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RESEARCH REPORT

Learning Health Systems

# Conceptualizing learning health systems: A mapping review

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## Abstract

**Introduction:** Health systems worldwide face the challenge of increasing population health with high-quality care and reducing health care expenditure growth. In pursuit for a solution, regional cross-sectoral partnerships aim to reorganize and integrate services across public health, health care and social care. Although the complexity of regional partnerships demands an incremental strategy, it is yet not known how learning works within these partnerships. To understand learning in regional cross-sectoral partnerships for health, this study aims to map the concept Learning Health System (LHS).

**Methods:** This mapping review used a qualitative text analysis approach. A literature search was conducted in Embase and was limited to English-language papers published in the period 2015-2020. Title-abstract screening was performed using established exclusion criteria. During full-text screening, we combined deductive and inductive coding. The concept LHS was disentangled into aims, design elements, and process of learning. Data extraction and analysis were performed in MAX QDA 2020.

**Results:** In total, 155 articles were included. All articles used the LHS definition of the Institute of Medicine. The interpretation of the concept LHS varied widely. The description of LHS contained 25 highly connected aims. In addition, we identified nine design elements. Most elements were described similarly, only the interpretation of stakeholders, data infrastructure and data varied. Furthermore, we identified three types of learning: learning as 1) interaction between clinical practice and research; 2) a circular process of converting routine care data to knowledge, knowledge to performance; and performance to data; and 3) recurrent interaction between stakeholders to identify opportunities for change, to reveal underlying values, and to evaluate processes. Typology 3 was underrepresented, and the three types of learning rarely occurred simultaneously.

**Conclusion:** To understand learning within regional cross-sectoral partnerships for health, we suggest to specify LHS-aim(s), operationalize design elements, and choose deliberately appropriate learning type(s).

KEYWORDS
conceptualization, learning health system, types of learning

## 1 | INTRODUCTION

Worldwide health systems are challenged to provide high-quality, accessible, and affordable care.[1] During the last decade, multiple transformational programs have emerged in various countries among which Accountable Care Organizations (U.S.),[2] Vancouver City Programs (Canada),[3] Vanguards (UK),[4] Gesundes Kinzigtal (Germany),[5] and the Population Health Management initiatives (the Netherlands).[6] In general, these initiatives comprise regional cross-sectoral partnerships for health, which aim to reorganize and integrate services across public health, health care, social care, and wider public services to increase population health with high-quality care and a reduction in health care expenditure growth.[7]

These partnerships are complex due to the interdependence of multiple factors contributing to health and well-being itself, the large number of involved stakeholders with potentially conflicting interests, and the interrelatedness within the health system environment including existing legislations and regulations.[8] Complexity in regional cross-sectoral partnerships demands an incremental strategy in order to remain sight of the formulated goals, while at the same time meeting upcoming challenges.[9,10] Hence, learning cycles and emergent learning are considered as a prerequisite in cross-sectoral partnerships for health.[6,7,11]

Up until now, it is not known how to operationalize "learning" within regional cross-sectoral partnerships. To understand how regional partnerships for health learn, the concept of Learning Health System was expected to be closely related. Originally introduced to shorten the time from proven effective drugs in evidence-based medicine to clinical practice, the definition of LHS has been evolved over time into "*within a LHS, science, informatics, incentives, and culture are aligned for continuous improvement and innovation, with best practices seamlessly embedded in the delivery process and new knowledge captured as an integral by-product of the delivery experience*"[12]; see full definitions in Table 1. The development of the concept LHS has been an effort by all. Several (semi-) governmental agencies (eg, AHRQ and PCORI) and multi-stakeholder networks (eg, Learning Health Community) have built upon on and contributed to existing work.[15–17] Furthermore, the journal of *Learning Health System* and the academic Department of Learning Health Sciences at the University of Michigan Medical School have played a role in shaping operational views of the LHS vision. In the scientific literature, several models describe different angles of the concept LHS such as data infrastructure,[18] data architecture,[19,20] LHS classification,[21] and value-creating operationalization.[22] A recent study by Easterling et al. clarified the operationalization of LHS within organizations and revealed an LHS-taxonomy and five bodies of work.[23]

However, an overview of the concept LHS is lacking. As the Institute of Medicine put a broad definition on LHS in place to enable context-independent implementation, LHS is now interpreted widely.[20,24] Hence, we aim to clarify the use of the concept LHS–by studying the description of LHS in scientific literature. As such, we strive to reveal the underlying vision and various perspectives on LHS. In this article, in order to understand learning within regional partnerships, the overall aim is to get more insight in the use of the concept LHS. Therefore, we focus on the following research questions: which aims are formulated regarding LHS? How are the LHS-design elements interpreted? And last, what processes of learning are applied?

