

TECHNICAL REPORT

Developing a codebook to characterize barriers, enablers, and strategies for implementing learning health systems from a multilevel perspective

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Funding information

The Duncan Leary Bequest

Abstract

Introduction: Learning health systems (LHSs) play a crucial role in improving healthcare delivery and outcomes through continuous learning and data-driven decision-making. Implementation of LHSs spans individual, organization, and systemic levels of healthcare. This paper outlines a systematic approach for developing a comprehensive codebook to identify barriers, enablers, and strategies associated with the establishment and operation of LHS from a multilevel perspective.

Methods: The codebook development process was divided into two phases and employed a coding team. Phase 1 involved the synthesis of previous literature, which drove the development of initial codes. Phase 2 included the testing of the codebook with a pilot dataset to derive new codes or iterative refinement, ensuring robustness, and validity.

Results: The literature search revealed 12 papers that detailed the barriers, enablers, and strategies for LHS implementation. Micro-level codes were derived from a mixture of existing literature and our pilot dataset. Most meso-level codes barriers and enablers were derived from the literature, with some subcodes derived from participant interviews. All strategies for implementation at the meso-level were identified in the literature. At the macro-level, all codes and subcodes were from the literature.

Conclusions: The codebook contributes to the advancement of implementation science in LHS. The codebook facilitates effective analysis and understanding of the key factors influencing the success of LHS implementation, offering practical insights for policymakers, healthcare practitioners and researchers engaged in the ongoing evolution of LHS.

KEYWORDS

codebook, implementation, learning health systems

1 | INTRODUCTION

Learning health systems (LHSs) offer a transformative approach to healthcare by integrating data, research, and practice, to continuously improve patient care and outcomes.^{1,2} LHSs require the engagement and cooperation of healthcare professionals, researchers, and other stakeholders. However, for many healthcare professionals and organizations, implementation of LHSs is still relatively novel. Furthermore, despite the growth in empirical use of LHSs over the past decade, high-quality studies detailing implementation and evaluation are scarce.³

Several frameworks have been developed to optimize LHS implementation and evaluation.^{4–8} For example, McLachlan et al.⁷ developed a framework to analyze barriers, benefits, and facilitating factors for LHS implementation. Their framework outlined overcoming barriers that have the most impact and identifying benefits that will be realized once the barriers are resolved.⁷ Menear et al.⁸ suggested incorporating core values, pillars and accelerators, processes and outcomes to foster learning and improvement. Foley and Vale's⁵ focused on the design, development and evaluation of LHSs at various scales—local, regional, national, and international.

LHS maturity models and grids, such as those developed by Lannon et al.⁹ and Rentes et al. (2022), provide structured approaches to evaluating LHS development.^{9,10} These models typically assess maturity across several domains and stages, offering a roadmap from basic to advanced implementation. Lannon et al.⁹ maturity grid categorizes LHS development across different dimensions, including governance, data infrastructure, and continuous learning processes, allowing organizations to benchmark their current status and identify areas for improvement.⁹ Rentes et al. (2022)¹⁰ maturity model evaluates LHS maturity, based on criteria such as data integration, stakeholder engagement, and adaptive learning capabilities. It provides a detailed roadmap for LHS development and encourages continuous assessment and improvement.¹⁰ While these models offer high level assessments, they lack granularity in understanding factors influencing LHS implementation at different levels.

Evaluation of LHSs is necessary for continuous system improvement and collaboration within the healthcare system. However, optimal methods for successful implementation and comprehensive evaluation are still not well understood.¹¹ A review found that 30.2 per cent of LHS studies considered barriers and enablers, but there was limited evidence on strategies to overcome identified barriers.³ To address this, it is recommended that LHS studies utilize an evaluation framework focusing on barriers, enablers, and strategies.^{3,12,13}

A comprehensive codebook that integrates qualitative implementation research is essential for understanding LHS implementation. The Consolidated Framework for Implementation Research (CFIR) identifies factors influencing implementation outcomes across five domains: intervention characteristics, outer setting, inner setting, characteristics of individuals, and process.¹⁴ Our proposed codebook for LHSs shares features with CFIR but introduces unique elements, offering an ecological systems perspective (EST)¹⁵ to healthcare. In line with EST and population health approaches, LHSs are thought to be multilevel in nature,⁸ with learning components spanning individual

(micro), team and organizational (meso), and whole system (macro) levels.¹⁶ Existing LHS implementation frameworks often fall short in distinguishing the barriers, enablers, and strategies across these levels, overlooking critical aspects like organizational assessments or individual competencies.^{8,17} A codebook offers a structured approach with defined codes, definitions, and examples, serving as a quality assurance tool.^{18,19} However, detailed reporting of codebook development and use in LHS studies is often lacking, limiting replicability, and robustness.

This paper presents a comprehensive methodology for developing a codebook to evaluate qualitative data on LHS implementation barriers, enablers, and strategies at micro-, meso-, and macro-levels. Future researchers can use this codebook to evaluate LHS implementations in various contexts, unifying parts of the LHS literature and bridging gaps in understanding LHS implementation.

2 | RESEARCH QUESTIONS

At the individual (micro), organizational (meso), and policy (macro) levels of healthcare systems:

1. What are the types of barriers to implementation of a learning health system?
2. What are the types of enablers to implementation of a learning health system?
3. What types of strategies can be employed to overcome the barriers to implementation of a learning health system?

3 | METHODOLOGY

The codebook development process involved the creation of a structured document that outlined the codes, subcodes, and definitions for barriers, enablers, and strategies related to LHS implementation. These are presented at the micro-, meso-, and macro-levels of healthcare systems. The codebook built upon previously established frameworks^{5,20} and theories of implementation science using a semi-inductive approach. The process of the development of the codebook was iterative comprising two major phases dedicated to initial creation and subsequent refinement, respectively.²¹ During the first phase, a deductive approach was employed involving the synthesis of existing literature, which drove the development of the initial codes. In the second phase, codes were refined using qualitative data from interviews (inductive codes) with five healthcare professionals enrolled in an LHS Academy fellowship program to develop LHS skills in Australian clinicians.²² This approach enabled methodological flexibility, helped to address different narrative perspectives, and summarized the findings into single codes.²³

3.1 | Phase 1: Synthesis of previous literature

Phase 1 of the codebook development was deductive with the creation of a preliminary codebook based on the research questions and

literature review.²⁴ Figure 1 details the steps undertaken. To ensure a comprehensive synthesis of the relevant literature all peer reviewed, English language citations on the databases Scopus, Google scholar, and Ovid Medline were searched until we reached a level of saturation that was deemed acceptable for the purpose of constructing the codebook. This approach allowed us to capture a broad and relevant range of studies without adhering to the formal protocols of a systematic review. A range of years was not specified to ensure a comprehensive capture of relevant literature since the inception of LHSs. Search terms comprised variations of the base “learning health* system*” and closely related synonyms, combined with terms such as implementation, evaluation, barriers, enablers, and strategies (see Figure S1: Decision-making tree).

