

REVIEW

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Evaluating health organization readiness for implementing a learning health system: a scoping review

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Abstract

Objective Learning health systems (LHS) may improve healthcare access, innovation, coordination, continuity and quality. To ensure implementation success, healthcare organizations must be able to assess their current readiness to adopt an LHS approach; however, there is a paucity of LHS-specific readiness tools in the extant literature. Thus, the overarching aim of this study was to map the depth and breadth of LHS literature to identify the domains and items, alongside barriers, facilitators, implementation strategies and competencies relevant to include in an LHS readiness tool.

Methods A scoping review informed by Arksey and O'Malley's framework and updates proposed by Levac et al. was employed. Scopus, MEDLINE, Embase, CINAHL, PsychINFO, Education Source and Business Source Complete were searched from inception to May 2024. English or French publications that addressed the definitions, frameworks, competencies, barriers and facilitators of an LHS were eligible.

Results The bibliographic database search and screening process yielded 90 articles, published between 2007 and 2024. A total of 72 articles defined LHS, with most emphasizing continuous learning cycles, evidence integration, infrastructure and stakeholder engagement. In addition, 56 articles presented 21 frameworks (educational, logic, maturity, organizational, equity and implementation), and 50 described key domains, including the D2K–K2P–P2D cycle, core values, and leadership, governance, and data infrastructure. Barriers to implementation included limited resources, unsupportive culture, poor interoperability and ethical challenges, while facilitators were strong leadership, shared purpose, robust partnerships and supportive policies. Identified competencies spanned research, informatics, quality improvement, systems science, engagement and ethics, with educational strategies ranging

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from collaboratives and training programs to graduate curricula and peer learning. Readiness and maturity assessments were discussed in 28 articles, but only a few operationalized these concepts. No specific LHS readiness assessments were identified.

Conclusions Current readiness tools derived from quality-improvement contexts may be helpful but not sufficiently specific for assessing healthcare organizations' readiness to implement an LHS approach. This review identified important barriers, facilitators, and strategies related to the collective behaviour change required to implement an LHS approach that should be considered in the future development of an LHS readiness assessment.

Keywords Learning health systems, Organizational readiness to change, Barriers and facilitators, Implementation, Assessment

Background

In North America, specifically in Canada, an ageing population faces increasingly complex chronic diseases [1, 2]. Effective, adaptable healthcare transformation is essential. Yet, research takes an average of 17 years for just 14% of findings to reach practice [3–5], creating an evidence-to-practice gap that undermines care quality, patient experience and outcomes [6]. A promising solution is the learning health system (LHS) approach, which leverages information technologies and health data to generate and apply evidence in real time, while using care delivery itself to drive innovation and transformation [7]. Introduced by the Institute of Medicine [now National Academy of Medicine (NAM)] in 2007, the LHS concept emphasizes continuous organizational learning across clinical, operational and research activities to deliver high-value care [8, 9]. Through cyclical transitions – from data to knowledge, knowledge to performance, and performance back to data – LHSs strengthen knowledge translation and advance the quintuple aim, with improved patient care, population health, care experience, equity and cost-efficiency [10–12].

At its inception, the Institute of Medicine (IoM) identified 12 requirements for successful LHS implementation, including adaptation to change, clinical decision support, interoperable data systems, aligned incentives, public engagement and leadership [9]. Building on this, Trillium Health Partners' Institute for Better Health developed the LHS Action Framework, which outlines key accelerants (e.g. leadership, patient partners) and barriers (e.g. privacy regulations, system capacity) that shape an LHS's ability to achieve the quintuple aim [13]. Despite these roadmaps, few organizations have fully realized an LHS. Systematic reviews identified only 31 unique LHSs [14, 15] and 23 LHS environments, mostly in the United States, raising questions about applicability in other health system contexts.

Adoption challenges are multifaceted owing to unclear evidence, inconsistent terminology and uncertainty about whether LHSs are best pursued at the organizational or network level [9, 14–17]. The

literature increasingly points towards learning health networks, where interoperable, population-level data support large-scale learning across sites and systems [18]. However, local organizations must first assess their readiness to implement and sustain such change [8]. While there are many frameworks that can help inform the implementation of novel programs or initiatives (e.g. the Consolidated Framework for Implementation Research) [19], we have opted to frame our discussion drawing from Weiner's (2009) theory of organizational readiness for change, which is rooted in psychological theories such as Bandura's self-efficacy and collective efficacy [20]. According to Weiner (2009), organizational readiness refers to organization members' shared resolve to implement a change (i.e. change commitment) and their shared belief in their collective capacity to do so (i.e. change efficacy) [20]. Considering that an organization's readiness for change can determine whether an intervention is successfully implemented by members of the organization, [21, 22] it is a factor that should be assessed.

Some examples of successfully implemented LHS approaches exist. Alberta Health Services (AHS) has embedded an LHS approach across its system through strategic clinical networks, which spread innovations and enable value-based care [10, 23–25]. These networks reflect core LHS principles – participatory leadership, inclusiveness and transparency – and use an innovation pipeline to design, test and scale new practices [23]. Programs such as early supported discharge, enhanced recovery after surgery and appropriate antipsychotic use illustrate how an LHS can deliver measurable benefits [23–25]. Still, little is known about LHS use outside high-income, largely private systems [10]. Measuring readiness is therefore essential. While tools such as the Organizational Readiness to Change Assessment (ORCA) [26] and Organizational Readiness for Implementing Change (ORIC) [22] assess organizational readiness for change, they are not tailored to LHS implementation. Weiner recommends adapting measures to the specific change under study [20], and

systematic reviews suggest that broader readiness tools must be context-specific to be effective [27].

Given the scope and complexity of LHS implementation, a tailored readiness assessment is needed. Developing such a tool requires clarifying the knowledge, processes and resources (e.g. information systems) required to support an LHS approach. The objective of this study was therefore to map the breadth and depth of the LHS literature, with a focus on identifying potentially relevant domains (i.e. interrelated attributes such as behaviours, attitudes or values) and items (i.e. specific questions) for inclusion in an LHS readiness assessment [28]. We also sought to identify key barriers, facilitators, strategies and competencies that should be considered. Ultimately, we anticipate that these findings will inform a questionnaire to help healthcare organizations self-assess their readiness to implement an LHS and, in turn, improve practices, patient outcomes and resource use.

Methods

We followed the first five steps outlined in Arksey and O'Malley's [29] framework for conducting scoping reviews, and updates proposed by Levac et al. [30] and Peters et al. [31, 32]. We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) guidelines [33]. We did not publish a study protocol for this review, but a previous report on this topic is available on Open Science Framework (<https://osf.io/fub36>).

Step one: identify the research question(s)

For the purpose of this study, we define readiness as organizational members' change commitment and change efficacy to implement organizational change (i.e. in a state of being both psychologically and behaviourally prepared – willing and able – to take action) [20]. We sought to answer the following research questions:

- (1) How are LHSs defined and characterized in the extant literature?
- (2) What are the barriers and facilitators that health organizations may face when implementing an LHS approach?
- (3) What competencies are required by members of health organizations working within an LHS approach?
- (4) What tools exist in the literature to help health organizations assess their level of readiness to implement an LHS approach?

Step two: identify relevant publications and other important information

Database searching

Four authors (C.G., A.T., A.B., and S.A.) met to define the review scope, potential search terms and relevant databases. Following this meeting, a search strategy was developed by C.G. in MEDLINE in consultation with a health sciences librarian (L.S.) and then it was adapted to the other databases as appropriate (Appendix 1). The following databases were searched by C.G., in consultation L.S.: MEDLINE (Ovid), Embase (Ovid), APA PsycINFO (Ovid), Education Source (EBSCOHost), CINAHL (EBSCOHost) and Business Source Complete (EBSCOHost). All databases were searched from 7 to 9 May 2024. All references were exported into an Endnote file for records management ($n=960$), and then Covidence for deduplication and screening.

Step three: select studies and relevant information

We included all publications types, not just empirical studies. Publications were eligible if they: (1) addressed the concept of LHS; (2) addressed definitions, frameworks and characteristics associated with an LHS; and (3) were published in English or French between 2007 and 2024. Additionally, publications had to either: (4) present any organizational or system level barriers, facilitators or strategies associated with implementing an LHS; and/or (5) present any tools or specific items measuring organizational readiness to implement an LHS. Publications that focused on the individual level were excluded.

Three reviewers (F.M., Z.E. and C.G.) tested the inclusion criteria on a 10% subset of titles and abstracts ($n=78$) using Covidence. They met weekly to facilitate calibration and to discuss any disagreements. Once the screeners achieved 90% agreement, they independently screened each article by title, abstract and full text. An additional reviewer (S.A.) was available to discuss any disagreements.

Step four: charting the data

C.G. and S.A. developed a data extraction form that was reviewed by the research team. We extracted study characteristics (i.e. bibliometric data) and LHS definitions; theories, models or frameworks; barriers and facilitators to LHS approach implementation; and tool names, domains and items used to evaluate organizational readiness. Specifically, we extracted any domains or items included in existing LHS readiness or maturity assessments that may help to inform the content of this new measure. Four reviewers (C.G., Z.E., N.G. and F.M.) independently pilot-tested the extraction form on 5% of articles ($n=5$). On the basis of this pilot, the extraction

form was modified and tested on a further two articles. Conflicts were resolved through discussion. Once they reached 90% agreement, they divided the remaining articles equally among themselves for extraction.

Step five: collate, summarize and report the results

We conducted two types of analyses: (1) a bibliometric analysis consisting of calculating descriptive statistics using Microsoft Excel to describe year of publication, location, study design and discipline; and (2) a conventional content analysis of extractions [34] related to the definitions, domains, barriers, facilitators, competencies, implementation and educational strategies, and associated LHS readiness or maturity tools. Conventional content analyses use inductive coding approaches to describe a phenomenon when existing theory or research is limited; researchers code inductively without a preconceived code book, allowing codes and categories to flow from the data [34]. Preliminary codes were then collapsed into categories during a second cycle of coding; this was carried out using a series of matrices and displays to facilitate data analysis and to explore relationships between categories [35]. Consistent with standard practices in scoping reviews [29, 30, 36], we did not conduct an assessment of methodological quality of included articles because of the heterogeneity of publication types and the exploratory nature of this review.