**TABLE 1** Evolving definitions of learning health system

| | |
|---|---|
| Etheredge 2007 | LHS is a system aimed at increasing the value of health care without draconian cost cutting. Rapid learning from new evidence for practice and policy, adapting electronic health records (EHRs) in clinical settings aimed at integrating clinical, financial, and administrative data."[13] |
| Institute of Medicine 2007 | The LHS generates and applies the best evidence for the collaborative healthcare choices of each patient and provider; drives the process of discovery as a natural outgrowth of patient care; and ensures innovation, quality, safety and value in healthcare."[14] |
| Institute of Medicine 2011 | Within a LHS science, informatics, incentives, and culture are aligned for continuous improvement and innovation, with best practices seamlessly embedded in the delivery process and new knowledge captured as an integral by-product of the delivery experience."[12] |

## 2 | METHODS

As the aim of this study is to clarify the use of the concept LHS, a mapping review was conducted. The purpose of a mapping review is to categorize, classify, and characterize patterns, trends or themes with regard to a specific review question.[25] Unlike a systematic review, a mapping review does not appraise the findings, but merely aims to examine the range, nature and evolution of a topic area.[26] We chose the mapping review approach as our aim to clarify the concept LHS corresponds to the purpose of mapping review to "map out" and thematically understand the pre-existing topic, including visual synthesis of the data.[27] Moreover, pre-existing literature on LHS is numerous and highly diverse in article types. This mapping review used a 3-step approach: composing the search strategy, selecting relevant studies, and data-extraction and analysis.

### 2.1 | Search strategy

The search was conducted using Embase and was limited to English-language papers published between January 2015 and May 2020. Although the early development and historical context shaped the understanding of the concept LHS, the scope of this study focused on the most recent literature to reflect the current use of the concept LHS. A concise search strategy was developed in collaboration with a

scientific librarian to identify studies matching the following search term: learning health*[tiab] OR LH*[tiab]. In this way, the search strategy included all possible terminology of learning health system such as learning healthcare systems and learning health networks and did not exclude any articles based on spelling differences.

### 2.2 | Study selection

Title-abstract screening was performed by two researchers (JB and ChB). In preparation, one researcher (JB) developed draft in- and exclusion criteria in close collaboration with the research group. In a 50-articles pilot screening by JB and ChB, the inclusion and exclusion criteria were clarified and finalized, see Table 2. The researchers then screened all articles independently and, in case of noncongruent opinions, discussed the abstracts until an agreement was reached. Articles were excluded in full-text screening if a) full-text were not available, b) they were abstract-only (eg, conference papers), c) they did not explicitly describe the concept LH*, or d) they were not available in English.

### 2.3 | Data extraction and analysis

This mapping review used a qualitative text analysis approach. We systematically extracted data using the search term Learning Health and LH; and subsequently coded the entire paragraph. For analysis, we chose to combine deductive and inductive coding. We used deductive coding with the codes "definition," "aim," "process of learning," and "design elements" to differentiate between the sub questions; inductive coding to stick to the articles' description of the concept LHS. Text was coded as "definition" when cited in italic or presented between brackets. The code "aim" was used when the goal of LHS was described. This could either be explicitly, for instance, when words as *goal* or *aim* were used: "*the goal of LHS is*" or "*the aim is to*," or implicitly using the words *to* or *for* within the description. The code "process of learning" was used when authors described the process of learning within LHS. Qualitative analysis lead to a framework of "process of learning." We used this framework to study the (co)-occurrence of the process of learning within the included articles. Lastly, the code "design element" was applied when a component within the LHS paragraph was stated as important for operationalization or developing LHS, such as "stakeholders" or "data."

During data extraction and data analysis, two researchers (JB, ChB) first executed a pilot of 20 articles, reducing researcher's bias. After both researchers independently coded 10 articles, the coded articles were crosschecked and discussed to develop a codebook. To finalize the codebook and to ascertain the replicability of the researchers strategy, 10 additional articles were coded together. Proposed methods and preliminary findings were discussed within and agreed upon by the research group. Using the established codebook and methods, one researcher (JB) extracted the data and analyzed the remaining articles. Due to the explorative study design, both the main researcher and the research group both reflected on findings and added codes when needed. Even though saturation was reached after 70 articles, all included studies were analyzed to ensure no viewpoint was missed.

Data-extraction and analysis were performed in MAX QDA. To visualize the code *aims*, the option Code Matrix in MAX QDA was used.