The titles and abstracts of the articles were screened along with the methods and background sections to determine their relevance to our research questions. We specifically looked for studies that identified barriers, enablers, and strategies for implementing LHS at the individual (micro), organizational (meso), and policy (macro) levels. All definitions and approaches of LHS, such as healthcare delivery organizations, national networks, and large databases were included. Studies

that did not focus on LHS evaluation or implementation, those focused only on the advantages or disadvantages of LHS frameworks, or LHS studies that focused solely on the recommendations for implementation in a specific health institution only, were excluded.

Twelve articles satisfied the criteria for subsequent assessment (Table 1). These articles were thoroughly analyzed to identify existing knowledge describing barriers, enablers, and strategies to implementing an LHS. This approach ensured that our literature review was comprehensive and that the selected articles were relevant to our research objectives.

3.2 | Codebook version 1

Publications that satisfied the inclusion and exclusion criteria were reviewed, key concepts and definitions were identified, and relevant themes and categories were extracted. A coding team consisting of four members was established to ensure inter-coder agreement through coding exercises and discussions. The team were supported by numerous strategies including explanation of the purpose of the

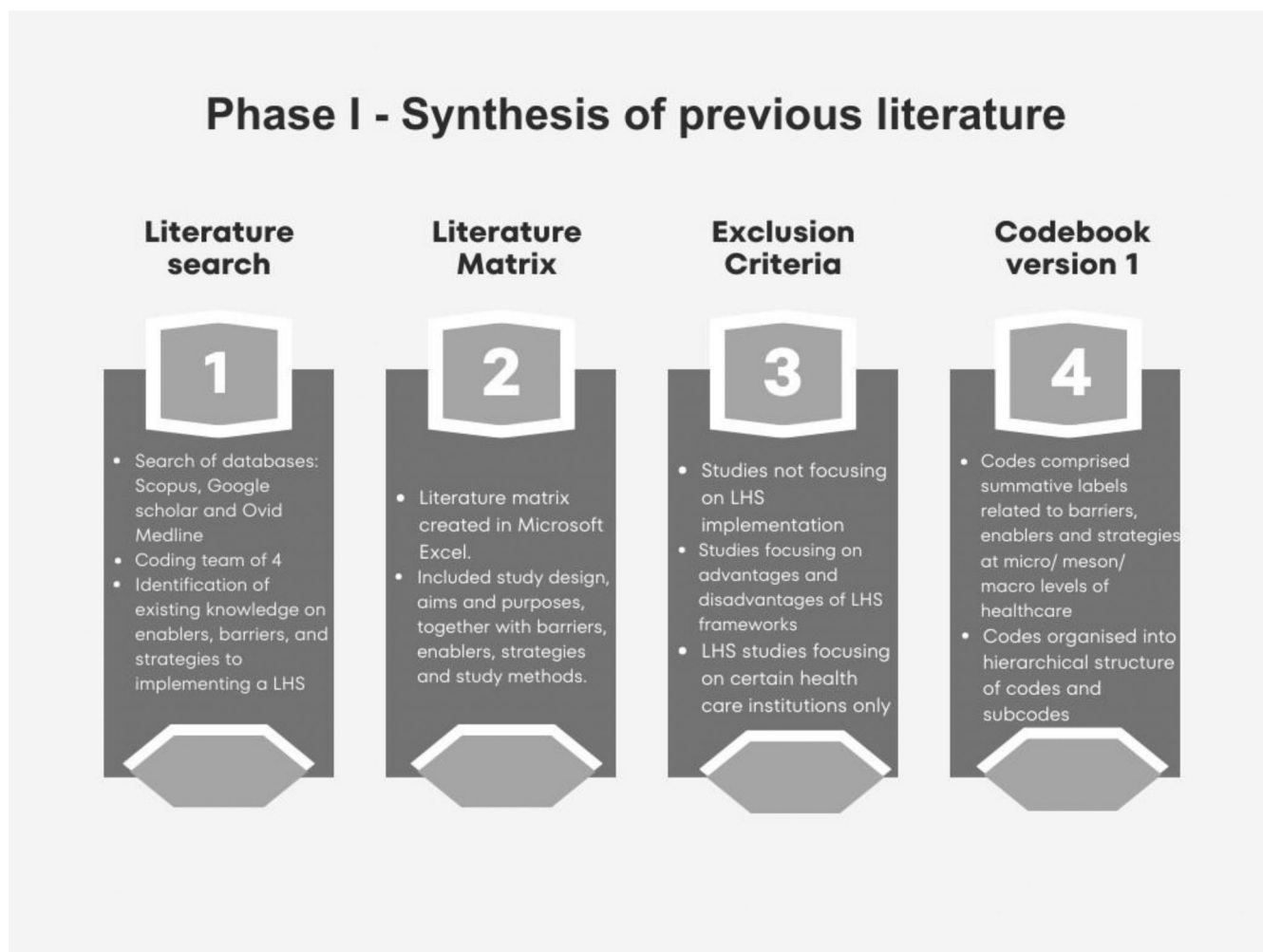


FIGURE 1 Phase 1—Synthesis of previous literature. LHS, Learning health system.

TABLE 1 Table of included articles that met the search criteria.

