Published by Country (insert figure 3)

This scoping review considered requisite competencies by level of analysis; correspondingly, Figure 4 presents the number of publications by level of analysis. In our analysis, we isolated those articles that focused solely on one level of analysis and those that represented combined levels of analysis or addressed competencies at more than one level. As indicated by the figure, the largest number of publications represented competencies at the systems level alone. The next highest level of articles related to those indicating both system and health system worker competencies.

Figure 4. Number of Publications by Level of Analysis (insert figure 4)

Thematic analysis

Individual/Patient Level

Three articles were identified in the scoping review that addressed individual/patient level competencies for engaging in LHS. Two articles addressed the knowledge and skills of individuals/patients required to access and understand health related information and to understand and share information with an established system, including the need for explicit

directions and instructions for sharing.[11-12] Fore and colleagues emphasized the importance of a patient's ability to interact with the technology used to collect data. One article addressed the ability of patients to partner with physicians on research.[13]

Health System Worker Level

Of 89 articles reviewed, 21 addressed competencies required of healthcare system workers working in an LHS. Themes identified within this literature related to skills required of health system workers were skills in evidence-based practice, leadership and teamwork skills, analytical and technological skills required to use a "digital ecosystem," data-science knowledge and skill, and self-reflective capacity. Ten articles addressed practitioner related competencies, with early work done in the field of nursing.[14-23]

Early work emphasized skills in evidence-based practice.[14,21] These skills included the ability to use of guidelines and quality improvement programs for evidence-based practice, the ability to use electronic health record data to assess quality and provide quality care, and the ability to use practice guidelines and clinical decision support (CDS) for evidence-based practice.[14,21] Newhouse further discussed the ability to model these skills in practice.[21] Subsequent publications focused on the analytical and technological skills (computer and information technology) required to use a "digital ecosystem" and the data science knowledge and skills required to access and make-sense of the data from EHR systems.[16,20,22-23] Early work in the field of nursing highlighted the requirement for leadership skills to move data into clinical practice by fostering an appreciation of data and information.[14] Several subsequent articles focused on other leadership skills required of practitioners in LHS, such as skills in collaboration and teamwork, motivation and engagement, and self-reflective capacity.[18-20,22,24]

Three articles focused on competencies required of researchers embedded in learning health systems.[7,25-26] Reid et al.'s work proposed researchers partner with stakeholders across the health system (leaders, managers, analysts and clinicians) on all phases of a learning cycle,[25] requiring skills in analyzing health services delivery systems for problems and synthesizing evidence related to solutions; applying solutions appropriate to the content and assisting with key system modifications or redesigns; assigning with executing, spreading, and evaluating implemented changes; identifying required adjustments; and disseminating findings beyond the organization. With regard to producing and conducting evidence reviews, specify that researchers must be able to develop a review scope and identify key questions important to multiple stakeholders and subsequently engage a variety of stakeholders in the review process.[26] As noted in our introduction, Forrest et al. identified seven domains comprising 33 competencies for researchers embedded in LHS.[7] These domains address general competencies required of researchers embedded within any health system (application of appropriate research methods and standards of scientific evidence and ethical conduct of research): however, these domains have been interpreted from the lens of applying the competencies to investigate learning health systems.[7] For example, the definition of the domain of "Research Questions and Standards of Scientific Evidence" is defined as "to ask meaningful questions relevant to health systems stakeholders and evaluate usefulness of scientific evidence and insights" (p. 2623).[7] The domains also extend to unique requirements of researchers embedded in LHS not always associated with other embedded researchers (knowledge and application of systems science, informatics, improvement science, and implementation science).[7]

System Level

Most articles in this review (64 of 89) addressed requisite system level competencies for LHS. Articles within this review noted that a mature LHS would have the capability to use diverse and integrated data for multiple purposes, namely developing clinical decision supports for patents and clinicians to make good evidence based decisions;[27-32] supporting quality improvement and continuous learning within and among systems;[27-29,31,33-41] supporting ethically sound research that is integrated into practice and enhances knowledge;[27,29,37,39-40,42-43] and, developing sound and evidence-based healthcare and social policy.[32,34,44-48]

The thematic analysis resulted in three themes reflecting major areas of competence that would allow the system to address the multiple purposes required in a mature LHS. The themes include: (1) data, infrastructure, and standardization; (2) integration of data and workflow; and (3) culture and climate supporting ongoing learning.