**TABLE 2** Inclusion and exclusion criteria in title abstract screening

| |
|---|
| Inclusion criteria |
| • Presence of learning health* (LH*) |
| • LH* in a OECD Country |
| • Published after January 2015 |
| Exclusion criteria |
| • Absence of LH* (#1) |
| • LH* is only part of the institute's name, the author's title or the conflict of interest statement. (#2) |
| • LH* explicitly described in a non-OECD Country (#3)* |
| • Abstract not available (#4) |
| • LH* only mentioned in conclusion as a possible application for a specific method/analysis/tool (#5) |
| • LH* only described as data source for effect studies (#6) |

*Source: https://www.oecd.org/about/members-and-partners/.

## 3 | RESULTS

### 3.1 | Study selection

The Embase-search yielded 631 articles. During title abstract screening, 319 articles were excluded. After data extraction and analysis, 164 articles were excluded resulting in a total of 155 included articles (Figure 1). For the entire list of included articles, see Data S1.

### 3.2 | Formulated aims

Overall, 25 aims were described in relation to LHS in the included articles (Table 3). The most prevalent aims were accelerating research, clinical decision-making, and improving quality of care. To test whether distinct clusters of aims for LHS could be identified, Figure 2 shows the relatedness of the *aim*-codes that co-occur in one article for a minimum of four times. In Figure 2, the various nodes lack any thematic congruence. Consequently, we are not able to interpret the LHS-aims as clusters.

### 3.3 | Design elements

In the description of the concept LHS, nine design elements were found (Table 4). Most design elements were described identically; however, the interpretation of the three elements *stakeholders*, *data*

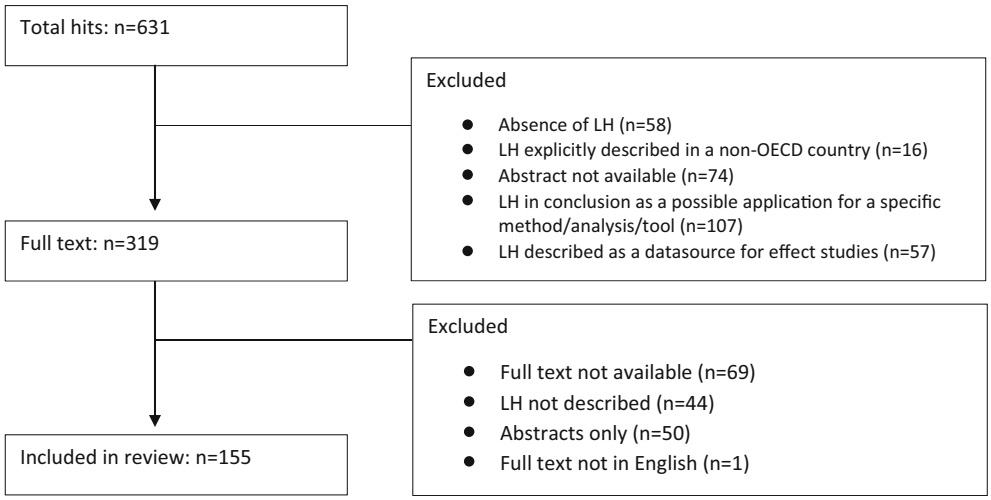


**FIGURE 1** Flowchart study selection

**TABLE 3** List of *aims* in relation to the concept Learning Health System (LHS); ranked on occurrence

- accelerate research/formulate hypothesis[28]
- clinical decision-making[29]
- quality of care[30]
- clinical outcomes/patient outcomes[24]
- care delivery/health services[15]
- reducing healthcare cost[15]
- value /cost-effective care[12]
- innovation[11]
- system improvement/transformation[11]
- patient health[10]
- learning[10]
- population health[10]

*Note*: Aims occurred less than 10 times: safety (n = 9), improvement, not-specified (n = 9), patient experience (n = 5), efficiency (n = 5), policy and management (n = 5), personalized care (n = 5), public health (n = 4), equity (n = 3), panel management (n = 3), data-sharing (n = 2), pilots (n = 1), stakeholder input (n = 1), consumer education (n = 1), solving health-related problems (n = 1), providers in general (n = 1), access to services (n = 1).

*infrastructure*, and *data* varied considerably. As such, we will discuss these three elements in more detail here.

First, although many articles stressed the importance of "(multi-) stakeholder engagement" in LHS, differences are found in the kind of stakeholders to be engaged and their role. The included articles described various kind of stakeholders: ranging from patients – *patients*, *family members*, *patient advocates*; providers – *care providers* and *clinicians*; to payers, policy makers –*healthcare administrators*, *policy makers*; and other experts – *researchers*, *technology experts*, *health system leaders*, *thought leaders on continuous improvement*, *health service managers*, and *planners*. Moreover, the roles of patients and care providers differ substantially between articles. In some articles, patients and care providers were not described as stakeholder, in others as active participators,[36,37] or even co-creators.(eg 31).