Results

Bibliometric information

The bibliographic database search yielded 960 records, leaving 775 citations after duplicates were removed. Overall, 90 studies were eligible for inclusion after screening by title, abstract and full text (Fig. 1 depicts the PRISMA flow diagram). Table 1 presents an overview of the characteristics of the included studies, notably their country of origin, publication year, discipline, study design and study aim. Most included publications are commentaries or experience reports ($n=53$; 59%) within the realm of health services research ($n=63$; 70%), originating in the United States of America ($n=60$; 67%), and published in 2022 ($n=25$; 28%).

Narrative findings

Defining and conceptualizing learning health systems (research question 1)

In total, 72 articles defined the term learning health system. Overall, 43 author teams used the definition provided by, or cited alignment with, the NAM/IoM [18, 37–78]. This definition states that an LHS is a system in which science, informatics, incentives and culture are aligned for continuous improvement and innovation – with best practices and discovery seamlessly embedded

in the delivery process and new knowledge generated as an integral byproduct of the delivery experience [9]. Two articles cited the definition of LHS put forth by the Agency for Healthcare Research and Quality (AHRQ), which states that an LHS is a system in which internal data and experience are systematically integrated with external evidence, and that knowledge is seamlessly put into practice [79, 80]. Four articles cited definitions of LHS put forth by Friedman and colleagues [41, 61, 81, 82], which indicates that an LHS approach involves learning cycles where data are generated in usual care settings, and knowledge is rapidly generated from these data and then widely used, refined and scaled to advance policy and practice [12]. Three articles defined LHS in alignment with Menear and colleagues [41, 64, 80], indicating that an LHS provides a framework for organizing people and resources to address common challenges and support the rapid dissemination of findings to enable decision-making [10].

Overall, the main components of the included definitions were that an LHS approach: (1) continuously generates data, creates new evidence and applies this evidence in practice using learning cycles [18, 37, 38, 40–45, 47–56, 58–66, 68, 69, 71, 73–77, 79–103]; (2) has the overall purpose of driving improvement in healthcare [18, 37, 38, 40–42, 44, 45, 47–49, 52, 55–63, 66, 68, 69, 71–74, 76, 78, 80–83, 89, 90, 92–97, 100–102, 104–107]; (3) aligns science, informatics, incentives and culture [17, 37, 42, 44–48, 51, 54, 55, 57, 59, 66, 68, 69, 71, 73, 74, 78, 83, 92, 102]; (4) provides technical infrastructure [40, 42, 51, 52, 57, 66, 75, 82, 84, 88, 94, 95, 97, 98, 104, 108–110]; and (5) promotes collaborative and active engagement [18, 37, 40, 45, 47, 48, 52–54, 56, 57, 59, 60, 62, 64, 72, 73, 76, 87, 90, 93, 95, 103, 105, 106, 108, 110]. Additionally, five publications identified the reduction of costs as a primary feature of an LHS approach [47, 61, 75, 80, 87], five articles indicated that an LHS approach could guide policy- and decision-making [49, 64, 84, 88, 99], and three publications described LHS' impact on health equity [37, 41, 95].

Frameworks: In total, 56 articles presented 21 unique LHS frameworks. Table 2 presents an overview of all included LHS frameworks.

Domains: In total, 50 articles presented domains associated with an LHS approach. Eight described the data to knowledge (D2K), knowledge to performance (K2P) and performance back to data (P2D) cycle as being key LHS domains [4, 49, 60, 74, 81, 82, 85, 88]. Additionally, six articles presented subdomains related to this D2K–K2P–P2D cycle, notably, actions such as assembling data, analysing data, integrating external evidence, interpreting results, designing an intervention, taking action, forming a learning community and capturing data about practice

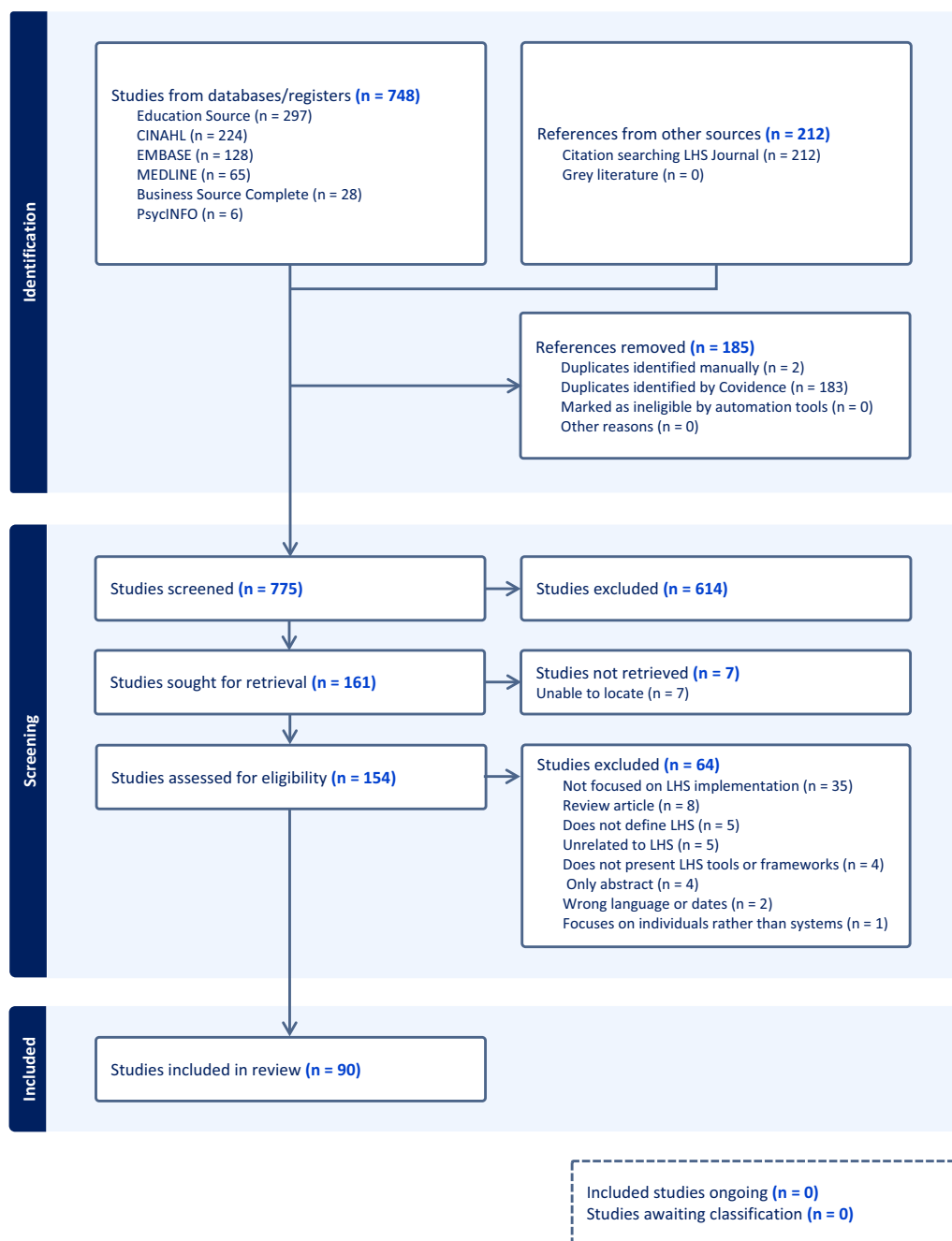


Fig. 1 PRISMA flow diagram

[60, 61, 69, 87, 104, 109]. Seven articles presented core values associated with an LHS approach. These core values included: (1) person-focused care; (2) privacy; (3) inclusiveness; (4) transparency; (5) accessibility; (6) adaptability; (7) governance; (8) cooperative and participatory leadership; (9) scientific integrity; (10) value; (11) patient safety and experience; (12) performance on externally reported measures; (13) interoperability and

adaptability; and (14) engagement and growth mindset [42, 47, 49–51, 56, 86]. Finally, 17 articles described domains that aligned with the NAM/IoM LHS roadmap to varying degrees. These domains included: (1) systems of leadership; (2) governance and management; (3) quality improvement; (4) engagement and community building; (5) data, analytics, and research; (6) creating a data infrastructure; (7) establishing a supportive culture of

Table 1 Characteristics of included publications

Author (year)	Country of origin	Discipline	Publication type	Publication aim
Adler-Milstein (2019)	United States	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Explore the technical components needed for an LHS
Ainsworth (2015)	United Kingdom	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Explore the technical components needed for an LHS
Allen (2021)	United States	Health services research	Measure development	Propose rules or best practices for designing and implementing LHS
Anderson (2021)	United States	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Reflect on an organization or network's LHS experience
Austin (2021)	United States	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Reflect on an organization or network's LHS experience
Azar (2022)	United States	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Use novel research methods or theories to inform LHS development and scale up
Bailes (2021)	United States	Health services research	Cross-sectional study	Implement and evaluate a novel LHS in an organization
Beck (2021)	United States	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Reflect on an organization or network's LHS experience
Bindman (2019)	United States	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Reflect on an organization or network's LHS experience
Blizinsky (2018)	United States	Medicine	Text and opinion (e.g. commentaries, perspectives, experience reports)	Develop or test a new LHS framework
Boes (2018)	Switzerland	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Reflect on an organization or network's LHS experience
Bradbury (2014)	United Kingdom	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Reflect on an organization or network's LHS experience
Britto (2018)	United States	Health services research	Case study	Develop or test a new LHS framework
Brooks (2017)	United States	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Develop or test a new LHS framework
Cameron (2018)	United States	Health services research	Case study	Explore the technical components needed for an LHS
Carr (2022)	United States	Health services research	Qualitative research	Explore the technical components needed for an LHS
Ciemins (2020)	United States	Health services research	Survey	Explore the potential of LHS for capacity building
Coley (2022)	United States	Health professions education	Text and opinion (e.g. commentaries, perspectives, experience reports)	Develop or test a new LHS framework
Colldén (2022)	Sweden	Health services research	Qualitative research	Explore facilitators and barriers to implementing an LHS
Daniel (2017)	France	Health services research	Case study	Develop or test a new LHS framework
Davis (2021)	United States	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Explore facilitators and barriers to implementing an LHS
Dushyanthen (2022)	Australia	Health professions education	Evaluation	Implement and evaluate a novel LHS in an organization

Table 1 (continued)