Author and year	Journal/sources	Title of paper	Type of research	Country study conducted
Allen et al. ²⁵	Learning Health Systems 5(4): e10258.	A roadmap to operationalize and evaluate impact in a learning health system.	Narrative review	United Kingdom
Easterling et al. ²⁶	Learn Health Systems 6(2): e10287.	Clarifying the concept of a learning health system for healthcare delivery organizations: Implications from a qualitative analysis of the scientific literature.	Qualitative literature review	USA
Ellis et al. ³	JMIR medical informatics 10(2): e34907.	The science of learning health systems: scoping review of empirical research.	Scoping review	Australia
Enticott et al. ²⁷	BMC Health Services Research 21: 1–16.	Learning health systems using data to drive healthcare improvement and impact: a systematic review.	Systematic review	Australia
Foley and Vale ⁵	Learning Health Systems 7(1).	A framework for understanding, designing, developing, and evaluating learning health systems.	Framework development	United Kingdom
Hardie et al. (2022) ³⁴	The Health Foundation, UK	Developing Learning Health Systems in the UK: Priorities for Action.	Report (based on literature and interviews)	United Kingdom
Lindsell et al. ²⁸	Academic Medicine 96(9): 1291–1299.	Learning from what we do, and doing what we learn: a learning health care system in action.	LHS Platform model	USA
McDonald et al. ¹⁷	BMJ open 12(8): e061124.	Identifying requisite learning health system competencies: a scoping review.	Scoping review	USA
McLachlan et al. ⁷	Learning Health Systems 3(4): e10189.	A framework for analyzing learning health systems: Are we removing the most impactful barriers?	Framework development	United Kingdom
Nash et al. (2023) ³⁵	Learning Health Systems 7(1): e10321.	The Alliance for Healthier Communities' journey to a learning health system in primary care.	Qualitative descriptive study	Canada
Steels et al. (2021) ³⁶	Learning Health Systems 5(2): e10224.	Implementation of a “real-world” learning health system: Results from the evaluation of the Connected Health Cities program.	Qualitative evaluation	United Kingdom
Zurynski et al. ²⁰	Australian Institute of Health Innovation and the NHMRC Partnership Centre for Health System Sustainability, Macquarie University	Mapping the learning health system: A scoping review of current evidence. A White Paper	Scoping review	Australia

study and explanation of the rationale behind the methods for development of the codebook.²⁹ The entire coding team independently reviewed and qualitatively analyzed each of the 12 publications and extracted relevant information. The team followed a consensus process, meeting regularly to discuss their findings. Any discrepancies in the analysis were discussed and resolved collaboratively.²¹

Analysis of the evidence was carried out with the use of a literature matrix created in Microsoft Excel. The matrix included the study design, aims, and purposes, together with barriers, enablers, strategies, and study methods. Keywords, such as “barriers” and “enablers” together with their synonyms, were extracted from the selected publications. Potential codes and definitions comprised summative labels related to the barriers, enablers, and strategies to any individual, organizational, or policy level for implementing learning health systems.¹⁹ The coding team aimed to develop code labels that were conceptually meaningful, clear, and concise.³⁰ Codes were arranged into a hierarchical structure of codes and subcodes. Codes were the overarching themes, with subcodes assigned to add detail to the primary code.²⁹ Definitions and descriptions for each code or

subcode and examples of when to apply each code were included in the first draft of the codebook.

3.3 | Phase 2: Rationale

Phase 2 was designed to refine the initial coding scheme developed from the literature review by testing and modifying it against real-world data obtained from interviews with health professionals. While the literature provides a foundational understanding of the barriers, enablers, and strategies for implementing learning health systems (LHS), these interviews are crucial for ensuring the codebook reflects the practical realities and challenges faced by those directly involved in the field. This process allowed for the identification of context-specific factors and ensured the codebook's applicability and relevance in practice. Despite the small sample size, the iterative refinement through direct engagement with the data ensured it was robust, comprehensive, and aligned with the current state of knowledge in the implementation of LHSs. It can be used to assess qualitative data

in the evaluation of LHS implementation from a multilevel perspective. The development of a codebook is iterative allowing changes and updates as new information becomes available.

3.4 | Methods for data familiarization

Phase two of the process involved reviewing and revising the codes that were generated from the LHS implementation and evaluation research.³⁰ The initial draft of the codebook 1 was transferred into NVivo™ version 1.7.1. for pilot testing. Pilot testing of the codebook was conducted on a dataset of five entry interviews with health professionals enrolled in a fellowship program to develop LHS skills in Australian clinicians.²² Interviews were transcribed using Otter.ai™ and validated by human coders. The approach to this phase of the codebook development was inductive, with new codes coming from the data itself or priori deductive codes being refined.^{18,19,21,30}

During calibration, the coding team immersed themselves in the data by reading through transcripts to gain familiarity with the content. To ensure coding consistency and inter-coder agreement, two (40%) interview transcripts were analyzed by all four team members as a team. The purpose was to train coders, reduce risk of bias, and for data calibration. The remaining three interview transcripts were coded individually by each of the four coders and then discussed, to test the codebook's effectiveness and resolve any disagreements. Dorr Gould et al.,²¹ report that this method of team coding is beneficial as it brings varying skills and knowledge to the project to establish content validity and test coder agreement. As new insights emerged and the coding team gained a greater understanding of the data, the codebook was regularly re-visited and modified, with new changes

and discrepancies to codes recorded in NVivo™. Refinement of the codes involved deleting, merging, relabeling, and expanding codes, with a continual focus on aligning them with the research questions and conceptual framework, the literature, and the study data.²⁹ One member of the team was designated as the codebook editor, who updated and revised the codebook in NVivo™ as required³¹ (see Figure 2). In the transition from phase 1 to phase 2, an example of a code that was modified included addressing barriers at the individual level. Initially, distinct codes were used for various issues such as lack of experience and knowledge, personality traits, and difficulties adapting to different working styles. In a later iteration, these codes were consolidated under a broader category: “Insufficient skillset to undertake LHS work.” This overarching code encompasses subcodes like difficulties managing competing demands and lacking necessary knowledge and experience.

4 | RESULTS

The literature search revealed 12 papers that detailed the barriers, enablers, and strategies for LHS implementation (see Table 1). All papers were published between 2019 and 2023. The studies were mainly conducted in high-income countries, including the United Kingdom ($n = 5$), United States of America ($n = 3$), Australia ($n = 3$), and Canada ($n = 1$). Included papers employed a range of research methods. Half of the papers were literature reviews, including three scoping reviews,^{3,17,20} one qualitative literature review,²⁶ one structured systematic review,²⁷ and one narrative review.²⁵ Two studies outlined frameworks of LHS development,^{5,7} while one described a LHS model.²⁸