Second, the often-mentioned design element "data-infrastructure" was occasionally extended with a so-called "support system." In general, data infrastructure was interpreted as the linkage and/or storage of different data-sources. Some articles described the availability of data for (end-) users as well, for instance via patient and providing facing data-dashboards, (eg, Reference 33) or via prognostic models and/or clinical decision support tools.(eg, References 30,34,38,39) In addition, several articles stressed that the data infrastructure included a supportive system. Friedman et al describes the supportive system as "*the technologies, policies, and standards comprising these [supportive] services constitute the infrastructure for the LHS.*"[40] Maddox et al. specifies this supportive system by "*data oversight, which encompasses data governance, regulation, privacy protection, and data security, has an essential supporting function for the LHS data infrastructure.*"[41] Furthermore, the focus of the element data infrastructure varied considerably. LHS might be complaint-based; (eg, Reference 42) disease-based[43]; or patient-based.[29]

Last, the description of the design element "data" varied widely. The basic and most narrow interpretation of LHS data was routine care data, for example, "*based on data flowing from routine care.*"[22] Several articles expended routine care data with other data (sources) such as *health-related data* (not specified[32]), *patient-reported outcomes*, (eg, References 43-45), *experience of care* (patient and professional,[35]) *social determinants of health*, (eg, Reference 46) *patient generated data*, (eg, References 33,47) and *geospatial data* (eg, Reference 18). These additional data (sources) could be linked, for instance, as Steels et Van Staa described: "*To link data across multiple agencies including health (physical and mental), social care, criminal justice, housing and education to develop a more complete Learning Health System.*"[48] Rubinstein et Warner described the LHS data-sources explicitly, including patient generated data: "*the data originate in a variety of sources, including electronic health records (EHRs), claims databases, pharmaceutical clearinghouses, and clinical trial databases. The newest and potentially richest source, as measured by kilobytes generated, is patient-generated health data.*"[47] All findings related to the element "data" were of quantitative nature, we did not find (explicit) use of qualitative data.

## 3.4 | Process of learning

Using inductive analysis of the code "process of learning," we have identified three types of learning (Table 5):