Author (year)	Country of origin	Discipline	Publication type	Publication aim
Easterling (2024)	United States	Health professions education	Text and opinion (e.g. commentaries, perspectives, experience reports)	Reflect on an organization or network's LHS experience
El-Kareh (2023)	United States	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Develop or test a new LHS framework
Ethier (2018)	Canada	Health services research	Case study	Implement and evaluate a novel LHS in an organization
Feldman (2022)	United States	Health professions education	Text and opinion (e.g. commentaries, perspectives, experience reports)	Explore the learning components or competency requirements of an LHS
Flynn (2018)	United States	Health informatics	Case study	Develop or test a new LHS framework
Foley (2017)	United Kingdom	Health services research	Qualitative research	Explore the role of LHS for quality improvement (QI) activities in an organization
Foley (2023)	United Kingdom	Health services research	Mixed methods	Develop or test a new LHS framework
Franklin (2022)	United States	Health professions education	Mixed methods	Explore the learning components or competency requirements of an LHS
Friedman (2022)	United States	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Explore the technical components needed for an LHS
Fung-Kee-Fung (2018)	Canada	Medicine	Case study	Investigate whether or how an LHS could improve health outcomes for specific health conditions
Gilmartin (2021)	United States	Medicine	Survey	Use novel research methods or theories to inform LHS development and scale up
Greenberg-Worisek (2021)	United States	Health professions education	Text and opinion (e.g. commentaries, perspectives, experience reports)	Develop or test an LHS readiness/maturity measurement tool
Grob (2022)	United States	Health services research	Qualitative research	Plan for patient engagement in an LHS
Groot (2022a)	Canada	Medicine	Evaluation	Implement and evaluate a novel LHS in an organization
Groot (2022b)	Canada	Medicine	Text and opinion (e.g. commentaries, perspectives, experience reports)	Reflect on an organization or network's LHS experience
Harrison (2021)	United States	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Develop or test a new LHS framework
Hartley (2021)	United States	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Reflect on an organization or network's LHS experience
Heys (2023)	United Kingdom	Medicine	Text and opinion (e.g. commentaries, perspectives, experience reports)	Investigate whether or how an LHS could improve health outcomes for specific health conditions
Johnston (2017)	United Kingdom	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Develop or test an LHS readiness/maturity measurement tool
Kass (2018)	United States	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Discuss the ethical, legal or cultural considerations of an LHS
Keck (2021)	United States	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Reflect on an organization or network's LHS experience

Table 1 (continued)

Author (year)	Country of origin	Discipline	Publication type	Publication aim
Keugoung (2021)	Benin and Guinea	Health services research	Qualitative research	Reflect on an organization or network's LHS experience
Kilbourne (2022)	United States	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Explore the learning components or competency requirements of an LHS
Kohn (2022)	United States	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Explore the technical components needed for an LHS
Koscielniak (2022)	United States	Rehabilitation	Text and opinion (e.g. commentaries, perspectives, experience reports)	Investigate whether or how an LHS could improve health outcomes for specific health conditions
Krapohl (2020)	United States	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Reflect on an organization or network's LHS experience
Lannon (2021)	United States	Health services research	Measure development	Develop or test an LHS readiness/maturity measurement tool
Lehmann (2018)	United States	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Propose rules or best practices for designing and implementing LHS
Levin (2023)	Canada	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Implement and evaluate a novel LHS in an organization
Lozano (2022)	United States	Health professions education	Text and opinion (e.g. commentaries, perspectives, experience reports)	Explore the potential of LHS for capacity building
Masica (2022)	United States	Health professions education	Text and opinion (e.g. commentaries, perspectives, experience reports)	Develop or test a new LHS framework
Matsumoto (2021)	Japan	Medicine	Retrospective chart review	Investigate whether or how an LHS could improve health outcomes for specific health conditions
McCreary (2022)	United States	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Investigate whether or how an LHS could improve health outcomes for specific health conditions
Morain (2017)	United States	Medicine	Qualitative research	Explore facilitators and barriers to implementing an LHS
Myers (2018)	United States	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Develop or test a new LHS framework
Naimoli (2018)	United States	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Explore the role of LHS for building resilience in LMICs
Nash (2023)	Canada	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Reflect on an organization or network's LHS experience
Noseworthy (2021)	Canada	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Explore the technical components needed for an LHS
Okun (2017)	United States	Health services research	Qualitative research	Implement and evaluate a novel LHS in an organization
Ong (2022)	United States	Medicine	Text and opinion (e.g. commentaries, perspectives, experience reports)	Develop or test an LHS readiness/maturity measurement tool
Parsons (2021)	United States	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Propose rules or best practices for designing and implementing LHS
Pestka (2022)	United States	Medicine	Qualitative research	Use novel research methods or theories to inform LHS development and scale up

Table 1 (continued)

Author (year)	Country of origin	Discipline	Publication type	Publication aim
Platt (2018)	United States	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Discuss the ethical, legal or cultural considerations of an LHS
Porcaro (2022)	United States	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Reflect on an organization or network's LHS experience
Potts (2017)	United States	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Explore the learning components or competency requirements of an LHS
Pronovost (2017)	United States	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Reflect on an organization or network's LHS experience
Ramaswamy (2022)	United States	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Explore the potential of LHS for capacity building
Reid (2022)	Canada	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Explore facilitators and barriers to implementing an LHS
Resnik (2022)	United States	Rehabilitation	Needs assessment	Explore the learning components or competency requirements of an LHS
Rubin (2018)	United States	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Propose rules or best practices for designing and implementing LHS
Schleyer (2021)	United States	Health services research	Case study	Reflect on an organization or network's LHS experience
Scobie (2020)	United Kingdom	Health services research	Policy analysis	Explore facilitators and barriers to implementing an LHS
Seid (2020)	United States	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Use novel research methods or theories to inform LHS development and scale up
Seid (2021a)	United States	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Use novel research methods or theories to inform LHS development and scale up
Seid (2021b)	United States	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Propose rules or best practices for designing and implementing LHS
Sheikh (2020)	United Kingdom	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Propose rules or best practices for designing and implementing LHS
Soejima (2021)	Japan	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Reflect on an organization or network's LHS experience
Steele Gray (2018)	Canada	Health services research	Case study	Explore facilitators and barriers to implementing an LHS
Steels (2021)	United Kingdom	Health services research	Qualitative research	Explore facilitators and barriers to implementing an LHS
Stensland (2022)	United States	Health services research	Qualitative research	Use novel research methods or theories to inform LHS development and scale up
Sunderland (2018)	Australia	Health professions education	Case study	Explore the potential of LHS for capacity building
Teichert (2024)	Netherlands	Pharmacy	Case study	Develop or test an LHS readiness/maturity measurement tool
Thygeson (2021)	United States	Health services research	Case study	Use novel research methods or theories to inform LHS development and scale up

Table 1 (continued)

Author (year)	Country of origin	Discipline	Publication type	Publication aim
Varnell (2023)	United States	Medicine	Text and opinion (e.g. commentaries, perspectives, experience reports)	Investigate whether or how an LHS could improve health outcomes for specific health conditions
Vinson (2021)	United States	Social Science	Text and opinion (e.g. commentaries, perspectives, experience reports)	Discuss the ethical, legal or cultural considerations of an LHS
Wood (2021)	Canada	Health professions education	Text and opinion (e.g. commentaries, perspectives, experience reports)	Explore the learning components or competency requirements of an LHS
Wu (2019)	Taiwan	Health services research	Text and opinion (e.g. commentaries, perspectives, experience reports)	Reflect on an organization or network's LHS experience
Yang (2019)	Taiwan	Medicine	Implementation study	Reflect on an organization or network's LHS experience

Table 2 LHS frameworks

Framework type	References
Educational frameworks: - Friedman learning cycle - 3-M framework for building learning organizations - Knowledge grid framework	Adler-Milstein 2019; Dushyanthen 2022; Flynn 2018; Friedman 2022; Kilbourne 2022; Krapohl 2020; Levin 2023; Masica 2022; Naimoli 2018; Noseworthy 2021; Resnik 2022; Wu 2019
Maturity models: - International Family Maturity Matrix	Teichert 2024
Logic models: - LHS Logic Model - Cystic Fibrosis Learning Organization Logic Model - Kaiser Permanente Washington Logic Model	Allen 2021; Beck 2021; Collden 2022; Groot 2022a; Heys 2023; Ong 2022
Equity frameworks: - PETAL framework - Patient/family microsystem framework - Socially accountable health professions education LHS framework	Brooks 2017; Parsons 2021; Wood 2021
LHS classification frameworks - Types of LHS - Definitions of LHS	Foley 2017; Lehman 2018; Koscielniak 2022
National Academy of Medicine LHS-inspired frameworks	Blizinsky 2018; El Kareh 2023; Pronovost 2017; Rubin 2018; Varnell 2023
Project-specific LHS flow diagrams	Ainsworth 2015; Austin 2021; Boes 2018; Britto 2018; Davis 2021; Ethier 2018; Foley 2023; Fung-Kee-Fung 2018; Grob 2022; Groot 2022b; Keugoung 2021; Kohn 2022; Matsumoto 2021; Myers 2018; Nash 2023; Soejima 2021; Yang 2019
Implementation frameworks - Pragmatic framework for LHS - Quality enhancement research initiative programs framework - Knowledge to action framework	Anderson 2022; Cameron 2018; Schleyer 2021
Organizational frameworks - Actor-oriented architecture framework - Actor-oriented network - Relational coordination theory - Community of solutions framework	Carr 2022; Porcaro 2022; Seid 2021a; Seid 2021b; Thygeson 2021;

learning; (8) building data-driven decision-making competencies; (9) incentivizing ongoing engagement; (10) creating information systems, data warehouses and integrated data portals; (11) ethics; (12) systems science; and (13) people and partnerships [40, 48, 52, 54, 65, 69, 72, 76, 79, 83, 103, 110–115].

Considerations for implementing an LHS approach (research questions 2 and 3)

The articles outlined barriers, facilitators and strategies to consider when implementing an LHS approach. Articles also reported key competencies that people working within an LHS approach should possess. Several of these

barriers and facilitators appeared to be two sides of the same coin, meaning that the same concept could help or hinder LHS implementation depending on how it was applied. Examples are provided below.

Barriers to implementing an LHS approach: There were two main categories of barriers to implementing an LHS approach: (1) interpersonal, organizational and financial resources, and (2) challenges related to research, data collection and synthesis.

Interpersonal, organizational, and financial resources: Limited human and financial resources were barriers to implementing an LHS approach. Two publications indicated that adopting an LHS approach was time and resource intensive [43, 116], with one author team articulating that few high-quality studies of successful LHS implementation are available as models to follow [38]. An unsupportive organizational culture was reported to hamper implementation efforts [75], as could difficulties sustaining a virtual community commons or space to share learning and best practices across the organization and with members [40]. Similarly, the complexity of partnerships within the LHS, and a lack of shared objectives, were cited as barriers to adopting an LHS approach in one article [41]. Financially, the authors of two articles indicated that there were few ways to fund local system and community priorities, and there were few LHS-specific funding opportunities [41, 75].