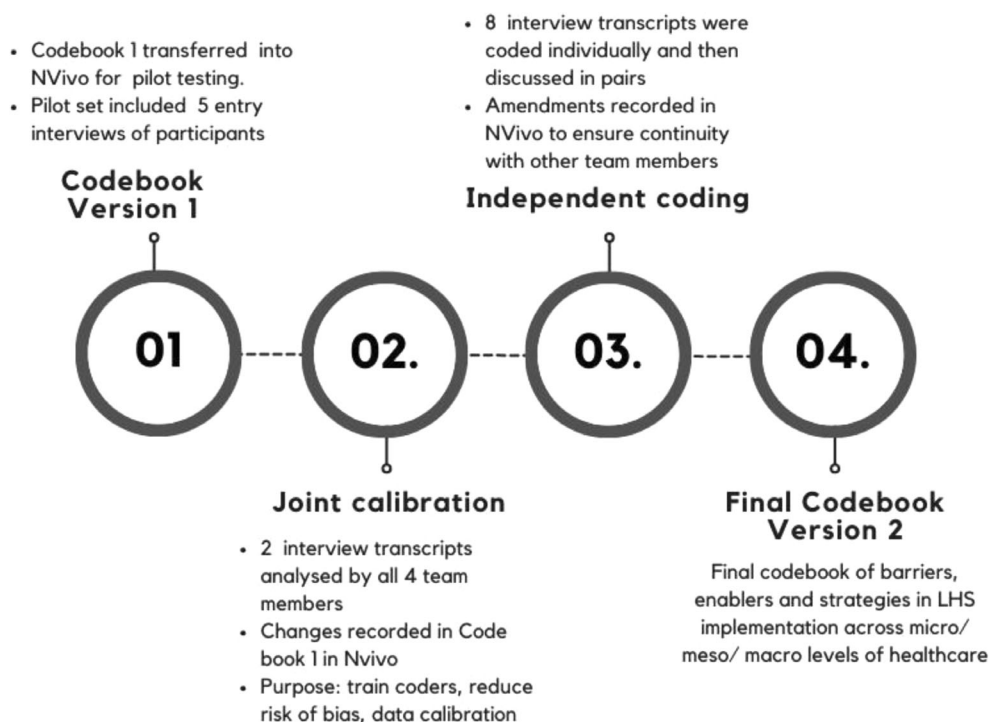


FIGURE 2 Codebook methods phase II. LHS, Learning health system.

Tables 2–4 outline the codebook to characterize barriers, enablers, and strategies for implementing learning health system projects from a multilevel perspective. At the macro-level, all the identified codes and subcodes were from the literature. At the meso-level, most codes for barriers and enablers were from the literature, with some subcodes derived from participant interviews. All strategies for implementation at the meso-level were identified in the literature. At the micro-level, codes and subcodes identified for barriers, enablers, and strategies were obtained from a combination of the literature and participant interviews.

Table 5 shows a summary of the codes at each level of the healthcare system, highlighting the various factors that enable, hinder, and strategize the implementation of LHSs. The table categorizes these factors across micro-, meso-, and macro-levels, providing a detailed view of the different dimensions influencing LHSs. Investment of sufficient resources and sustainable funding were found to be pivotal at both the meso- and macro-levels, underscoring their significance in the broader healthcare framework. Digital “readiness” emerged as a consistent contributing factor across all levels, with digital infrastructure playing a crucial role at the meso- and macro-levels, while a proficient digital skillset was essential at the micro-level. At the micro- and meso-levels, the possession and cultivation of adequate skills to undertake LHS work were identified as key contributing factors to successful LHS implementation.

5 | DISCUSSION

This study described the development of a codebook for evaluating LHS implementation emphasizing an ecological systems perspective. Our novel framework has shared features with CFIR including evaluation from a multilevel perspective, identification of barriers and enablers to implementation, and implementation strategies.¹⁴ However, our framework is specifically designed to address the particular challenges and enablers relevant to LHSs. The incorporation of Bronfenbrenner's EST provides a more nuanced understanding of the interactions between different system levels and helps in identifying how various contexts influence LHS implementation, offering a deeper analysis compared to CFIR's broader categories. Our framework also enhances the evaluative capacity of maturity models by providing detailed qualitative insights and context-specific strategies, contributing to a more nuanced and actionable understanding of LHS implementation. For example, at the developing stage of Lannon et al. maturity grid,⁹ our framework can help pinpoint the precise micro-, meso-, and macro-level barriers that need to be addressed. Our codebook also includes strategies for overcoming barriers, which can be used to inform the action plans developed from maturity model assessments.

Micro-level codes were derived from a mixture of our pilot dataset (interviews of clinicians implementing LHS projects) and existing literature. By contrast, meso-level codes mostly originated from the literature. The pilot dataset revealed additional codes beyond those found in the literature, indicating the need for further research to

identify and characterize barriers, enablers, and strategies for LHS implementation at the micro-level. Most evaluations exploring the barriers, enablers, and strategies for implementation of LHS did not distinguish between different levels of the healthcare system.¹⁷ Therefore, extracting this information from the literature and categorizing codes according to the level of healthcare required interpretation. Frequently, a single code was applicable across multiple levels. The micro-level has the fewest codes and subcodes, possibly because many studies did not consider individual contributing factors. The LHS interviews used in the study were conducted at the start of the fellowship year. Conducting interviews later in the fellowship year might reveal more codes as individuals reflect on how their attributes, mindset, and skill set contributed to their project's development and implementation. The meso-level had the greatest number of subcodes, possibly reflecting that more of the current literature focuses on LHS implementation at the organizational level. Alternatively, this could suggest that most barriers and enablers to LHS implementation are at the organizational level.

Macro-level codes were distinct, reflecting large-scale regulatory, governance, or policy changes required for LHS implementation. Smaller scale contributing factors (subcodes) at the macro-level may not yet have been researched or evaluated. More barriers than enablers to implementation were identified at the micro- and meso-levels, possibly due to a lack of relevant evidence on strategies to overcome these barriers.³ Developing an understanding of the multilevel barriers that influence the establishment and effectiveness of LHSs, whilst leveraging the enablers to overcome challenges, could inform the successful development and operation of an LHS. This approach aims to create a healthcare system that continuously learns and improves patient care.^{3,32,33}

The creation of a standardized, ecologically informed codebook for LHS implementation research is not only beneficial but also essential for advancing the field, ensuring theory-driven, comprehensive, systematic, and replicable research practices that address the complexity of LHS implementation at all system levels. The codebook could provide researchers with an empirically grounded analytic tool for future studies of factors affecting the implementation of an LHS. It can be used as an easy reference means to guide further exploration, improve the potential for inter-coder agreement, and ensure accurate analysis of qualitative data in the evaluation of LHSs. By following a structured approach that includes a literature review, qualitative analysis, and iterative refinement, researchers and practitioners can optimize their comprehension of the factors influencing LHS implementation.