Data, Infrastructure, and Standardization

Several articles emphasized that systems need the capability to provide access to real-time, secure data with integrated data infrastructures and EHR interoperability that captures patient care experiences digitally and is accessible from multiple locations and harmonized at the system level.[35,47-52] Other authors suggest that systems need the capability to access big data from multiple sources including national clinical trials databases, population-based data, and national and international databases.[28-29,32,35,53-54] Data sharing across access points within the system was a commonly recognized required capacity.[18-20,23,25,29,32,36-37,44-53,55-56] Usable and flexible data sharing among local stakeholders (clinicians, researchers and patients) was emphasized with special emphasis on the ability to share data across silos and networks without regulatory and institutional barriers.[43,46-47,49,56] Several authors

recommended national level systems for monitoring data access and transfer across different settings.[26,54]

Numerous articles suggested specific technological capabilities required for data access and management in a mature LHS.[16,22,28-30,35-36,43,45-47,54-60] A sound technological infrastructure (at the organizational and inter-organizational levels) is required to support health data collection, access, interoperability, and exchange.[35,46-47,58-59] The infrastructure should ensure that data are easily available for many uses and purposes and supplied "to the right person at the right time".[23,29-30,36,43-47,61-63] Technological systems must have the capacity to manage information from clinical entities to facilitate research within practice settings and be flexible to allow for local tailoring.[29,43,46] Computational tools should allow quick, real-time analysis, providing stakeholders the ability to visualize data to support important clinical decisions.[16] One study recommended the need for real time natural language processing capabilities, so that data from patient narratives could be easily used as a data source.[59] Another indicated that the system must develop and support "citizen-centered smart and mobile devices" in order to monitor progress and care.[28] Finally, the system should be able to assist in promoting public health by providing surveillance of health concerns that could inform public policy.[46]

Fifteen articles discussed capabilities for data standardization and governance in LHS.[18-19,24,28,33,35-36,43-46,55,64-66] Trustworthy and high-quality data that is evidence based, ethically sound, and interchangeable were essential factors.[24,35-36,43,65] Standards must be transparent and apply good governance practices to ensure trustworthiness.[24,64] One study suggested that the adoption of internationally recognized standards (i.e. Fast Healthcare Interoperability Resources - FHIR) would ensure standardization of all systems supporting

efficient clinical decision making.[46] Data should be available for use by individual stakeholders (clinicians, researchers, patients) in a manner that maintains privacy and confidentiality and incorporates appropriate levels of consent in order to assist in making clinical decisions.[23,44-47,61]

Integration of data and workflow

To support the multiple and varied uses of data within a "digital ecosystem" data must be integrated into workflow.[16,19,22,25,28-29,42-43] Such integration would facilitate collaborative design on program evaluation among researchers and stakeholders and increase the potential for timely evaluation and feedback .[29,42] It would increase the capacity to manage information-intense workflows.[43] Ultimately, such a digital ecosystem would increase capacity for clinical decision-making,[27-32] particularly when data is aggregated at the appropriate learning unit level or point of care and decision-supports are based upon real-time data mining.[25,28,30]