Research, data collection and synthesis: additional barriers pertained to the research and data collection process, as well as to the technological requirements supporting these processes. Firstly, a lack of consensus on outcomes being measured [108] and a lack of interoperability across regions, systems and countries [43] limited the efficacy of using diverse electronic health record (EHR) platforms to support an LHS approach. Four articles identified the lack of quantitative data analysis or visualization tools and the challenges of translating evidence to practice as key barriers [37, 41, 75, 83]. The authors of these four studies cited data-sharing barriers, such as complex and multisource data that cannot be easily interpreted. Reid (2022) identified the fuzzy ethics boundaries between research and quality-improvement activities to be a limiting factor in an LHS [41]. Stensland (2022) indicated that an LHS approach may actually interfere with existing research practices, such as blinding in clinical trials, thereby limiting usefulness [81].

Facilitators to implementing an LHS approach: Key facilitators to implementing an LHS approach included creating a culture of learning and focusing on partnerships and processes that could enhance the uptake of an LHS.

Culture of learning: Eight articles indicated that promoting a psychologically safe institutional culture that

was supportive of an LHS approach facilitated its implementation [59, 61, 82, 92, 94, 108, 114, 117]; similarly, commitment from leadership [39, 47, 52, 56, 71, 75, 89, 99, 108, 109] and establishing a shared purpose [41, 47, 69, 80, 95, 106] were described as key facilitators. Five articles suggested that offering opportunities for continuing education [4, 89, 92, 97, 115] and protected time for research [66, 67, 71, 96, 103] could facilitate LHS implementation, as could providing recognition for efforts (e.g. considering LHS work in promotion and tenure decisions) [66, 103]. Finally, providing access to funding and resources was cited to be a key facilitator for LHS uptake [38–40, 54, 75].

Partnerships and processes: another important facilitator was the creation of partnerships. Three author teams recommended the development of robust data-sharing agreements to promote collaboration [50–52]. Others recommended establishing effective collaboration with representation from diverse disciplines and interested parties [51, 52, 80, 88–90, 94–96, 98, 103], including patients and families [45, 49, 57, 58, 71, 90, 93, 99, 106, 115, 118]. Blizinsky (2018) and Potts (2017) both called for partnerships with researchers who can help interpret the data generated as part of the LHS [46, 48]. For these partnerships to work in an LHS approach, 21 publications recommended establishing clear technology processes, infrastructure and workflows [37, 43, 46, 49, 52, 54, 57, 62, 70, 85, 91, 93, 109, 111, 115, 119–122], as well as clear knowledge translation processes [101, 109]. Finally, routine data collection processes that considered the interoperability of EHRs were identified as a major facilitator [37, 42, 54, 70, 88, 111, 122], alongside robust privacy policies [57].

Implementation strategies: Table 3 presents an overview of strategies that could facilitate the implementation of an LHS. Notably, these strategies focused on the data and technical components, the human components and the design components of an LHS.

Competencies and educational strategies: The included publications identified several competencies that health professionals and researchers working in an LHS should have. Specifically, these included research competencies, such as the ability to review and interpret data, pose feasible and timely research questions, select appropriate methods and synthesize evidence [41, 51, 57, 63, 72, 73, 76, 83, 95, 97, 98, 101, 113, 121]. Additionally, competencies in quality improvement [65, 72, 76, 83, 95, 98, 113], systems science (i.e. understanding health systems' strategic plan and capacities for change or the norms, values and practices associated with change) [41, 61, 69, 72, 76, 98, 113, 117, 121], informatics (i.e. building data and technology platforms, governance and safeguards that can jointly

Table 3 Strategies for implementing an LHS approach

Strategy type	Recommended implementation strategy	References
Data and technical components	Build on existing practices and analytics capabilities	Morain 2017; Naimoli 2018; Scobie 2020
	Use standardized data models/clear ontologies to promote interoperability	Daniel 2017; Flynn 2018; Koscielniak 2022; Varnell 2023; Yang 2019
	Use flexible data systems/warehouses	Ethier 2018; Koscielniak 2022
	Have ready-made toolkits to help troubleshoot; space to share resources	Keugoung 2021; Krapohl 2020; Seid 2020
Human components	Define a learning structure and community	Naimoli 2018; Varnell 2023
	Create new degree programs/learning opportunities focused on LHS	Feldman 2022; Kohn 2022; Levin 2023; Resnik 2022; Wu 2019
	Recruit or leverage skilled professionals (e.g. researchers, librarians, data scientists)	Adler-Milstein 2019; Naimoli 2018
	Develop strong leadership and culture that energizes individuals in an organization	Anderson 2022; Morain 2017; Vinson 2021
	Develop steering committees that involve patients/caregivers, and other partners	Koscielniak 2022; Levin 2023; Okun 2017
	Incentivize LHS participation (e.g. through promotion and tenure, financial incentives, protected time)	Dushyanthen 2022; El-Kareh 2023; Scobie 2020
	Identify and leverage champions	Schleyer 2021
Design components	Develop internal communications strategies	Colldén 2022; Pestka 2022; Schleyer 2021
	Seek and obtain appropriate resources	Morain 2017; Naimoli 2018; Schleyer 2021
	Start with small-scale implementations	Okun 2017
	Focus on integrating clinical and support services	Bradbury 2014; El-Kareh 2023; Kohn 2022; Morain 2017
	Standardize ethical, business and legal agreements	Seid 2020
	Use theory to support improvement work	Varnell 2023

accomplish care improvement, research needs and diversity while ensuring interoperability) [41, 48, 51, 63, 76, 85, 97, 98, 101, 113, 122, 123], and engagement (i.e. establishing mechanisms/relationships to set learning priorities with researchers, communities, patients and families) [41, 48, 49, 72, 76, 85, 98] were deemed important. Other competencies included knowledge of research ethics, data governance and privacy [43, 76, 98, 113]; leadership and communication skills [72, 76, 94, 96–98, 113]; and lifelong learning [46, 51, 57, 65].

Educational strategies: Our analysis revealed eight different educational strategies to support the development of LHS-specific competencies. These included: (1) quality-improvement collaboratives [65, 108]; (2) continuing education and training programs [47, 52, 66, 69, 76, 90, 108, 109]; (3) dissemination of printed information [59, 66, 108]; (4) learning laboratories or hubs [40, 98]; (5) peer-to-peer engagement [40, 47, 65, 69, 123]; (6) community conferences or workshops [40, 52, 66, 70, 73, 113, 117]; (7) graduate education programs [49, 55, 96–98]; (8) mentoring or coaching [55, 113]; and (9) educational rounds [64]. Five articles recommended the use of novel curricula to promote LHS competency development, including such curricula as a patient partner curriculum [54, 64], an informatics curriculum [121, 122], and an interdisciplinary collaboration curriculum [97].

Assessing readiness and maturity (research question 4)

Overall, 13 articles referenced assessing readiness to implement an LHS approach [17, 51, 59, 73, 78, 80, 88, 92, 93, 108, 109, 116, 124], but only three expanded on or contextualized the term [80, 116]. Teichert (2024) described organizational readiness for guideline implementation among pharmacists across the domains of (1) personalized care, (2) teamwork, (3) information systems and data exchange, (4) external collaboration and (5) education and research. Additionally, Pestka (2022) indicated that they were guided by the Consolidated Framework for Implementation Research (CFIR) domain of the inner setting: readiness for implementation. Finally, Adler-Milstein (2019) pointed to the framework produced from the NAM conference as a starting point for assessing the readiness of the United States healthcare system in a way that utilizes new knowledge and knowledge infrastructures. Similarly, 15 articles discussed assessing the maturity of an LHS [18, 40, 45, 59, 65, 72–74, 82, 93, 104, 110, 116, 123, 124], but only five operationalized the term maturity. Teichert (2024) defined maturity as the degree to which the team is aware and motivated, and able to perform, evaluate, improve and innovate. Porcaro (2022) and Britto (2018) discussed what a mature network would look like, stating that it is run independently from the parent organization and is self-governing. Mature

networks regularly evaluate their management structure and processes as part of routine operations. Lannon (2021) did not define maturity itself but rather specified that a maturity model identifies best practices and uses a yes/no questionnaire to assess performance. Similarly, Johnston (2017) outlined that digital maturity assessments can be used to allow organizations to understand their state of readiness to integrate digital technologies.

Moreover, 10 articles presented seven distinct tools that helped assess the readiness or maturity of an LHS. Table 4 presents an overview of the tool names, descriptions, domains, scales and items. Three tools focused on assessing maturity, three tools focused on assessing the learning environment, and one tool presented a series of questions for organizations to reflect on prior to implementing an LHS, aligning with the definition of readiness. Nine articles discussed other constructs that should be assessed when considering an LHS, aside from readiness or maturity [55, 58, 92, 93, 105, 106, 108, 117, 123]. These constructs included health system resilience [108], reliability enhancing work practices (i.e. practices that promote error-free performance in high-reliability organizations) [92], competence [55], engagement [57, 105, 106], staff experience [58], cultural infrastructure [117] and network functionality [123].

While there were several examples of patient and public engagement in LHS in general, there were no specific examples of having patients or the public help to assess organizational readiness or maturity to implement or scale an LHS approach. In terms of the broader discussion of patient and public engagement, 14 articles emphasized its importance when implementing an LHS approach [45, 49, 51, 56, 58, 64, 65, 73, 83, 86, 94, 109, 114, 115], and 9 presented examples of patient and public engagement in practice [40, 52, 58, 64, 72, 93, 106, 109, 116]. In one example, Ong and colleagues (2022) engaged people with cystic fibrosis, families, health professionals and community leaders in a proof-of-concept codesigned pilot study that aimed to develop a community structure that facilitated shared learning. Seid and colleagues (2020) initiated community conferences as part of an LHS approach that originally only included health professionals but evolved to being patient/family led. Two articles noted a lack of concrete examples of patient and family involvement in assessing and implementing an LHS approach and called for future stakeholder engagement [109, 116]. A total of 10 articles provided recommendations or suggestions for engagement, citing best practices such as financial compensation, codesign, collaborative priority-setting, patient-led learning activities, developing a clear governance structure with working groups or committees, and the use of frameworks to guide engagement [52, 57, 64, 65, 72, 73, 83, 106, 114, 116].