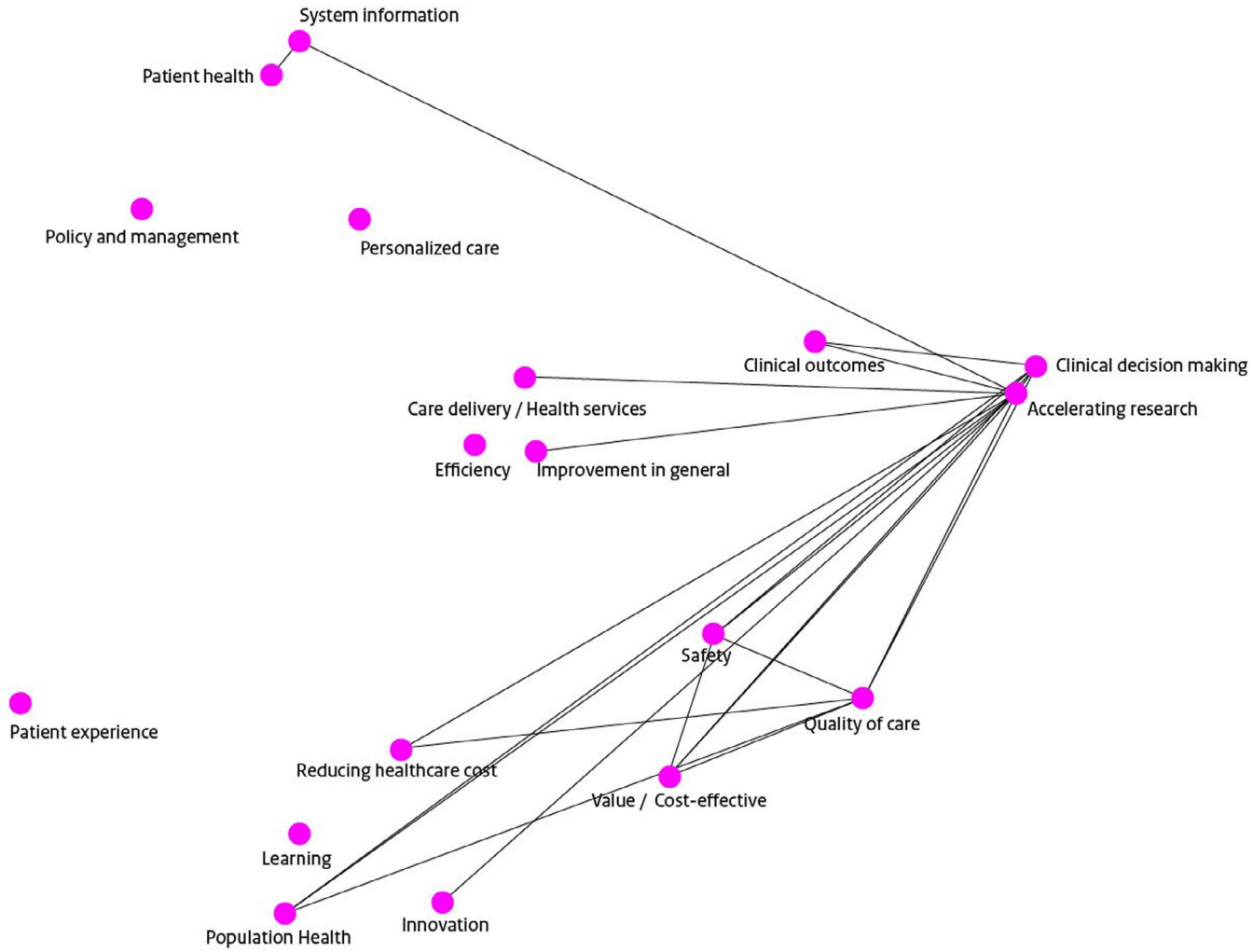


**FIGURE 2** The co-occurrence of Learning Health System (LHS) aims. The smaller the distance between the codes, the more often they simultaneously occur. The line between two codes show co-occurrence in at least 4 documents

### 3.4.1 | Interaction between clinical practice and research

The first type of learning describes learning as an intermittent information exchange between clinical practice and the research domain. This type of learning is seen as high potential for accelerating research and implementing knowledge into practice, (eg, References 45-51) for instance via clinical induced research priorities,(eg, References 52,53); via generating and testing hypothesis without randomised controlled trials, (eg, Reference 54), and/or to evaluate treatment effectiveness in specific subgroups, that cannot be studied adequately in randomized, controlled trials.(eg, References 55,56) Guise et al. stressed the two-way interaction between research and clinical practice with improving health as ultimate aim: "*As such, the LHS concept requires that evidence generation not be an end in itself; efforts to generate evidence must be accompanied by equally emphasized efforts to apply it to improve health.*"[57] Teare et al. combined research and quality improvement to form an LHS, "*improving health and services requires both better knowledge (research) and better action to adapt and use what is known (quality improvement). Bringing these functions together to create active, mutual learning cycles (…) has been labeled a 'learning health system*'."[58] We call this type of learning "interaction between clinical practice and research."

### 3.4.2 | Continuous circular routine care data-driven process

For the second type, learning within LHS is described as a (technology-aided) continuous circular process of converting (routine care) data to knowledge, knowledge to performance, and performance to data. In this type of learning, the information stream, data infrastructure, and data are key. Friedman et al described continuous learning cycle. "*Learning cycles can occur at various speeds and levels of scale but invariably consist of three core processes, namely*[1] *converting data to knowledge (D2K),*[2] *applying knowledge to influence performance (K2P), and*[3] *documenting changes in performance to generate new data (P2D).*"[40] Even though the levels of learning cycles are specified "*at*

**TABLE 4** List of codes "design element" in relation to Learning Health System (LHS)*

| Design elements | Example |
|---|---|
| Financial incentives | "The last area that a learning health system must have in place is the alignment of incentives. When the system is based on fee-for-service, full waiting rooms and even fuller procedure scheduling is the only way providers can pay the bills and live at the lifestyle level they desire.(…)"[31] |
| Data-infrastructure | "LHS foundational elements, such as harnessing contemporary technology and data support structures, enhances capacity to collect and use data and evidence (…)."[32] |
| Policy-infrastructure | "Upscaling a learning health system for palliative care will require intelligent navigation of several domains: (…) establishment of policies that favor culture change and reward measured performance; (…)."[33] |
| Technology | "LHS foundational elements, such as harnessing contemporary technology and data support structures, enhances capacity to collect and use data and evidence (…)."[32] |
| Data | "At the centre of a LHS ethos is routine capture, transformation and dissemination of data and knowledge, with various uses (.)"[28] |
| Learning | "As such, LHSs incorporate continuous learning at the system, organizational, departmental, and individual levels, in cycles or loops moving from data to knowledge and then from knowledge to practice and back again."[20] |
| Evidence and measurement | "The LHS brings together the elements of stakeholder engagement, clinician leadership, best available evidence and measurement, IS rigour with integration of HCI in an iterative model that learns from success and failures."[34] |
| Culture (change) | "Organizational culture plays a crucial role in supporting an effective learning health system approach. Specifically, organizations need to learn as they go and not be afraid to 'fail,' to foster a spirit of curiosity and courage."[35] |
| Stakeholders | "Importantly, the patients, clinicians, and communities are at the center of the model, indicating engagement and the alignment of care with their priorities."[36] |

*Due to the qualitative nature of this analysis, the ferquency of "design elements" is not specified, nor could the list be ranked on occurrence.