5.1 | Strengths and limitations

There were several strengths in the methods used to develop the codebook that contributed to the value of the results. The initial literature review ensured that the initial codes were informed by existing knowledge, providing a theoretical grounding for the key barriers, enablers, and strategies for LHS implementation. Grounding the

TABLE 2 Micro (individual)-level codes.

Codes	Subcodes	Description	Typical exemplars	Literature or data justification
Enablers	Proficiency in digital health tools within LHS	Individuals possess a foundational understanding and awareness of digital technologies, enabling them to navigate and use basic digital tools for information access and communication.	Basic proficiency in using standard computer applications. Ability to access and evaluate information from digital sources. Understanding of fundamental digital concepts and terminologies.	Easterling et al. (2022) ²⁶ , Enticott et al. (2021) ²⁷ , McDonald et al., ¹⁷ McLachlan et al. ⁷
	Developed digital technology skills	Individuals demonstrate advanced proficiency and practical skills in utilizing specialized digital technologies, tools, and platforms, particularly within the context of the LHS.	“And I think, a willingness to use digital tools to help facilitate that process if that is something that will, you know, be beneficial for patients.” Individuals showcase an elevated level of digital technology skills, reflecting a more advanced and specialized proficiency, in the context of an LHS. Individuals can help clean, structure, and interpret the data collected, making it more useful for research and improvement efforts.	Pilot dataset Enticott et al. (2022) ⁴
Positive personal attributes	Skilled in stakeholder engagement	Involve key stakeholders across the health system in planning, decision-making, and implementation processes to ensure buy-in and support. Individuals who can bridge interdisciplinary gaps are important enablers. Effectively communicates complex information to stakeholders.	“I think I do come to this with a reasonable degree of digital health [knowledge]...I'd already completed my CHIA certification. I've been working with EMR team for some time, I'm the virtual medical lead. I'm exposed to a lot of conversations about digital transformation, I guess. So, a lot of the content is not new to me, and it's just building.” “Having the connections within the EMR team to be...able to get that data readily and easily.”	Pilot dataset McDonald et al. ¹⁷
	Possesses leadership and teamwork skills	Individuals demonstrate strong capabilities in providing direction, guidance, and inspiration to the team. Emphasis on teamwork, shared decision making, and continuous improvement.	“I think it was also really valuable to have another GP within the cohort as well to be able to, I guess, engage with the secondary, tertiary care clinicians because I think primary and secondary care do not exist in isolation from each other, there should be flows of communication and digital information.” Signifies the capacity to not only take charge and provide direction but also to work harmoniously with others, promoting a positive and productive team dynamic.	Pilot dataset McDonald et al. ¹⁷
	Has appropriate implementation skills	Health professional researcher has the necessary skills to enable the successful implementation of LHS. For example, required program management and project coordination skills, knowledge on implementation science, quality improvement, clinical disciplines, operations.	“It's definitely a project that has potential for collaboration. And I've actually made those connections now...Sharing what we do in such a way that at some stage, you know, they both come together, when it comes to the data aggregation, you know, the piece of work that she's doing, will fit in nicely to what I'm doing and vice versa as well.” “I think, having good organization skills, so that's also a strength, because it's quite time limited project...So, making those timelines, setting priorities, and dividing the task, what I can and what I can't achieve”	Pilot dataset Allen et al., ²⁵ Lindsell et al. ²⁸ Pilot dataset

(Continues)

TABLE 2 (Continued)

Codes	Subcodes	Description	Typical exemplars	Literature or data justification
Adaptive mindset	Proficient time management skills	Ability to work flexibly to meet changing project implementation demands. Demonstrates ability to navigate and address challenges related to the integration of LHS into existing workflows.	“Well, I guess, that ability to work flexibly and meet demands, like I have no hesitation that the project will get done and get done well. I think and the comfort with being able to flex hours if and when they're needed.”	Pilot dataset
	Positive attitude towards innovation.	Engaged and open to new ideas. Consistently optimistic and receptive mindset regarding the adoption, integration, and ongoing development of LHS principles and practices.	“One of my strengths would be just to give it a go, just to try it out. And, you know, do the best I can with the skills that I have.”	Easterling et al. (2022), ²⁶ McDonald et al. ¹⁷ Pilot dataset
	Sees the importance of evidence-based practice	LHS seen as a valuable tool for evidence-based decision-making and use of data for quality improvement. Individuals who see the potential benefits of LHS in improving patient outcomes are more likely to actively participate in data collection and analysis.	“I'm open to new ideas...But I also think trying to think laterally as well. Being open to other people's ideas. Yeah, that's always been a start. I don't shut someone down.” Demonstrates a commitment to evaluating and adjusting practices based on the latest evidence and research outcomes. “This is the reason why we want to do it because we are looking really bad right now in this one area and we think we can really improve and then after maybe half a year... it has improved, your work has paid off.”	McDonald et al. ¹⁷ Nash et al. (2022)
	Capacity to be self-reflective	Demonstrates the ability and willingness to engage in thoughtful self-reflection, evaluating one's actions, decisions, and contributions within the LHS context to promote personal and professional growth.	“I'm open minded so I'm really open to receive constructive feedback and check on that feedback on both moving forward with my project, and also try to do my best to improve the skills or strategies that I can apply to complete this project.”	McDonald et al. ¹⁷ Pilot dataset
	Attends specific training in LHS competencies	Attends LHS relevant courses. For example, her-specific training and skills in evidence-based practice.	“I guess I found the resources in there...the initial kind of more didactic formal training sessions, the foundational course to be really valuable, I think.”	Easterling et al. ²⁶ McDonald et al. [23] Pilot dataset
Barriers				
Insufficient skillset to undertake LHS work	Insufficient specific training undertaken	Inadequate training and education on LHS concepts and tools can hinder adoption.	Inadequate familiarity and preparation in LHS principles, which encompass the integration of research, clinical practice, and data-driven decision-making.	Easterling et al., ²⁶ McDonald et al. ¹⁷
	Under-developed data science knowledge and skills	Individual doesn't have the skills and knowledge to engage in quality improvement, data analysis etc. Unable to use data systems effectively or understand the potential benefits.	“I guess, the biggest barrier is the knowledge piece with regards... details around health informatics, computing, and AI, particularly, because, you know, the AI piece is so integral to my project as well.”	Enticott et al. (2021), ⁴ Hardie et al. (2022), McDonald et al. ¹⁷ Pilot dataset
	Difficulties with managing competing demands	Time constraints managing clinical and research role. Individuals experience difficulties balancing the workload and LHS training contribution: misaligned timelines; low tolerance to disruptions; systematic planning.	“But the fact that I haven't, I should have done a Diploma or a Master's in health informatics.” “Time, I guess, for busyness, juggling lots of different balls, I work across a lot of different roles anyway. And obviously, clinical tasks, always take priority.”	Enticott et al. (2021), ⁴ Hardie et al. (2022), Zurynski et al. ²⁰ Pilot dataset