Culture and climate of supportive learning

An important competency suggested by some authors is the need to create a culture and climate supportive of learning.[16,21,25-27,29-30,33,37,41,44,51,55,57,67-71] A learning culture is supported through system competencies and allows for reflection and a practicing mindful organization.[30,72] It necessarily requires a culture of transparency and effective communication supporting a "learning climate".[29,67] Several articles noted that enabling a learning culture requires the capability to build trust, respect, and affective commitment within the organization .[70-72] Establishing trust by engaging patients and the public is important,[70] with one article suggesting organizational "ambassadors" for this purpose.[71] Moreover, leadership capacity is required to promote a learning culture and climate.[51] Organizational

leadership must provide performance metrics and rewards aligned to the "value" placed on learning and continuous improvement.[21,27,51] Leadership capability is also required to motivate the workforce to engage in evidence-based practice and to take ownership of local processes for implementation.[27]

Interactions among individuals and engagement of individuals with the LHS system are required for ongoing learning and quality improvement. Capability for engagement and collaboration was emphasized in 13 articles within the review;[25-27,30,33,37,41,44,55,57,67-69], a LHS system must support engagement from all key stakeholders with a particular focus on engagement of patients and family members with the system.[30,37,55,57] It should also enable and promote collaboration across stakeholders.[26-27,33,41,57,67-68] Two articles noted collaboration as a necessary outcome of establishing shared goals within the system.[33,41] Others focused on the capacity for interprofessional collaboration within a LHS specifically noting collaboration among organizational leaders and researchers to establish the scope of problems and research methods,[26-27,67] collaboration within multidisciplinary teams for high quality patient care,[30] and collaboration with policy experts embedded within the system.[69] One article emphasized the capacity for inter-organizational collaboration for rapid synthesis and conversion of data to portable formats (e.g. tools and guidelines).[68]

Finally, a LHS system should have the capacity to train and educate the workforce to maximize participation and potential for ongoing learning and quality improvement.[16,27,72] An organization must be able to train frontline workers to deliver evidence-based practice and a data-science workforce to engage with a digital ecosystem.[27,73]

DISCUSSION

This scoping review described requisite competencies at patient, health system worker, and system level in relation to operationalizing LHS. Themes identified at the individual/patient level were knowledge and skills to understand and share information with an established system, and the ability to interact with the technology used to collect data. Themes at the health system worker level were skills in evidence-based practice, leadership, self-reflection, and teamwork and analytical and technological skills required to use a "digital ecosystem." Researchers within LHS require a specific set of competencies. Themes identified at the system level were data, infrastructure, and standardization; integration of data and workflow; and culture and climate supporting ongoing learning.

The scoping review identified that the current literature on LHS competencies has been steadily growing since 2013. As the concept of LHS is relatively new and closely associated to health care policy initiatives (Quadruple Aim), it is not surprising that there is growing interest. We also identified that a large majority of the work is being performed in the United States, United Kingdom, and Canada while a few studies have been identified from other parts of the world. Although this finding may be due to the search terms we used and the differences in global research, this finding may prove important for the future growth of LHS. An underlying premise of developing mature LHS is the need for national and international collaboration with data exchange, process sharing, and outcome standardization. For mature LHS to evolve, competent individuals and systems that effectively communicate globally is required. Further study of the global needs individual and system competencies is needed.

In this scoping review we identified individual competencies of patients/individuals, healthcare workers, and system capabilities published in the literature and considered requisite to operationalizing LHS. Regarding individual level competencies, very few articles described

competencies at the patient level. Those published related to the patient's capacity to access the system, to understand and share health related information, to interact with the technology used to collect data, and to partner with healthcare workers. The lack of literature is surprising especially in consideration of the effort for patient centered care that focuses on care that is responsive to individual patient preferences, needs and values' while relying on the patient to provide important aspects of self-care and health monitoring.[74,75] In many cases, basic understanding and capability to use and understand technology is requisite to appropriately and safely sharing personal health information, obtaining reliable health information, and actively engaging in one's own health care. Although further research is needed to determine the extent of the competencies required of patients to interact with and contribute to LHS, our work suggests that some level of technological comprehension is required of individual patients to interact effectively within LHS. At the LHS worker level, the need for skills in evidence-based practice and the ability to model these skills in practice was identified, as well as the use of data and information to evaluate quality of practice and to inform quality improvement initiatives. Competencies of researchers embedded in LHS have been described in detail reflecting seven domains; two of those domains were reinforced by other articles reviewed. The seven competency domains for researchers in LHS described by Forrest et al. provide a comprehensive framework for the further development of individual knowledge, skills, and attitude of researchers.[7] Greenberg-Worisek subsequently identified the domains from this work as competencies required of healthcare providers working in LHS.[15] However, this author did not consider the alignment between the competencies identified by Forrest et al. and the skills and knowledge required by practitioners beyond identification of the domains.[7] Further research should explore which of the specific competencies as identified by Forrest et al.