*the system, organizational, departmental, and individual level."*[20,40,59] Most articles did not discriminate between these levels when describing the concept of LHS. In addition, some articles took a more clinical perspective. Serena et al. described "*In a LHS, knowledge is obtained continuously through routine clinical documentation at the point of care (POC) and turned into guidance through clinical decision support (CDS), with a resulting vast repository of data on treatment effectiveness to enhance RCTs and evidence-based medicine."*[44] We call this type of learning "the continuous circular routine care data-driven process."

**TABLE 5** Typology of learning within Learning Health System (LHS)

| Type of learning | Example |
|---|---|
| Learning as (intermittent) *information exchange between the clinical domain and the research domain* | Thus research priorities are aligned with key issues clinicians face in everyday practice, and research on those issues informs best practice. (Price-Haywood-2015-Clinical comparative effect, P. 3:5317) |
| Learning as a (technology-aided) *continuous circular process of converting (routine care) data* to knowledge; knowledge to performance; and performance to data. Central is the information stream. | "Learning cycles can occur at various speeds and levels of scale but invariably consist of three core processes, namely[1] converting data to knowledge (D2K),[2] applying knowledge to influence performance (K2P), and[3] documenting changes in performance to generate new data (P2D)."[40] "In a LHS, knowledge is obtained continuously through routine clinical documentation at the point of care (POC) and turned into guidance through clinical decision support (CDS), with a resulting vast repository of data on treatment effectiveness to enhance RCTs and evidence-based medicine."[44] |
| Learning as *recurrent interaction between stakeholders* to reveal/discuss underlying values, to evaluate processes, and to identify opportunities for change, and share best-practices. Human interaction and the exchange of experiences and ideas are central. | "shared learning between centers with the intention of driving the emergence of a nationwide community of practice" (Wildman 2019) |

### 3.4.3 | Recurrent interaction between stakeholders for collaborative learning

For the third type, learning within LHS is interpreted as (recurrent) interaction between stakeholders to identify opportunities for change, for joint goal setting, to reveal underlying values, to evaluate processes, and to share best practices. In this type of learning, human interaction and the exchange of ideas and experiences are central. For instance, Hirsch et al. described activities as "*ABI* [adaptive biomedical information] *involves bringing stakeholders together to set shared objectives, foster trust, structure decision-making, and manage expectations through rapid-cycle feedback loops that maximize product knowledge and reduce uncertainty in a continuous, adaptive, and sustainable learning healthcare system."*[60] Menear et al. went a step further and stated that networks and learning communities contribute to the culture switch in LHS "*Networks and learning communities that foster trusting relations between diverse stakeholders can nurture cultures in which*