TABLE 2 (Continued)

Codes	Subcodes	Description	Typical exemplars	Literature or data justification
Personal attributes: areas for growth	Lacking necessary knowledge and experience	Individuals demonstrate limited understanding of the core concepts and goals of LHS. Lack experience in applying data-driven decision-making within the healthcare context. Express uncertainty about best practices and strategies for successful LHS implementation.	“I’m in the process of sort of trying to forge that pathway to continuity, because I don’t want, you know, all of the learnings that I’ve had at the end of this year to be lost. But...you can’t build a learning healthcare system in in one year, it’s not possible.” “I think one of the other barriers is maybe my role itself is ...not clinically based. So, I’m non-clinical, I have to have an understanding of the clinical. But since the EMR has been implemented, like I had the baseline training like everyone else, but if you don’t use that training, you kind of you don’t get a good feeling on what, you know, what the issues are with the EMR, and the workflows and all of that, and you’re really relying on other people to inform you.”	Pilot dataset Easterling et al. (2022), ²⁶ Enticott et al. (2021), ⁴ Hardie et al. (2022), McDonald et al. ¹⁷ Pilot dataset
	Difficulties with stakeholder engagement and relationship building	Individuals encounter obstacles and difficulties in effectively engaging stakeholders and building positive relationships within the LHS, potentially impacting collaboration and the success of LHS initiatives.	“It took me a long time to get my head around what (name)’s department is, what (name) is doing, you know, the role of the Chief Information Officer, how it’s also brought together, gel together, mesh together, that really has been a bit of a barrier, because, you know, I’ve had to find my way, weave my way through, to find out, you know, who’s where, in order to contact them.”	McDonald et al. ¹⁷ Pilot dataset
	Lacking project implementation skills	Difficulty developing project ideas and protocols. Lack of knowledge around implementation of healthcare LHS projects.	“I think being better prepared to come up with, you know, my project idea and the details of the, of the project itself...I think that was the main sort of barrier that I personally felt.” “I came to the academy without a lot of knowledge about what it involves to implement a digital health project like this...I guess I would describe that as a barrier.”	Pilot dataset
	Lacking in confidence	Individuals exhibit hesitancy, self-doubt, or a perceived lack of confidence in their ability to successfully contribute to the implementation and functioning of a LHS. “Imposter syndrome”; perceived hierarchical level within organization.	“I think one of the first barriers would probably be confidence. And I think for the past 6 months, I’ve really struggled with the idea that I have this kind of imposter syndrome.” “Another barrier I guess my level in the organization I noticed like some of the other fellows are a bit higher you know, they’ve achieved a bit more than myself, which is probably where the imposter syndrome theory came through right?”	McDonald et al. ¹⁷ Pilot dataset Pilot dataset
	Unfamiliar communication methods	Shows uncertainty in adapting communication style from face-to-face to virtual settings. Expresses challenges in maintaining engagement and clarity during online discussions within LHS teams. Demonstrates unfamiliarity with leveraging appropriate communication tools for virtual collaboration in the LHS framework.	“And then, from a personal point of view, I think it was also you know...having this disjointed interface with the faculty. Being online, particularly the early stages, it does create a sort of a virtual environment, which in my mind... has been a barrier, because I’m kind of the kind of person who likes to get to know people face to face. And then it’s easy for me to communicate with them as well”	Pilot dataset

(Continues)

TABLE 2 (Continued)

Codes	Subcodes	Description	Typical exemplars	Literature or data justification
Non-adaptive mindset	Individuals resistant to change	Individuals are hesitant to adopt new technologies or workflows associated with LHS. Preference for traditional methods and reluctance to participate in data-sharing initiatives. Concerns that the system would diminish the importance of clinical judgment.	"I guess the barriers have been the fact that the medical record was designed as a clinical tool, not as a data capture tool. So, there's a lot of data that's entered as free text, the discrete data isn't always entered. You know, unless you've got clinicians who are motivated to put and understand why you want to put the right data in the right fields, which is certainly not the busy clinician on the ED floor, then the data is only as good as what you've put in."	Hardie et al. (2022), McDonald et al., ¹⁷ Zurynski et al. ²⁰ Pilot dataset
	Difficulty adapting to various working styles	Individuals face obstacles in navigating and harmonizing with the varied workstyles of their colleagues. It signifies challenges related to communication, collaboration, and overall adaptability in a diverse work environment.	"Because in my case, I had to flex a lot. And I had to pivot a lot. And I think I lost a lot of time and effort doing that. So, from a personal point of view, I think that was the major barrier."	Pilot dataset
	Devaluing tasks necessary for LHS implementation	Individuals articulate negative sentiments or challenges associated with the incorporation of LHS administrative tasks into their regular duties.	Mention feeling overwhelmed by administrative duties linked to LHS implementation. Expressions of concern regarding the impact of LHS-related paperwork on daily tasks. Statements indicating a sense of increased workload due to LHS administrative responsibilities.	Zurynski et al. ²⁰
Strategies				
Implement structured patient engagement processes		Involve consumers in the co-design, development, and implementation of LHS, by conducting regular patient feedback sessions and integrating their perspectives to build trust and improve outcomes. Implement transparent clinical decision-making processes.	Communication can be enabled by systems that allow patients to engage with their health providers, access their own EHRs and patient peer-support programs.	Allen ²⁵ & Easterling et al., ²⁶ Ellis et al., ³ McDonald et al., ¹⁷ McLachlan et al., ⁷ Nash et al. (2022), Zurynski et al. ²⁰
Cultivate mindsets and skills important to LHS	Develop individual collaboration and networking skills	Engage in early collaborations between researchers and clinicians actively participate in networking opportunities and interdisciplinary collaboration to enhance understanding and application of LHS principles. Participate in LHS-focused communities of practice.	"This networking has helped me to figure out what's going on. For instance, we have, another anesthetist who's working on a whole... informatics program, which is implementing a health assessment questionnaire in epic, and that's got direct sort of, consequences to the project that I'm working on, because the data that comes from the assessment questionnaire is basically what I am after."	Easterling et al (2022), ²⁶ Enticott et al. (2021), ⁴ McLachlan et al. ⁷ Pilot dataset
	Develop a positive attitude and self-reflective capacity	Regularly engage in self-reflection and actively seek feedback to foster a positive attitude towards innovation and continuous improvement in LHS work. Cultivate openness to innovation.	Use of feedback on their own practice; engaged and open to new ideas.	Foley and Vale, ⁵
	Build confidence in undertaking LHS work	Participate in professional development workshops and mentorship programs focused on enhancing research and implementation skills. Share experiences with peers.	"I went to an imposter syndrome workshop. And that, yeah, that that helps. It didn't complete like, I don't think completely okay, it's bit of a process really a bit of a journey that I had to go on by myself, and you know, I have good days and bad days, like everyone else does. But yeah, the workshop really helped."	Easterling et al. ²⁶ Foley and Vale, ⁵ Hardie et al. (2022), Lindsell et al., ²⁸ McDonald et al. ¹⁷ Pilot dataset