should be developed for practitioners working in LHS and should also focus on the competencies of patients in the LHS.[7]

Leadership plays a pivotal role in supporting the development of a learning culture and climate in LHS, and leaders at clinical, operational, and strategic level are deemed important for creating and supporting requisite individual and system capabilities including stimulating a culture and climate of supportive learning. Yet, questions remain regarding how to build individual level competencies within stakeholders in the system to support a culture and climate supportive of learning. The use of champions and leadership support are well established strategies in the field of quality improvement and implementation science. However, additional research is required to distinguish the unique leadership capabilities required in relation to the complexity of the "system" (i.e., group within an organization, organization, inter-organizational network, national system, international network).

Understanding individual competency level requirements to act within a LHS is vital to the successful development and implementation of LHS. Further research should investigate individual competencies for acting within a LHS to inform important stakeholders like educational systems and industry-based training entities and policymakers to reach the Quadruple Aim of healthcare.

The preponderance of the included articles described system level capabilities for which we identified three main themes: (1) data, infrastructure, and standardization; (2) the integration of data and workflow; and (3) the culture and climate supporting ongoing learning. However, within the literature related to systems competencies, the meaning of "system" varied from being related to referring to units within organizations, to organizations, to intra-organizational groups, inter-organizational networks, national networks, and international networks. While this review

did not seek to analyze system level competencies according to degree of size or complexity associated with respective levels of "systems," analysis did suggest that as the organization of the respective "systems" became more complex, so did the establishment of requisite competencies within those systems (i.e., data standardization, data sharing, data governance).

Our scoping review expands on previous efforts to establish frameworks that model how a LHS best functions. This scoping review demonstrates the importance of alignment of competencies and capabilities across different levels-comprehensive of the system and all the system stakeholders. Our analysis indicates that system competencies for a LHS are fairly well identified. Yet, further development is necessary to effectively integrate those competencies with those required of individual stakeholders within the system.

Multiple aspects of health systems can be evaluated in continuous learning cycles. The framework of the World Health Organization (WHO) is often used in evaluating health system performance, which includes six "building blocks": service delivery; health workforce; health information systems; access to essential medicines; financing; and leadership/governance.[76]. Braithwaite and colleagues compared health system frameworks in a comparative international analysis, showing that commonly used domains in evaluating health system performance were safety, effectiveness and access.[77] In addition, the WHO has conceptualized the "learning" process in LHS, by describing the learning process at multiple interconnected levels: individual, team/group, organizational, and cross-organizational level. Learning across levels can be established through feedback and feedforward loops.[78] Such (international) frameworks and approaches can be used by LHS in their further development.

The need for the further development of LHS has been recognized through several international initiatives. Core values have been described, a research agenda was established,

[79] and the current knowledge on LHS was synthesized in a recent scoping review.[80] Despite the high potential of LHS, their development and implementation are a challenge, and many organizations are seeking support in becoming a LHS. Exemplars of outcomes from establishment of LHS are required. In addition, guidance and tools for developing and implementing a LHS are needed to support the enactment of LHS within and across organizations.

Our scoping review has several limitations. Many studies included in this review are based on preliminary analyses of LHS which limits the ability for robust data synthesis. In addition, quantitative evaluations of LHS are scarce and causal inferences about necessary competencies and capabilities cannot be reliably constructed. However, the scoping review approach is congruent with the current developmental phase of LHS and allows for the identification of knowledge gaps and future directions for research, policy, and practice.