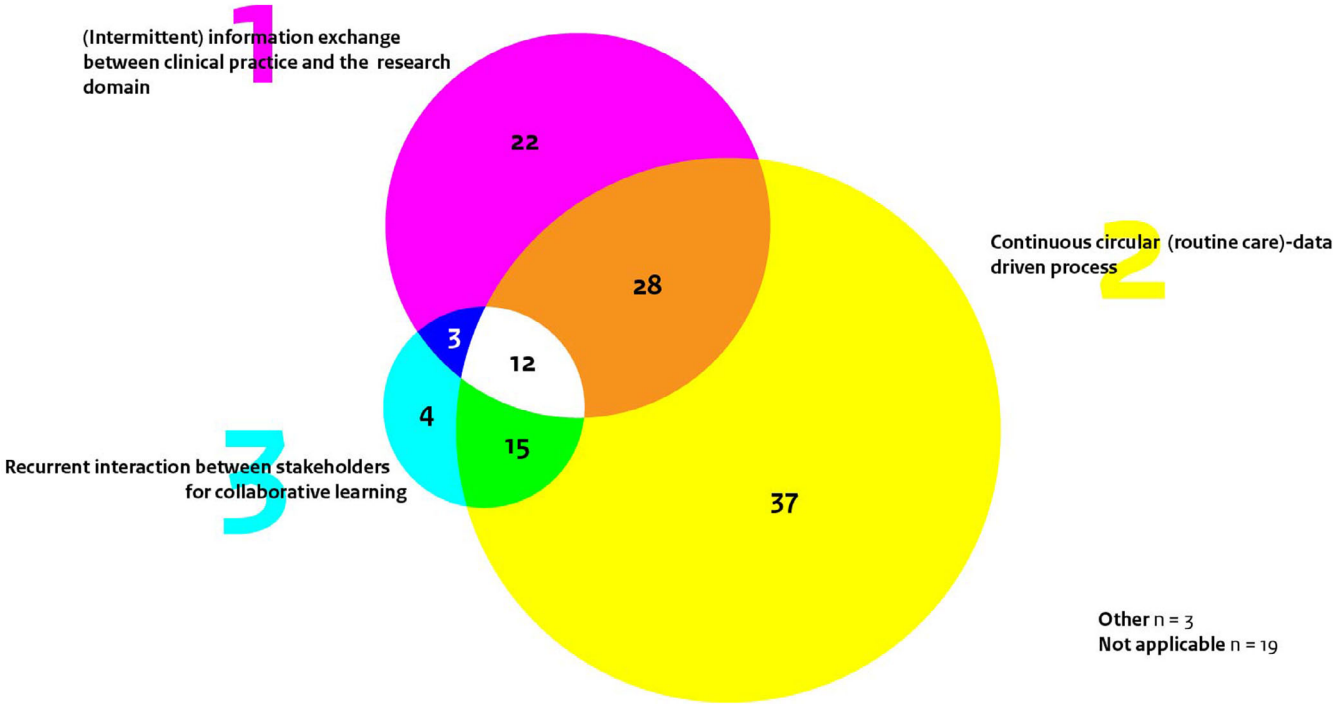


**FIGURE 3** The (co-)occurrence of learning types

*learning and improvement is ingrained within their normal operations, though fully realizing such culture shifts is considered one of the most challenging tasks of LHS implementation.*"[22] We call this type of learning "recurrent interaction between stakeholders for collaborative learning."

Analysis of the included articles demonstrates the (co-) occurrence of the learning types (Figure 3). Figure 3 shows that the majority of the articles (n = 92) used the second type of learning "*the continuous circular (routine-care) data-driven process.*" The first type of learning "*interaction between clinical practice and the research domain*" was represented in more than one third of the articles (n = 65), and the third type of learning *'recurrent interaction between stakeholders for collaborative learning'* occurred the least (n = 34). In total, twelve articles applied all three typologies of learning. These twelve articles varied in LHS-scope, focus, scientific background and author. Other combinations of learning types were described as well, such as Teare et al. relating to both typology 1 and typology 3. "*Improving health and services requires both better knowledge* [research] *and better action to adapt and use what is known* [quality improvement]. *Bringing these functions together to create active, mutual learning cycles, which tap the experience and expertise of health service users, service providers, researchers and people skilled in facilitating quality improvement, has been labelled a "learning health system.*"[58]

## 4 | DISCUSSION

This mapping review conceptualizes the term LHS to understand learning from a regional cross-sectoral partnership perspective. We analyzed the interpretation of LHS with respect to the aims, interpretation of design elements, and processes of learning. We found that the concept is associated with 25 highly interconnected aims showing no specific clustering. Furthermore, nine elements were cited as design elements; we found that variation occurred in the interpretation of the elements "stakeholder engagement," "data infrastructure," and "data." Lastly, three types of learning processes were identified. The majority of the articles focused on the second type of learning "*continuous circular (routine care) data-driven process.*" The third type of learning "*recurrent interaction with stakeholders for collaborative learning*" was underrepresented.

Putting these results in perspective, we are—as far as we know—the first to use a qualitative text analysis approach mapping current LHS interpretations to understand learning within regional cross-sectoral partnerships. In addition to existing literature,[20,23,24] this study provides in-depth insights in how (widely) the LHS concept is interpreted. Furthermore, the result of this mapping review is similar to that of other health system concepts, among which population health management.[61]

Looking in more detail, the extensive number and interrelatedness of LHS aims shows readiness for the use of the concept LHS but is a point of concern as well. This broad use of LHS aims can possibly be explained by the author's background and by the differences in underlying health system goals. For instance, Menear et al. explicitly described the translation of the concept LHS—based on USA-system goals—to the public-funded Canadian health system.[22] Our point of concern is that - as a result of the high number and interrelatedness of LHS aims—the concept LHS might become diluted and possibly become a catchall. In that case, the potential of LHS might not be

realized.[24,62] Translating our insights to learning within regional cross-sectoral partnerships, we would recommend regional partnerships to formulate clear and specific aims.

The three elements stakeholders, data, and data infrastructure provide food for thought. Interestingly, the role and responsibilities of stakeholders varied, whereas several articles did not even described patients and clinicians as stakeholders at all. This is in contrast with the IOM model of LHS that put patients, clinicians, and communities at the core of LHS.[63] Furthermore, the multiple data sources and selected measures may contribute to the challenges in LHS comparability. This might be caused by the different measures selected in various countries,[64] and by methodological reasons as the chosen data sources, measures, and analysis might affect LHS-prediction models and clinical decision support tools (learning type 2). Data sources, selected measures, and analyses should thus be chosen carefully. Moreover, although we did not find (explicit) data sources of qualitative nature, one might hypothesize that a combination of quantitative and qualitative data provides added value for learning. As research has embraced mixed-methods design for several reasons among which understanding context, providing explanations for research findings, and confirming and testing hypothesis[65,66]; this mixed-method approach might be applied in learning processes as well. Last, as the process of learning is described to occur *in various cycles and at various scales* (namely individual, organizational, and system),[20,21,40] we suggest regional partnerships to operationalize learning and concurrent multilayered data infrastructure for all stakeholders, including patients, clinicians, representatives of healthcare organizations, and policy makers.