TABLE 2 (Continued)

Codes	Subcodes	Description	Typical exemplars	Literature or data justification
	Recognize the importance of continuous learning and improvement	Engage in continuous education by attending relevant training and take advantage of support offered to stay current with LHS developments and practices. Develop skills in structured learning and quality improvement.	“I tried to do a good job by learning new skills and practising...which is quite rewarding at the end, but at the same time, it's quite stressful because it's just put me out of my comfort zone.”	Easterling et al. (2022), ²⁶ McDonald et al., ¹⁷ McLachlan et al., ⁷ Pilot dataset
Seek appropriate support as required		Actively seek support and mentorship from stakeholders and experienced colleagues to navigate challenges and enhance LHS project outcomes. Utilize organizational resources.	“And you know, being humble and asking for help, when needed, can allow a project to get off the ground, as opposed to one that never does.” “...talking to others...if I'm struggling with something in particular. I have a few people that I can use as a soundboard to discuss difficulties whether they are involved in the project or not. Yeah, so that's a good strategy.” “Sometimes I've laid it out during our team meetings that just having trouble, I don't know what I'm doing well, so get some, I guess, some encouragement from the supervisors as your mentor.”	Pilot dataset
Protect time available to work on LHS activities	Implement effective time management strategies	Prioritize LHS-related tasks by setting aside dedicated time and managing workload effectively to ensure continued progress on LHS activities. Communicate LHS commitments to colleagues.	Allocate specific time blocks each week to focus solely on LHS projects, to improve productivity and progress.	Nash et al. (2022)

Abbreviation: LHS, Learning health system.

TABLE 3 Meso (organization)-level codes.

Codes	Subcodes	Description	Typical exemplars	Literature or data justification
Enablers	Established digital technology infrastructure	Well-integrated EMR with efficient sharing of patient data across different departments and specialties. Data systems are analyzed to support knowledge generation and research questions that support LHS.	Digital platforms (e.g., EHRs, disease registries, mobile devices) utilized for the real-time capture, production, and application of knowledge based on best available data. “I think the EMR has really enabled it [the project], the focus is on how the EMR might support low value care. So, the fact that we've got an EMR that is an excellent system; it has been well configured to Australia. It is part of the team. So that has really supported the ability to put the right alerts and get the right design people in the team. And then it's facilitated the data extraction as well.”	Easterling et al., ²⁶ Enticott et al. (2021), ⁴ Hardie et al. (2022), Lindsell et al., ²⁸ McDonald et al. ¹⁷
	Sound data quality and integrity	Data systems meet standardized processes in safeguarding digital health information. Supportive regulatory frameworks, data storage, ethics.	Access to good quality and reliable research data supports LHS, for example, extraction and application.	Easterling et al., ²⁶ Enticott et al. (2021), ⁴ Hardie et al. (2022), Lindsell et al., ²⁸ McDonald et al., ¹⁷ Zurynski et al. ²⁰
	Interoperable data systems	Transparent processes that encourage data sharing. Ensure privacy protection, governance and data security, and innovation.	Data sharing among local stakeholders—health professionals, researchers, and patients.	Easterling et al., ²⁶ Hardie et al. (2022), McDonald et al. ¹⁷
	Data are available and accessible	Data available on a range of issues for learners in the organization to use for analysis and is of high quality.	Web-based systems designed to facilitate access to large-scale data collections to support LHS. Access to large volumes of data, for example, EHRs, genomics data, systems for routine data collection, data warehouses/repositories.	Easterling et al., ²⁶ Hardie et al. (2022), McDonald et al., ¹⁷ Zurynski et al. ²⁰
	Data and workflow are integrated	Digital ecosystem increases capacity for clinical decision-making.	Flexible systems that are embedded within electronic medical records (EMRs) and support engagement with data as part of the normal clinician workflow and joint decision-making.	Ellis et al., ³ McDonald et al. ¹⁷
	Data analytics expertise available within the organization	Staff with highly developed data management and analysis skills.	Data analytics expertise embedded at various levels.	Enticott et al. (2021), ⁴ Nash et al. (2022)
Supportive organizational culture with visible leadership	Organizational readiness for implementation	Leadership commitment and engagement. Leaders understand the value of LHS and provide the necessary support to drive implementation. Leadership aligned to the value placed on innovation, learning, and continuous improvement.	“The structure is there within the department to support something like this....that was one of the visions for the department—to have more of a presence in the research field. So, putting that structure in place, it's important to our managers.” “Practice facilitation, clinical decision support, workflow development, EHR optimization, integration of implementation science frameworks and strategies, and tailoring interventions to organizational context.”	Allen et al., ²⁵ Easterling et al., ²⁶ Enticott et al. (2021), ⁴ Lindsell et al., ²⁸ McDonald et al. ¹⁷
				Pilot dataset

TABLE 3 (Continued)