Discussion

The purpose of this review was to explore the current state of the literature on organizational readiness to implement an LHS, with the goal of informing the content of an LHS readiness questionnaire. Most of the literature included in this scoping review reflected the context of the privately funded United States healthcare system. Moreover, most articles consisted of commentaries or perspective pieces, with very few empirical examples of LHS that had been successfully implemented in practice. The predominance of commentaries may reflect the complexity of implementing an LHS approach. This outcome may be attributed to the dominance of theoretical discussions in the literature, limited practical implementation of LHS and a lack of funding or infrastructure to support empirical studies in this area. Of the articles outside the United States context, most ($n=19$) of the remaining studies reflected the Canadian and United Kingdom health systems. Only one article reflected a low- or middle-income country (LMIC) context, indicating a pressing need to critically explore whether and how an LHS approach aligns with LMICs' contexts, needs, priorities and available resources. Indeed, as Witter and colleagues (2022) argued, there is an emerging appreciation of LHS but limited research related to its level of acceptability and feasibility in LMIC contexts [125]. While their literature review on LHS in LMICs suggested that many of the domains, barriers and facilitators may appear similar to those identified in this review, additional work is needed to explore what organizational readiness to implement an LHS looks like in LMIC contexts and what organizations will be involved as key actors (e.g. governmental organizations, civil society organizations, among others) and how.

The extant literature states that the objective of an LHS is to align science, informatics, incentives and culture for long-term improvement and innovation. Our scoping review found that many articles drew upon the original NAM definition to inform their understanding of an LHS [18, 37–78]. One author explained the rationale for this use of the NAM/IoM definition, stating that the definition was sufficiently broad that it could be applied to diverse contexts [67]. Other definitions emphasized the importance of an LHS being dynamic, having a culture of health system improvement and increasing the value of healthcare services provided by reducing costs and promoting health equity [37, 41, 47, 61, 75, 80, 87, 95]. While definitions can be helpful, overstandardizing them risks oversimplifying complex issues and limiting the flexibility needed to address the unique challenges that each context presents [126, 127]. Our findings align with those of de Bruin and colleagues [128], whose mapping review of the LHS landscape identified key aims related

Table 4 (continued)

Tool name	Tool description	Tool domains	Tool scales	Item examples	References
Learning Organization Survey (LOS)	The LOS-27 is a 27-item reliable and valid measure of organizational learning designed to pinpoint areas needing improvement. The tool was developed to examine the three building blocks of organizational learning: supportive learning environments, concrete learning processes and practices, and leadership that reinforces learning. Together, the building blocks produce supportive learning environments, which are essential to LHS	Supportive learning environments Learning processes and practices Leadership Effective commitment Mindful organizing Organizational citizenship Respectful interactions	Likert scale: Highly inaccurate Moderately inaccurate Slightly inaccurate Neither accurate nor inaccurate Slightly accurate Moderately accurate Highly accurate	- Experienced employees receive training when new initiatives are launched - People are eager to share information about what does not work as well as what does work	Gilmartin 2021
Consolidated Framework for Implementation Research (CFIR)	The CFIR synthesizes findings from empirical studies and frameworks on knowledge transfer, implementation, evidence-based practice, dissemination and organizational change. The CFIR facilitates research on learning by including a criterion for learning climate, defined as one in which leaders actively seek team members' inputs; team members feel they are essential partners in the change process and feel psychologically safe to try new methods; and members have enough time and space for reflective thinking and evaluation	Intervention characteristics Outer setting Inner setting Characteristics of individuals Process	No scale provided	No items provided	Harrison 2021; Pestka 2022

Table 4 (continued)

Tool name	Tool description	Tool domains	Tool scales	Item examples	References
Digital Maturity Assessment	The Digital Maturity Assessment is a self-assessment mechanism that allows organizations to understand their current state of readiness to integrate digital technologies. Digital maturity asks an organization's managers and front-line service users to understand the current capacity of their digital landscape through a series of questions. This is intended to identify the anticipated, typical, logical and desired evolution path to readiness for an organization	Interoperability Digital architecture Digital strategy and literacy	No scale provided	No items provided	Johnston 2017
Project Assessment Tool	The Project Assessment Tool is a tool developed by the research team to help categorize projects by area of focus, potential impact and fit within an LHS	Scalability Development complexity Implementation complexity Impact timeline Allocated and required resources Direct care impacts	No scale provided	1. What are the key foci critical to initial development and future sustainability of the LHS? 2. How can the LHS enhance existing culture, operations and clinical care in healthcare systems and in the market-place?	Schleyer 2021
Framework for understanding, designing, developing, and evaluating LHS	The framework presents key questions to ask when developing an LHS. The questions should be worked through in an iterative rather than linear fashion	No domains provided	No scale provided	1. What is our rationale for developing an LHS? 2. What sources of complexity exist at the system and intervention level? 3. What strategic approaches to change do we need to consider? 4. What technical building blocks will we need?	Foley 2022

to the concept of LHS. These aims included accelerating research, enhancing decision-making, improving care quality and outcomes, optimizing service delivery, reducing costs, increasing value and innovation, driving system transformation, advancing patient and population health, and fostering learning. Together with de Bruin and colleagues' identified aims, these definitions underscore the potential of an LHS to capture and report data across the quintuple aim framework: patient needs, population health, care experiences, equity and costs [129]. Such an approach is relevant for health and social systems looking to adapt their models of care due to shifting demographics, such as an ageing population and an increasing incidence of chronic conditions. For example, Rosen and colleagues [130] argued that LHS approaches are being implemented in academic medical centres and large health systems, but that these organizations are less able to address issues of health equity owing to limited meaningful connections with patients and communities. They recommended expanding LHS models to a broader range of healthcare organizations, such as local hospitals and primary care or community settings, to more effectively reach patients who may otherwise be underserved [130]. However, additional work on how to critically assess and address organizational readiness to implement an LHS approach at the macro, meso, and micro levels of a health system – that includes the diverse settings proposed by Rosen and colleagues – is required.

Regarding an LHS framework, several studies indicated that the role of an LHS was to iteratively move from data to knowledge, from knowledge to practice, and from practice to data [4, 49, 60, 74, 81, 82, 85, 88]. This cycle depicts the potential of an LHS to accelerate evidence use in practice. Many of these frameworks focused on the technical aspects of an LHS (e.g. interoperability), with only a few providing insights into the competencies required by people working within an LHS (e.g. ability to interpret and use data) and how to develop those competencies (e.g. communities of practice, peer teaching). Indeed, one article argued that LHSs are heavily focused on data generation and use, and the current literature does not necessarily address the learning needs of people working within an LHS [46]. Considering the many and complex competencies (i.e. the ability to review and interpret data or pose feasible and timely research questions) that are required for health professionals and researchers to operate within an LHS is essential for ensuring that members of an organization are ready and able to do so. Since organizational readiness consists of having members of an organization be both willing and able to adopt a change [20], organizations looking to implement an LHS approach must ensure that its members are appropriately equipped to do so otherwise uptake of

an LHS approach may be hindered. While educational interventions such as quality-improvement collaboratives or continuing education/training programs are helpful, they may not be sufficient. The knowledge and competencies required to work within an LHS – and indeed the LHSs themselves – are embedded within complex webs of social and political contexts that interact in dynamic ways. It may therefore be helpful to holistically consider the environments that enable competency development and collaborative capacity building within and implementation of an LHS approach [131, 132].

While other reviews have aimed to map the LHS landscape [14, 16, 125, 128], none of them catalogued tools that assess organizational readiness to implement an LHS approach. Some articles focused on assessing the maturity of an LHS exist at present [18, 116], but these appear to assume that an LHS is already in place and could thus be scaled across a larger network. The focus of maturity exists at a network and technical level [18, 116, 124], whereas readiness appears to focus on the people within an organization [22, 26, 27]. For an LHS to be successfully implemented, organizational readiness to change – an essential precursor to uptake – must be addressed [20]. Indeed, large-scale change in healthcare organizations requires collective behaviour change related to both the technical aspects (e.g. interoperability) and inter-professional dynamics (e.g. trust); in other words, for a change to be successfully implemented, those implementing the change will need to consider staffing, workflow, decision-making and rewards to promote buy-in among those working within the organization [20]. These factors are not exhaustive or fixed; rather, they may interact in complex and context-dependent ways, depending on the specific LHS and the broader environment in which they operate [133]. Arguably, organizational readiness to adopt an LHS approach needs to be established before beginning to implement an LHS approach and to guide further progress towards an LHS. Once an LHS approach has been successfully implemented, maturity can be assessed, and the subsequent spread or scale of the approach can be explored [134, 135]. The use of a readiness assessment tool may help organizations establish whether they have both the capacity and willingness to embrace change and can serve as a foundation for dialogue and brainstorming. However, there appears to be a lack of assessment tools that can help members of an organization establish their readiness to implement such a change. In this review, we identified seven distinct LHS tools that were intended to assess the readiness for or maturity of an LHS approach. While all tools touched on the concept of LHS within the context of the articles in which they were presented, not all tools were LHS-specific. Of those that were, two tools presented a series of

helpful questions to consider when planning for an LHS approach [73, 109]. One article [18] presented a maturity grid for learning networks, but the objective of this study was to provide guidance on tangible steps for developing and maturing newly implemented LHS, rather than on assessing readiness to implement an LHS. No specific or formal tools related to assessing organizational readiness to implement an LHS approach were found. This finding is important because an LHS-specific tool can help inform organizations that are interested in implementing an LHS approach about the specific resources they should invest in to achieve their goals. It could also help organizations identify essential resources and processes, as opposed to those that are merely nice to have, allowing them to invest time and financial resources strategically. Finally, having a content-validated and psychometrically tested questionnaire will ensure that organizational readiness is being effectively measured by organizations looking to adopt an LHS approach. Despite these findings, it is important to recognize that an LHS-specific organizational readiness tool represents only one aspect of the overall picture. It can provide a starting point for iterative discussions among members of an organization to critically explore and evaluate the next steps they need to take to be ready to embrace an LHS approach.

These findings highlight the need for an LHS readiness questionnaire that draws on adjacent fields such as behaviour change, change management, education and quality improvement. Existing tools (e.g. ORCA, ORIC) assess readiness for change, but the scale and complexity of LHS implementation demand a dedicated approach. A tailored tool would help organizations evaluate their capacity and willingness to address barriers (e.g. financial constraints, time, complexity) and leverage facilitators [e.g. high-quality data, comprehensive electronic medical records (EMRs), recognition of clinician effort]. It should also assess readiness to adopt LHS-specific strategies, such as engaging key users, selecting technologies requiring minimal training, and providing educational supports for behaviour change. Given the complexity of LHS implementation across settings, such a tool would be a valuable first step for healthcare organizations seeking to embrace this transformation.