The identified types of learning offer opportunity for learning strategies within regional cross-sectoral partnerships. Easterling et al. identified five bodies of work in operationalizing LHS within organizations.[23] A direct comparison with current article is hindered due to differences in both applied focus of articles (operationalization vs conceptualization), and scope (LHS within organization vs cross sectoral partnerships). However, the three types of learning show congruence with the five bodies of work. Our mapping review yielded only twelve articles that combined the three typologies of learning. The focus on the T2 "*continuous circular (routine care) data-centered process*" and relatively underrepresented T3 "*recurrent interaction between stakeholder for collaborative learning*" might be explained by context or path-dependency. For instance, available technologies for data infrastructure and data-sharing, up-to-date electronic health records, and positive experience with data sharing may impact the (first) preferred typology of learning.[67] In addition, it may be more ambitious to evolve in collaborative learning when a health system has emphasized competition. For regional partnerships, all three types of learning are of importance and might complement each other. Learning type 1 enables learning, innovation, and discovery (scientific dimension); learning type 2 addresses data integration (technical dimension), and learning type 3 focuses on building a community (the social dimension).[20] As the regional partnerships' underlying transformational challenge* is highly complex, the (interplay of the) three processes of learning could portray additional perspectives. These will enable regional partnerships to remain sight of complexity while keeping the next steps tangible enough to keep moving forward. Furthermore, as transition scholars underscore the importance of multistakeholder engagement and a multilevel approach in understanding and governing system transition,[68,69] typology 3 might be essential in commitment and alignment of stakeholders at various levels and at various sectors within regional cross-sectoral partnerships for health.

This study has limitations that need to be considered when interpreting the results. One is that the search string was limited to articles published after 2015. Yet, we do not expect that an extended publication dates would affect the results of this study, as the variation of LHS-interpretation is quite wide. In addition, this mapping review had a *qualitative* focus and did therefore not aim to be exhaustive. Second, in order to conceptualize the use of the term LHS, we only analyzed the *written* description of the term LHS and did not focus on the *visualizations* of LHS models. As our aim was to gain insights in the possible *use* of the concept LHS, we decided not to study the theoretical visualizations, but focus on the written LHS descriptions by the wider public. However, it might be interesting to compare the different LHS visualizations and relate the results to current study.

For further development of learning within regional partnerships, we recommend a more in-depth understanding of (emergent) learning within real-life learning health systems. For instance, it might be beneficial to study *how* to increase the learning capacity of regional partnerships in real life LHS, providing leverage points for facilitators. A realist study can present program theories on *which strategies increase regional partnerships' learning capacity*, *in which context*, *and why*?[70] In addition, it could be valuable to focus on the role of patients. Several studies showed that patient and citizen engagement in regional partnerships is challenging.[71,72] As such, we must learn how to engage (with) patients, citizens and communities in real-life LHS. Moreover, it would be interesting to analyze the three identified learning types within regional partnerships over time. For instance by using the 5-phase model *A pathway for transforming health and well-being through regional stewardship* as described by Rethink Health[73] and also observed in the Netherlands.[6] Last but not least, it would be illuminating to reflect upon the short-and long-term effect of the COVID-19 pandemic on learning within health systems. The COVID-19 pandemic showcases the importance of a learning health system.[74] Nevertheless, the question remains: what is the long-term effect of the COVID-19 pandemic upon learning (within) health systems?

To conclude, this study showed extensive variation in LHS interpretations and simultaneously provides leverage points for understanding learning within regional cross-sectoral partnerships for health. Although a concept such as LHS is dynamic and evolving, it is of importance to create shared language to facilitate operationalization. We recommend regional partnerships to describe the shared LHS-aims clearly, operationalize the design elements and choose deliberately appropriate learning type(s). We believe that the distinguished types of learning provide opportunities for reflection on learning within regional cross-sectoral partnerships. Learning from successes and failures is crucial to see full-impact of regional cross-sectoral partnerships for health.

## CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

## ENDNOTE

* To reorganize and integrate services across public health, health care, social care and wider public services to increase population health with high-quality care and a reduction in health care expenditure growth

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## SUPPORTING INFORMATION

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