In conclusion, the identified individual competencies of stakeholders within LHS as well as the system capabilities of LHS provide a solid base for the further development and evaluation of LHS. International collaboration for stimulating LHS will assist in further establishing the knowledge base for LHS.

CONFLICTS OF INTEREST

The authors report no conflicts of interest for this study.

AUTHOR CONTRIBUTION

The authors confirm contribution to the paper as follows: Study conception and design: PM; data collection: PM, JP, KH, JM, PVDW; analysis and interpretation of results: PM, KH, JM,

PVDW; draft manuscript preparation: PM, JP, KH, JM, PVDW. All authors reviewed the results and approved the final version of the manuscript.

ACKNOWLEDGEMENTS

None

FUNDING

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

DATA SHARING

No additional data available.

ETHICS STATEMENT

Review by an ethics committee or internal review board was not required for this study as it did not involve human subjects research.

FIGURE LEGEND

Figure 1. Search Results

Figure 2. Number of Articles Published Per Year

Figure 3. Number of Articles Published by Country

Figure 4. Number of Publications by Level of Analysis

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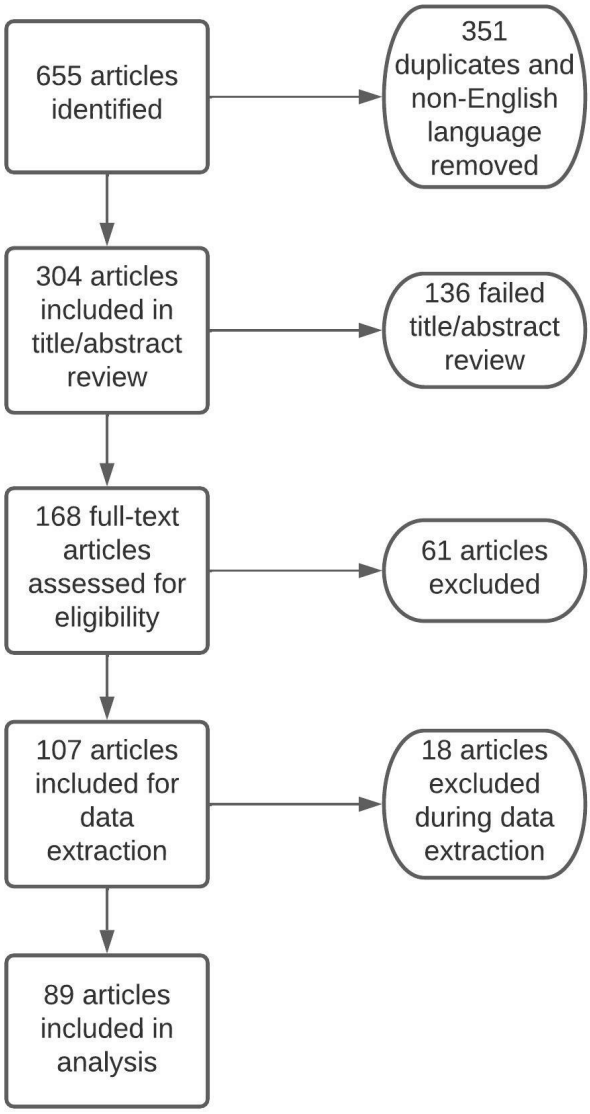