Limitations and future directions

This study has limitations. We executed a comprehensive search strategy but may have missed relevant articles owing to differences in the terminology used relating to LHS globally (i.e. some terms may be more aligned with the original NAM conceptualization and less applicable to country contexts outside the United States). Additionally, we focused on the peer-reviewed literature and acknowledge that the grey literature may contain relevant

reports that describe LHS implementation. We also included articles in English or French, perhaps excluding relevant articles published in other languages. While we aimed to include articles focusing on global contexts, including low- and middle-income countries (LMICs), most articles came from the United States. Future research specifically focusing on the barriers and facilitators to adopting an LHS approach in LMICs would be highly valuable. Our findings are largely based on weak research designs, with 59% of included articles consisting of commentaries or opinion pieces. Thus, there is a pressing need for more robust research related to LHS.

Conclusions

Learning health systems can capture and report data to address patient needs, population health, care experiences, equity and costs. Yet, few readiness tools exist, and those adapted from quality improvement lack the specificity needed for LHS implementation. Our review identified barriers, facilitators and strategies for collective behaviour change that should inform future tool development. We found that LHSs are consistently described as data-driven, continuously improving systems that integrate evidence into practice through learning cycles, supported by infrastructure, culture and stakeholder engagement. Implementation is challenged by resource limitations, interoperability issues and cultural barriers but facilitated by leadership, partnerships and supportive processes. Readiness and maturity assessments remain underdeveloped, with limited patient and public involvement, highlighting opportunities to advance both measurement and meaningful engagement. A future LHS readiness tool should evaluate culture (leadership, shared purpose, psychological safety), infrastructure (data, interoperability, funding, capacity), and competencies (research, informatics, QI, engagement, ethics), while explicitly incorporating patient and public voices in priority-setting and governance. It should also consider contextual factors such as partnerships, policies and resources, and explore the relationship between readiness and maturity for questionnaire development.

Appendix 1

MEDLINE database search strategy

Ovid MEDLINE(R) ALL < 1946 to May 08, 2024 >

1. Learning Health System/ 287.
2. learning health* system*.ti,ab,kw. 1343.
3. learning health* communit*.ti,ab,kw. 9
4. learning health* network*.ti,ab,kw. 33.
5. rapid learning network*.ti,ab,kw. 3
6. learning communit*.ti,ab,kw. 953.

7. improvement communit*.ti,ab,kw. 38.
8. or/1–7 2400.
9. organizational innovation/ or change management/ 25,563.
10. organi?ational readiness.ti,ab,kw. 598.
11. organi?ational innovation*.ti,ab,kw. 425.
12. maturity.ti,ab,kw. 41,583.
13. organi?ational efficac*.ti,ab,kw. 19.
14. collective efficac*.ti,ab,kw. 685.
15. change valence.ti,ab,kw. 12.
16. (change adj5 read*).ti,ab,kw. 4406.
17. (change adj5 manag*).ti,ab,kw. 12,369.
18. or/9–17 83,863.
19. 8 and 18 65.

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Author contributions

C.G., A.T., A.B., P.B., M.A., M.E.P., Y.C., P.K.T. and S.A. conceptualized this study. C.G., A.T., A.B. and S.A. developed the search strategy, screening criteria and extraction tools. C.G., Z.E., N.G. and F.M. completed the screening, data extraction and analysis. C.G. and S.A. wrote the final manuscript. All authors reviewed and approved the final manuscript.

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Declarations

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Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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References

1. Public Health Agency of Canada. Aging and chronic diseases: a profile of Canadian seniors. Government of Canada; 2020.
2. Steffler M, Li Y, Weir S, Shaikh S, Murtada F, Wright JG, et al. Trends in prevalence of chronic disease and multimorbidity in Ontario. *Canada Canadian Medical Association Journal*. 2021;193(8):E270–7.
3. Morris ZS, Wooding S, Grant J. The answer is 17 years, what is the question: understanding time lags in translational research. *J R Soc Med*. 2011;104(12):510–20.
4. Kilbourne AM, Evans E, Atkins D. Learning health systems: driving real-world impact in mental health and substance use disorder research. *FASEB Bioadv*. 2021;3(8):626–38.
5. Hanney SR, Castle-Clarke S, Grant J, Guthrie S, Henshall C, Mestre-Ferandiz J, et al. How long does biomedical research take? Studying the time taken between biomedical and health research and its translation into products, policy, and practice. *Health Res Policy Syst*. 2015;13:1.
6. MacDermid JC, Graham ID. Knowledge translation: putting the “practice” in evidence-based practice. *Hand Clin*. 2009;25(1):125–34.
7. Greene SM, Reid RJ, Larson EB. Implementing the learning health system: from concept to action. *Ann Intern Med*. 2012;157(3):207–10.
8. Maggio LA, Villalba K, German D, Kanter SL, Collard HR. Defining the learning health care system: an international health system leadership perspective. *Acad Med*. 2023;8:34.
9. Institute of Medicine. The learning healthcare system: workshop summary. Washington: DC, Institute of Medicine; 2007.
10. Menear M, Blanchette M-A, Demers-Payette O, Roy D. A framework for value-creating learning health systems. *Health research policy and systems*. 2019;17(1):79.
11. Kruk ME, Gage AD, Arseneault C, Jordan K, Leslie HH, Roder-DeWan S, et al. High-quality health systems in the Sustainable Development Goals era: time for a revolution. *Lancet Glob Health*. 2018;6(11):e1196–252.
12. Friedman CP, Rubin JC, Sullivan KJ. Toward an information infrastructure for global health improvement. *Yearb Med Inform*. 2017;26(1):16–23.
13. McDonald PL, Van Der Wees P, Weaver GC, Harwood K, Phillips JR, Corcoran M. Learning health systems from an academic perspective: establishing a collaboratory within a school of medicine and health sciences. *Med Educ Online*. 2021;26(1):1917038.
14. Enticott J, Johnson A, Teede H. Learning health systems using data to drive healthcare improvement and impact: a systematic review. *BMC Health Serv Res*. 2021;21(1):200.
15. Somerville M, Cassidy C, Curran JA, Johnson C, Sinclair D, Elliott RA. Implementation strategies and outcome measures for advancing learning health systems: a mixed methods systematic review. *Health Res Policy Syst*. 2023;21(1):120.
16. Vanderhout S, Bird M, Giannarakos A, Whitmore C. Mapping the landscape: a protocol for a jurisdictional scan of self-identified learning health systems. *medRxiv*. 2023 ((Vanderhout, Bird) Institute for Better Health, Trillium Health Partners, Mississauga, ON, Canada (Giannarakos) Library and Knowledge Services, Trillium Health Partners, Mississauga, ON, Canada (Whitmore) School of Nursing, McMaster University, Hamilton, ON).
17. Harrison MI, Shortell SM. Multi-level analysis of the learning health system: Integrating contributions from research on organizations and implementation. *Learning Health Systems*. 2021;5(2):1–11.
18. Lannon C, Schuler CL, Seid M, Provost LP, Fuller S, Purcell D, et al. A maturity grid assessment tool for learning networks. *Learning Health Systems*. 2021;5(2):e10232.
19. Damschroder LJ, Reardon CM, Widerquist MAO, Lowery J. The updated consolidated framework for implementation research based on user feedback. *Implement Sci*. 2022;17(1):75.
20. Weiner BJ. A theory of organizational readiness for change. *Implement Sci*. 2009;4(1):67.
21. Castaneda SF, Holscher J, Mumman MK, Salgado H, Keir KB, Foster-Fishman PG, et al. Dimensions of community and organizational readiness for change. *Prog Community Health Partnersh*. 2012;6(2):219–26.
22. Shea CM, Jacobs SR, Esserman DA, Bruce K, Weiner BJ. Organizational readiness for implementing change: a psychometric assessment of a new measure. *Implement Sci*. 2014;9:7.

23. Wasylak T, Benzie K, McNeil D, Zanoni P, Osioy K, Mullie T, et al. Creating value through learning health systems: the Alberta strategic clinical network experience. *Nurs Adm Q*. 2023;47(1):20–30.
24. Gramlich L, Nelson G, Nelson A, Lagendyk L, Gilmour LE, Wasylak T. Moving enhanced recovery after surgery from implementation to sustainability across a health system: a qualitative assessment of leadership perspectives. *BMC Health Serv Res*. 2020;20(1):361.
25. Noseworthy T, Wasylak T, O'Neill B. Strategic clinical networks in Alberta: Structures, processes, and early outcomes. *Healthc Manage Forum*. 2015;28(6):262–4.
26. Helfrich CD, Li Y-F, Sharp ND, Salek AE. Organizational readiness to change assessment (ORCA): Development of an instrument based on the Promoting Action on Research in Health Services (PARIHS) framework. *Implement Sci*. 2009;4:38.
27. Mlake-Lye IM, Delevan DM, Ganz DA, Mittman BS, Finley EP. Unpacking organizational readiness for change: an updated systematic review and content analysis of assessments. *BMC Health Serv Res*. 2020;20(1):106.
28. Joint Committee on the standards for educational and psychological testing of the American Educational Research Association TAPA, and the National Council on Measurement in Education, . Standards for educational and psychological testing. Washington, DC: American Educational Research Association; 2014.
29. Arksey H, O'Malley L. Scoping studies: towards a methodological framework. *Int J Soc Res Methodol*. 2005;8(1):19–32.
30. Levac D, Colquhoun H, O'Brien K. Scoping studies: advancing the methodology. *Implement Sci*. 2010;5:69.
31. Peters MDJ, Marnie C, Colquhoun H, Garrity CM, Hempel S, Horsley T, et al. Scoping reviews: reinforcing and advancing the methodology and application. *Syst Rev*. 2021;10(1):263.
32. Peters MDJ, Marnie C, Tricco AC, Pollock D, Munn Z, Alexander L, et al. Updated methodological guidance for the conduct of scoping reviews. *JBI Evid Synth*. 2020;18(10):2119–26.
33. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA extension for scoping reviews (PRISMA-ScR): Checklist and explanation. *Ann Intern Med*. 2018;169(7):467–73.
34. Hsieh H, Shannon S. Three approaches to qualitative content analysis. *Qual Health Res*. 2005;15(9):1277–88.
35. Miles M, Huberman A, Saldana J. Qualitative data analysis: a methods sourcebook. Thousand Oaks: SAGE; 2014.
36. Munn Z, Peters MDJ, Stern C, Tufanaru C, McArthur A, Aromataris E. Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. *BMC Med Res Methodol*. 2018;18(1):143.
37. Azar KMJ, Pletcher MJ, Greene SM, Pressman AR. Learning health system, positive deviance analysis, and electronic health records: synergy for a learning health system. *Learning Health Syst*. 2022;45:e10348.
38. Groot G, Baer S, Badea A, Dalidowicz M, Yasinian M, Ali A, et al. Developing a rapid evidence response to COVID-19: the collaborative approach of Saskatchewan, Canada. *Learning Health Systems*. 2022;6(1):e10280.
39. Groot G, Witham S, Badea A, Baer S, Dalidowicz M, Reeder B, et al. Evaluating a learning health system initiative: lessons learned during COVID-19 in Saskatchewan. *Canada Learning Health Syst*. 2022;23:e10350.
40. Ong T, Albon D, Amin RS, Bailey J, Bandla S, Britto MT, et al. Establishing a cystic fibrosis learning network: interventions to promote collaboration and data-driven improvement at scale. *Learning Health Syst*. 1998;8:e10354.
41. Reid RJ, Greene SM. Gathering speed and countering tensions in the rapid learning health system. *Learning Health Syst*. 2002;45:e10358.
42. Brooks D, Douglas M, Aggarwal N, Prabhakaran S, Holden K, Mack D. Developing a framework for integrating health equity into the learning health system. *Learning Health Systems*. 2017;1(3):e10029.
43. Daniel C, Ouagne D, Sadou E, Paris N, Hussain S, Jaulent M-C, et al. Cross border semantic interoperability for learning health systems: the EHR4CR semantic resources and services. *Learning Health Systems*. 2017;1(1):e10014.
44. Foley TJ, Vale L. What role for learning health systems in quality improvement within healthcare providers? *Learning Health Systems*. 2017;1(4):e10025.
45. Okun S, Goodwin K. Building a learning health community: by the people, for the people. *Learning Health Systems*. 2017;1(3):e10028.
46. Potts J, Thompson R, Merchant R, Ciemins EL, Bush RW, Anderson RA, et al. Learning: contemplating the unexamined core of learning health systems. *Learning Health Systems*. 2017;1(4):e10036.
47. Pronovost PJ, Mathews SC, Chute CG, Rosen A. Creating a purpose-driven learning and improving health system: the Johns Hopkins Medicine quality and safety experience. *Learning Health Systems*. 2017;1(1):e10018.
48. Blizinsky KD, Bonham VL. Leveraging the learning health care model to improve equity in the age of genomic medicine. *Learning Health Systems*. 2018;2(1):e10046.
49. Boes S, Mantwill S, Kaufmann C, Brach M, Bickenbach J, Rubinelli S, et al. Swiss Learning Health System: a national initiative to establish learning cycles for continuous health system improvement. *Learning Health Systems*. 2018;2(3):e10059.
50. Ethier J-F, McGilchrist M, Barton A, Cloutier A-M, Curcin V, Delaney BC, et al. The TRANSFoRM project: experience and lessons learned regarding functional and interoperability requirements to support primary care. *Learning Health Systems*. 2018;2(2):e10037.
51. Rubin JC, Silverstein JC, Friedman CP, Kush RD, Anderson WH, Lichter AS, et al. Transforming the future of health together: The Learning Health Systems Consensus Action Plan. *Learning Health Systems*. 2018;2(3):e10055.
52. Seid M, Hartley DM, Dellal G, Myers S, Margolis PA. Organizing for collaboration: an actor-oriented architecture in ImproveCareNow. *Learning Health Systems*. 2020;4(1):e10205.
53. Sheikh A. From learning healthcare systems to learning health systems. *Learning Health Systems*. 2020;4(3):e10216.
54. Davis FD, Williams MS, Stamez RA. Geisinger's effort to realize its potential as a learning health system: a progress report. *Learning Health Systems*. 2021;5(2):e10221.
55. Greenberg-Worisek AJ, Shippee ND, Schaffhausen C, Johnson K, Shah ND, Linzer M, et al. The Learning Health System Competency Appraisal Inventory (LHS-CALI): a novel tool for assessing LHS-focused education needs. *Learning Health Systems*. 2021;5(2):8.
56. Parsons A, Unaka NI, Stewart C, Foster J, Perez V, Jones NHY, et al. Seven practices for pursuing equity through learning health systems: notes from the field. *Learning Health Systems*. 2021;5(3):e10279.
57. Seid M, Hartley DM, Margolis PA. A science of collaborative learning health systems. *Learning Health Systems*. 2021;5(3):e10278.
58. Steels A, Ainsworth J, van Staa TP. Implementation of a "real-world" learning health system: Results from the evaluation of the Connected Health Cities programme. *Learning Health Systems*. 2021;5(2):e10224.
59. Collén C, Hellström A. From, "invented here" to "use it everywhere!": a learning health system from bottom and/or top? *Learning Health Systems*. 2022;6(3):e10307.
60. Friedman CP. What is unique about learning health systems? *Learning Health Systems*. 2022;6(3):e10328.
61. Koscielniak N, Jenkins D, Hassani S, Buckon C, Tucker JS, Sienko S, et al. The SHONet learning health system: infrastructure for continuous learning in pediatric rehabilitation. *Learning Health Systems*. 2022;6(3):e10305.
62. Masica AL, Velasco F, Nelson TL, Medford RJ, Hughes AE, Pandey A, et al. The Texas Health Resources Clinical Scholars Program: learning health-care system workforce development through embedded translational research. *Learning Health Systems*. 2022;6(4):e10332.
63. Resnik L, Clark MA, Freburger J, McDonough C, Poploski K, Ressel K, et al. Development of a rehabilitation researcher survey of knowledge and interest in learning health systems research. *Learning Health Systems*. 2022;6(2):e10298.
64. Levin A, Malbeuf M, Hoens AM, Carlsten C, Ryerson CJ, Cau A, et al. Creating a provincial post COVID-19 interdisciplinary clinical care network as a learning health system during the pandemic: integrating clinical care and research. *Learning Health Systems*. 2023;7(1):e10316.
65. Nash DM, Rayner J, Bhatti S, Zagar L, Zwarenstein M. The Alliance for Healthier Communities' journey to a learning health system in primary care. *Learning Health Systems*. 2023;7(1):e10321.
66. Varnell CD Jr, Margolis P, Goebel J, Hooper DK. The learning health system for pediatric nephrology: building better systems to improve health. *Pediatr Nephrol*. 2023;38(1):35–46.