Figure 1. Search Results

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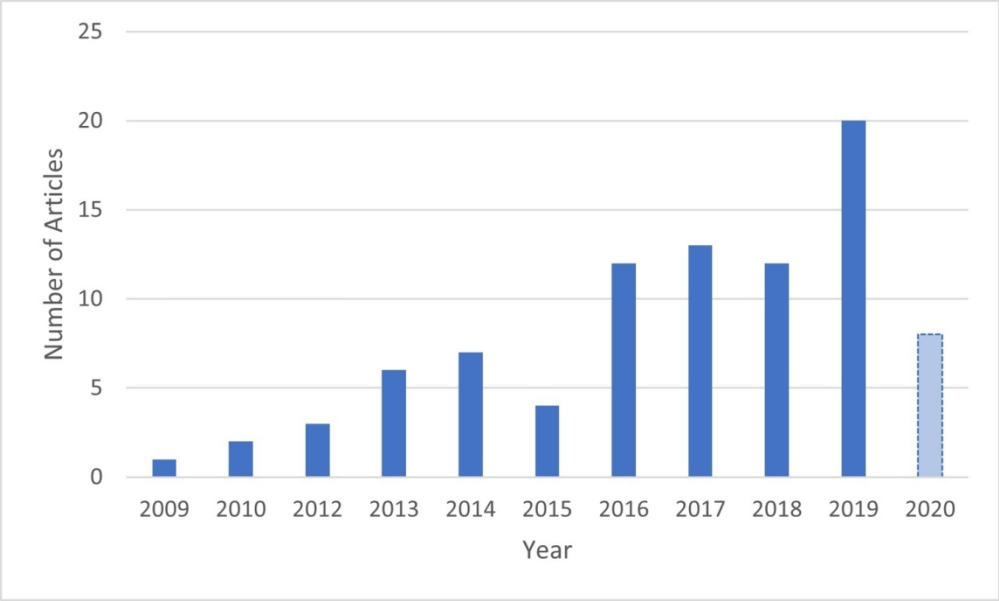

Figure 2. Number of articles published per year

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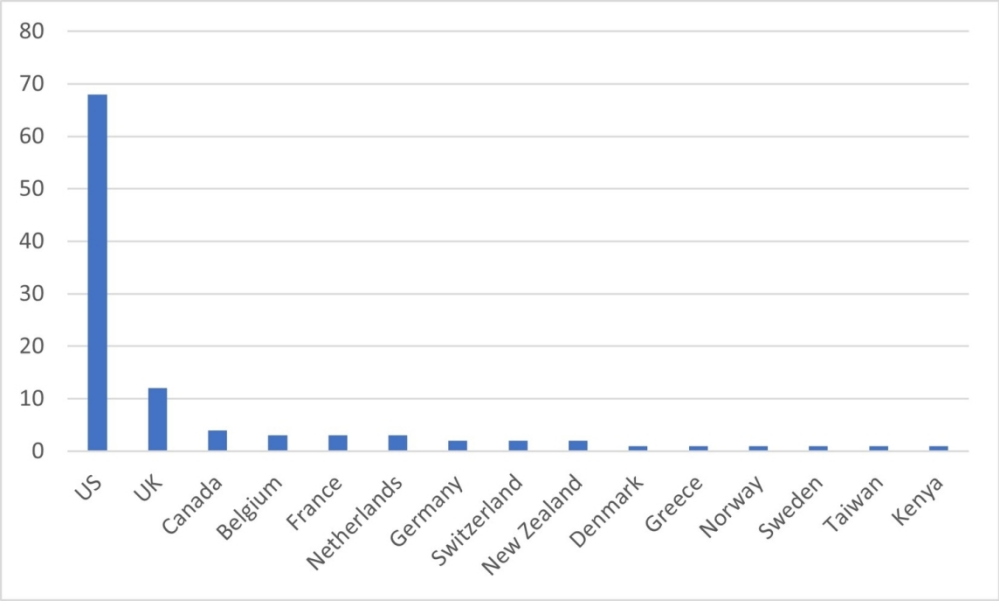