67. Easterling D, Perry A, Miller D. Implementing the learning health system paradigm within academic health centers. *Learning Health Syst.* 2023;56:e10367.
68. McCreary EK, Kip KE, Bariola JR, Schmidhofer M, Minnier T, Mayak K, et al. A learning health system approach to the COVID-19 pandemic: system-wide changes in clinical practice and 30-day mortality among hospitalized patients. *Learning Health Systems.* 2022;6(3):1–10.
69. Fung-Kee-Fung M, Maziak DE, Pantarotto JR, Smylie J, Taylor L, Timlin T, et al. Regional process redesign of lung cancer care: a learning health system pilot project. *Curr Oncol.* 2018;25(1):59–66.
70. Wu CY, Huang C-W, Yang H-C, Li Y-C. Opportunities and challenges in Taiwan for implementing the learning health system. *Int J Qual Health Care.* 2019;31(9):721–4.
71. Noseworthy T. Innovation in the Canadian health system. *Healthc Manage Forum.* 2021;34(1):5–8.
72. Bailes AF, Kean J, Gross PH, Narayanan U, Noritz G, Hurvitz E, et al. The cerebral palsy research network: building a learning health network for cerebral palsy. *J Pediatr Rehab Med.* 2021;14(2):161–71.
73. Foley T, Vale L. A framework for understanding, designing, developing and evaluating learning health systems. *Learn Health Syst.* 2023;7(1):e10315.
74. Soejima H, Matsumoto K, Nakashima N, Nohara Y, Yamashita T, Machida J, et al. A functional learning health system in Japan: experience with processes and information infrastructure toward continuous health improvement. *Learning Health Systems.* 2021;5(4):e10252.
75. Morain SR, Kass NE, Grossmann C. What allows a health care system to become a learning health care system: results from interviews with health system leaders. *Learning Health Systems.* 2017;1(1):e10015.
76. Coley RY, Duan KI, Hoopes AJ, Lapham GT, Liljenquist K, Marcotte LM, et al. A call to integrate health equity into learning health system research training. *Learning Health Systems.* 2022;6(4):e10330.
77. Lehmann HP, Downs SM. Desiderata for sharable computable biomedical knowledge for learning health systems. *Learning Health Systems.* 2018;2(4):e10065.
78. Lozano PM, Lane-Fall M, Franklin PD, Rothman RL, Gonzales R, Ong MK, et al. Training the next generation of learning health system scientists. *Learn Health Syst.* 2022;6(4):e10342.
79. Allen C, Coleman K, Mettett K, Lewis C, Westbrook E, Lozano P. A roadmap to operationalize and evaluate impact in a learning health system. *Learning Health Systems.* 2021;5(4):e10258.
80. Pestka DL, White KM, DeRoche KK, Benson BJ, Beebe TJ. "Trying to fly the plane while we were building it": Applying a learning health systems approach to evaluate early-stage barriers and facilitators to implementing primary care transformation: a qualitative study. *BMJ Open.* 2022;12(1):e053209.
81. Stensland KD, Richesson RL, Vince RA, Skolarus TA, Sales AE. Evolving a national clinical trials learning health system. *Learning Health Syst.* 2003;8:e10327.
82. Platt J, Spector-Bagdady K, Platt T, De Vries R, Markel D, Hutchinson R, et al. Ethical, legal, and social implications of learning health systems. *Learning Health Systems.* 2018;2(1):e10051.
83. Ramaswamy R, Ramaswamy V, Holly M, Bartels S, Barach P. Building local decision-making competencies during COVID-19: accelerating the transition from learning healthcare systems to learning health communities. *Learning Health Syst.* 2021;45:e10337.
84. Sunderland N, Singh P, Del Fabbro L, Kendall E. Spaces of knowing: an Australian case study of capacity building across boundaries in a health promotion learning network. *Glob Health Promot.* 2018;25(2):47–55.
85. Flynn AJ, Friedman CP, Boisvert P, Landis-Lewis Z, Lagoze C. The Knowledge Object Reference Ontology (KORO): a formalism to support management and sharing of computable biomedical knowledge for learning health systems. *Learning Health Systems.* 2018;2(2):e10054.
86. Kass NE, Faden RR. Ethics and learning health care: the essential roles of engagement, transparency, and accountability. *Learning Health Systems.* 2018;2(4):e10066.
87. Myers RE, DiCarlo M, Romney M, Fleisher L, Sifri R, Soleiman J, et al. Using a health system learning community strategy to address cancer disparities. *Learning Health Systems.* 2018;2(4):e10067.
88. Adler-Milstein J, Nong P, Friedman CP. Preparing healthcare delivery organizations for managing computable knowledge. *Learning Health Systems.* 2019;3(2):e10070.
89. Krapohl GL, Hemmila MR, Hendren S, Bishop K, Rogers R, Rocker C, et al. Building, scaling, and sustaining a learning health system for surgical quality improvement: a toolkit. *Learning Health Systems.* 2020;4(3):e10215.
90. Scobie S, Castle-Clarke S. Implementing learning health systems in the UK NHS: policy actions to improve collaboration and transparency and support innovation and better use of analytics. *Learning Health Systems.* 2020;4(1):e10209.
91. Austin EJ, LeRouge C, Lee JR, Segal C, Sangameswaran S, Heim J, et al. A learning health systems approach to integrating electronic patient-reported outcomes across the health care organization. *Learning Health Systems.* 2021;5(4):e10263.
92. Gilmarin HM, Hess E, Mueller C, Plomondon ME, Waldo SW, Battaglia C. A pilot study to assess the learning environment and use of reliability enhancing work practices in VHA cardiac catheterization laboratories. *Learning Health Syst.* 2021;5(2):e10227.
93. Seid M, Bridgeland D, Bridgeland A, Hartley DM. A collaborative learning health system agent-based model: computational and face validity. *Learning Health Syst.* 2021;5(3):e10261.
94. Thygeson NM, Logan C, Lindberg C, Potts J, Suchman A, Merchant R, et al. Relational interventions for organizational learning: an experience report. *Learning Health Syst.* 2021;5(3):e10270.
95. Wood B, Fitzgerald M, Kendall C, Cameron E. Integrating socially accountable health professional education and learning health systems to transform community health and health systems. *Learning Health Syst.* 2021;5(3):e10277.
96. Dushyanthen S, Perrier M, Chapman W, Layton M, Lyons K. Fostering the use of learning health systems through a fellowship program for interprofessional clinicians. *Learning Health Syst.* 2022;6(4):e10340.
97. Feldman SS, Allgood A, Hall AG, Lemak CH, Berner ES. Competency analysis and educational strategies to meet the demand for a learning health system workforce. *Learning Health Syst.* 2022;6(4):e10324.
98. Kilbourne AM, Schmidt J, Edmunds M, Vega R, Bowersox N, Atkins D. How the VA is training the next-generation workforce for learning health systems. *Learning Health Syst.* 2022;6(4):e10333.
99. Heys M, Kesler E, Sassoon Y, Wilson E, Fitzgerald F, Gannon H, et al. Development and implementation experience of a learning healthcare system for facility based newborn care in low resource settings: the Neotree. *Learn Health Syst.* 2023;7(1):e10310.
100. Easterling D, Perry A, Miller D. Implementing the learning health system paradigm within academic health centers. *Learning Health Systems.* 2024;8(1):1–6.
101. El-Kareh R, Brenner DA, Longhurst CA. Developing a highly-reliable learning health system. *Learning Health Syst.* 2023;7(3):1–4.
102. Ciemins EL, Mollis BL, Brant JM, Hassell LA, Albritton S, Amoroso P, et al. Clinician engagement in research as a path toward the learning health system: a regional survey across the Northwestern United States. *Health Serv Manage Res.* 2020;33(1):33–42.
103. Bindman AB. Learning healthcare systems: a perspective from the US. *Public Health Res Pract.* 2019;29(3):45.
104. Cameron B, Douthit B, Richesson R. Data and knowledge standards for learning health: a population management example using chronic kidney disease. *Learning Health Systems.* 2018;2(4):e10064.
105. Hartley DM, Keck C, Havens M, Margolis PA, Seid M. Measuring engagement in a collaborative learning health system: the case of Improve-CareNow. *Learning Health Systems.* 2021;5(2):e10225.
106. Keck C, Hartley DM, Havens M, Margolis PA, Seid M. Getting what is needed, when it's needed: sharing information, knowledge, and know-how in a collaborative learning health system. *Learning Health Systems.* 2021;5(3):e10268.
107. Wu CY, Huang C-W, Yang H-C, Li Y-C. Opportunities and challenges in Taiwan for implementing the learning health system. *Int J Qual Health Care.* 2019;31(9):721–4.
108. Naimoli JF, Saxena S. Realizing their potential to become learning organizations to foster health system resilience: opportunities and challenges for health ministries in low- and middle-income countries. *Health Policy Plan.* 2018;33(10):1083–95.
109. Schleyer T, Williams L, Gottlieb J, Weaver C, SAYSANA M, Azar J, et al. The Indiana Learning Health System Initiative: early experience developing a collaborative, regional learning health system. *Learning Health Systems.* 2021;5(3):e10281.

110. Porcaro K. Building responsive governance for learning networks. *Learning Health Systems*. 2022;6(2):e10288.
111. Yang U-C, Hsiao T-H, Lin C-H, Lee W-J, Lee Y-S, Fann YC. Integrative LHS for precision medicine research: a shared NIH and Taiwan CIMS experience. *Learning Health Systems*. 2019;3(1):e10071.
112. Anderson JL, Reamey RA, Levitan EB, Asif IM, Aswani M, Fletcher FE, et al. The University of Alabama at Birmingham COVID-19 Collaborative Outcomes Research Enterprise: developing an institutional learning health system in response to the global pandemic. *Learning Health Systems*. 2022;6(2):e10292.
113. Franklin PD, Drane D, Wakschlag L, Ackerman R, Kho A, Cella D. Development of a learning health system science competency assessment to guide training and proficiency assessment. *Learning Health Systems*. 2022;6(4):e10343.
114. Grob R, Gleason K, McLean P, McGraw S, Solomon M, Joffe S. Patients' roles in governance of learning: results from a qualitative study of 16 learning healthcare systems. *Learning Health Syst*. 2022;6(1):1–10.
115. Beck AF, Hartley DM, Kahn RS, Taylor SC, Bishop E, Rich K, et al. Rapid, bottom-up design of a regional learning health system in response to COVID-19. *Mayo Clin Proc*. 2021;96(4):849–55.
116. Teichert M, Fujita K, Braspenning J. Development of a maturity matrix to assess organizational readiness of community pharmacies for implementation of guideline recommendations in diabetes care. *Int J Pharm Pract*. 2024;32(1):52–60.
117. Vinson AH. Culture as infrastructure in learning health systems. *Learning Health Syst*. 2021;5(3):e10267.
118. Ainsworth J, Buchan I. Combining health data uses to ignite health system learning. *Methods Inf Med*. 2015;54(6):479–87.
119. Anderson JL, Mugavero MJ, Ivankova NV, Reamey RA, Varley AL, Samuel SE, et al. Adapting an interdisciplinary learning health system framework for academic health centers: a scoping review. *Acad Med*. 2022;97(10):1564–72.
120. Keugoung B, Bello KOA, Millimouno TM, Sidibé S, Dossou JP, Delamou A, et al. Mobilizing health district management teams through digital tools: lessons from the District.Team initiative in Benin and Guinea using an action research methodology. *Learning Health Syst*. 2021;5(4):e10244.
121. Kohn MS, Topaloglu U, Kirkendall ES, Dharod A, Wells BJ, Gurcan M. Creating learning health systems and the emerging role of biomedical informatics. *Learning Health Syst*. 2022;6(1):e10259.
122. Steele Gray C, Barnsley J, Gagnon D, Belzile L, Kenealy T, Shaw J, et al. Using information communication technology in models of integrated community-based primary health care: learning from the iCOACH case studies. *Implement Sci*. 2018;13(1):87.
123. Britto MT, Fuller SC, Kaplan HC, Kotagal U, Lannon C, Margolis PA, et al. Using a network organisational architecture to support the development of learning healthcare systems. *BMJ Qual Saf*. 2018;27(11):937–46.
124. Johnston DS. Digital maturity: are we ready to use technology in the NHS? *Fut Healthcare J*. 2017;4(3):189–92.
125. Witter S, Sheikh K, Schleiff M. Learning health systems in low-income and middle-income countries: exploring evidence and expert insights. *BMJ Glob Health*. 2022;7:7.
126. Sinsky CA, Bavafa H, Roberts RG, Beasley JW. Standardization vs customization: finding the right balance. *Ann Fam Med*. 2021;19(2):171–7.
127. Zaccagnini M, Bussi eres A, Mak S, Boruff J, West A, Thomas A. Scholarly practice in healthcare professions: findings from a scoping review. *Adv Health Sci Educ Theory Pract*. 2022;89:56.
128. de Bruin J, Bos C, Struijs JN, Drewes HWT, Baan CA. Conceptualizing learning health systems: a mapping review. *Learning Health Syst*. 2023;7(1):e10311.
129. Nundy S, Cooper LA, Mate KS. The quintuple aim for health care improvement: a new imperative to advance health equity. *JAMA*. 2022;327(6):521–2.
130. Rosen MA, Himmelfarb CD, Bauer T, Mullins CD. Expanding the learning health system model to be health literate. *J Comp Eff Res*. 2022;11(15):1079–83.
131. Reid RJ, Wodchis WP, Kuluski K, Lee-Foon NK, Lavis JN, Rosella LC, et al. Actioning the learning health system: an applied framework for integrating research into health systems. *SSM - Health Systems*. 2024;2:100010.
132. Bird M, Vanderhout S, Whitmore C. Learning health hub: co-envisioning the future of learning health systems in Canada 2024. <https://www.learninghealthhub.ca/about>.
133. Powell BJ, Waltz TJ, Chinman MJ, Damschroder LJ, Smith JL, Matthieu MM, et al. A refined compilation of implementation strategies: results from the Expert Recommendations for Implementing Change (ERIC) project. *Implement Sci*. 2015;10(1):21.
134. Domlyn AM, Scaccia J, Lewis N, Ebony Coleman S, Parry G, Saha S, et al. The community transformation map: a maturity tool for planning change in community health improvement for equity and well-being. *Am J Orthopsychiatry*. 2021;91(3):322–31.
135. Carvalho JV, Rocha  , Abreu A. Maturity models of healthcare information systems and technologies: a literature review. *J Med Syst*. 2016;40(6):131.

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