Figure 3. Number of articles published by country

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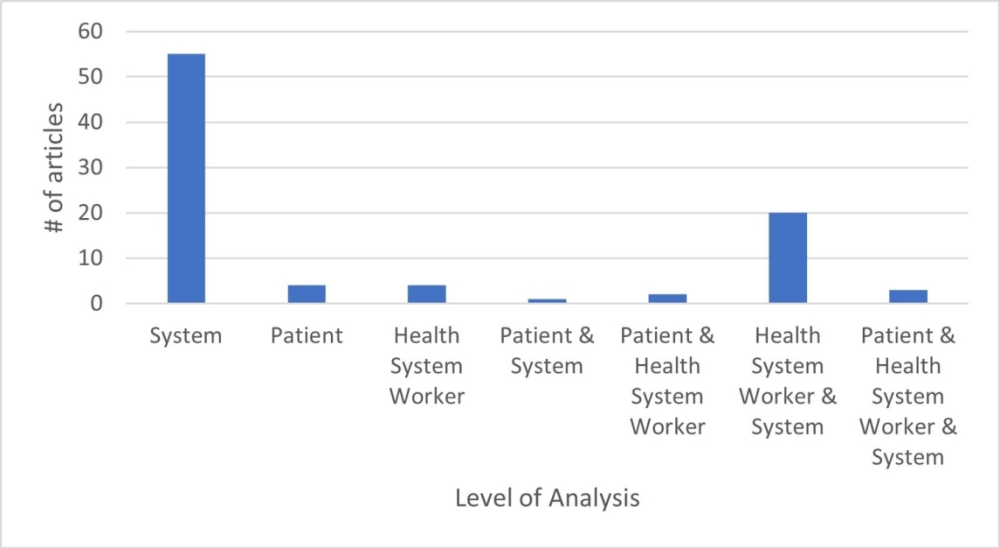

Figure 4. Number of publications by level of analysis

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Appendix 1: **Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist**

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
TITLE			
Title	1	Identify the report as a scoping review.	1; Title Page
ABSTRACT			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	2-3
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	4-5
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	5-6
METHODS			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	Review protocol exists; is not registered
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	6
Information sources*	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	6
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	6
Selection of sources of evidence†	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	6-8
Data charting process‡	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	7-8
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	Appendix 2
Critical appraisal of individual sources of evidence§	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe	n/a

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
		the methods used and how this information was used in any data synthesis (if appropriate).	
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	8-16
RESULTS			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	7
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	8-16
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	n/a
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	8-16
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	8-16
DISCUSSION			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	17-21
Limitations	20	Discuss the limitations of the scoping review process.	21
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	21
FUNDING			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	19

JBI = Joanna Briggs Institute; PRISMA-ScR = Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews.

* Where *sources of evidence* (see second footnote) are compiled from, such as bibliographic databases, social media platforms, and Web sites.

† A more inclusive/heterogeneous term used to account for the different types of evidence or data sources (e.g., quantitative and/or qualitative research, expert opinion, and policy documents) that may be eligible in a scoping review as opposed to only studies. This is not to be confused with *information sources* (see first footnote).

‡ The frameworks by Arksey and O'Malley (6) and Levac and colleagues (7) and the JBI guidance (4, 5) refer to the process of data extraction in a scoping review as data charting.

§ The process of systematically examining research evidence to assess its validity, results, and relevance before using it to inform a decision. This term is used for items 12 and 19 instead of "risk of bias" (which is more applicable to systematic reviews of interventions) to include and acknowledge the various sources of evidence that may be used in a scoping review (e.g., quantitative and/or qualitative research, expert opinion, and policy document).

From: Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMAScR): Checklist and Explanation. Ann Intern Med. 2018;169:467–473. doi: 10.7326/M18-0850.

Appendix 2: Data Points

- Authors
- Publication Title
- Originating Discipline
- Article Type (consensus, empirical, framework, review, perspective)
- Level of Analysis (patient, health system worker, system)
- Publication Year
- Study Location (country)
- Study Type
- Intervention Type, if any
- Duration of intervention, if any
- Study Population
- Study Aims
- Methodology Overview
- Outcomes & Measures
- Results
- Patient Level Competencies Described
- Health System Worker Level Competencies Described
- System Level Competencies Described
- Contribution of Article to Understanding of Objectives
- Reviewer Notes