Codes	Subcodes	Description	Typical exemplars	Literature or data justification
	Dedicated organizational teams	Emphasis on teamwork, shared decision-making, and continuous improvement. Leadership motivates their teams to embrace the system and implement improvements.	Team members have skills and knowledges on various aspects of LHS, which is useful for implementation, for example, skills and knowledge on implementation science, quality improvement, clinical disciplines, operations, IT, and analytics.	Allen et al., ²⁵ Easterling et al., ²⁶ Hardie et al. (2022), McDonald et al., ¹⁷ Steels et al. (2021)
	Organizational culture emphasizes and supports learning	Creation of a vibrant culture of continuous learning and improvement. Staff training, skill building and support to enable continuous refinement, is implemented.		Easterling et al., ²⁶ Enticott et al. (2021), ⁴ Hardie et al. (2022), McDonald et al. ¹⁷
	Organizational culture of research and monitoring and evaluation mechanisms	Organizations that emphasize continuous improvement can more easily adapt to the LHS model.	Leadership, policies, and procedures to organize and facilitate quality improvement work. Establishes systems to continuously monitor and evaluate the progress and impact of LHS	Allen et al., ²⁵ Zuryinski et al. ²⁰
	Stakeholder involvement and collaboration	Leaders instill a culture of collaboration and adaptability to support the learning process. Recognition that implementation requires collaboration between various disciplines, including health professionals, data scientists, informaticians, and administrators.	Includes cross-institutional and cross disciplinary collaboration with shared goals supported by structured interactions creates a strong framework for learning.	Lindsell et al., ²⁸ McDonald et al. ¹⁷ Pilot dataset
	Clear organizational communication	Transparent communication about the goals, benefits, and processes of LHS.	Variety of modes for communication including emails, staff meetings, newsletters, etc. Promotion of communication between clinicians.	Ellis et al., ³ Steels et al. (2021)
	Motivated staff and providers	Quality improvement ideas from health professionals rather than managerial staff increases motivation for project.	“Staff are very motivated and driven to achieve excellent clinical care.” “I think that’s been such a valuable thing to feel like, you know, every single person that we’ve worked with, or that’s, you know, had one of the founders in sessions with us, every single person has been so approachable and so willing to share their knowledge, which has been hugely valuable.”	Easterling et al. (2022), ²⁶ Enticott et al. (2021), ⁴ Nash et al. (2022) Pilot dataset
Patient-centered care	Support engagement from all key stakeholders, for example, patient and family engagement	Importance of integration of patient and family values, experiences, and perspectives into projects. Engaging patients in their care and in the LHS can validate its importance and drive its acceptance. Minimize barriers to patient participation.	Utilizes tools and resources that facilitate shared decision-making between healthcare providers and patients. Mechanisms available for individuals to provide feedback on the system, ensuring that the LHS develops based on user needs. Engaging user champions. “I’m happy to lean on others to inform the project. I mean part of the project is setting up a design thinking workshop, and that’s getting end users in and getting their thoughts.”	Allen, ²⁵ Easterling et al., ²⁶ Ellis et al., ³ McDonald et al., ¹⁷ McLachlan et al., ⁷ Nash et al. (2022), Nash et al. (2022), Zuryinski et al. ²⁰

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TABLE 3 (Continued)

Codes	Subcodes	Description	Typical exemplars	Literature or data justification
Organization invests sufficient resources/sustainable funding	Ensure consumers hold appropriate technological skills	Patients can interact with the technology used to collect the data.	“This is the reason why we want to do it because we are looking really bad right now in this one area and we think we can really improve and then after maybe half a year... it has improved, your work has paid off.” Appropriate training and supportive system for consumers to learn the required skills.	Pilot dataset McDonald et al. ¹⁷
	Organizational policies and resource availability to incentivize LHS activities	Incentives that encourage ongoing improvement of care. Organization provides protected, longer-term funding for research and other LHS activities.	Sufficient budget including capital investment, implementation, maintenance, and support costs (for LHS-related digital services and staff support). Respond to grant opportunities from external funding agencies. Employ embedded researchers. Dedicated center that provides focus and leadership for LHS work	Allen et al., ²⁵ Easterling et al., ²⁶ Gould et al., ¹² McLachlan et al., ⁷ Zurynski et al. ²⁰
	Time made available for LHS work	Dedicated work hours for LHS activities. Integration of LHS into routine workflows. Protected time for research. Flexibility in scheduling and work hours.	“Well, I guess, that ability to work flexibly and meet demands, like I have no hesitation that the project will get done and get done well. I think and the comfort with being able to flex hours if and when they're needed.”	Pilot dataset
	Continuous learning culture	Leadership-instilled culture of learning. Implements ongoing training programs to enhance staff skills and competencies in LHS methodologies. Continuous refinement of processes and system improvements.	Training provided to employees on, for example, EHR-specific training, and LHS competencies, for example, skills in evidence-based practice. Learning championed by organizational leaders. Embedded researchers to train.	Easterling et al. (2022), ²⁶ Enticott et al. (2021), ⁴ Hardie et al. (2022), McDonald et al., ¹⁷ Zurynski et al. ²⁰
Barriers	Digital and technology infrastructure	Fragmented data sources or lack of standardized data formats. Regulatory and legal barriers. Data not representative of all patient populations or free from bias. Data not available in electronic form. Delayed delivery of data. Data incomplete/missing/duplicated or incorrectly coded.	“Scarcity of data on specific conditions, especially rare diseases, can cause problems for developing programs to improve clinical decision making.” “There's not a rapid enough turnaround for it to actually be used in real time. And so that's maybe a gap... Like we have some access to good data.”	Enticott et al. (2021), ⁴ Hardie et al. (2022), Lindsell et al., ²⁸ McDonald et al., ¹⁷ Steels et al. (2021), Zurynski et al. ²⁰ Pilot dataset
	Data privacy and security issues	Data privacy and security concerns. Difficulties in maintaining confidentiality and integrity.	The way data is produced, stored, exchanged, or amalgamated may negatively impact privacy and confidentiality of patients.	McLachlan et al., ⁷ Nash et al. (2022), Steels et al. (2021)
	Under-developed or lack of Electronic Medical Record	A lack of technology or outdated systems that can not support LHS functionalities. Usability, dependability, maturity and requirements to integrate with other system can impact success.	“We do have a flash electronic healthcare system, but it is yet in evolution, it is yet in development. And there are lots of gaps and holes, and lots of reasons why people are getting quite you know, frustrated with it. Reporting from EHR is terrible, it's very, very hard.”	Foley and Vale, ⁵ Hardie et al. (2022), Zurynski et al. ²⁰

TABLE 3 (Continued)

Codes	Subcodes	Description	Typical exemplars	Literature or data justification
	Poor interoperability among systems	Information stored in discrete, often incompatible systems, resulting in difficulty in seamless communication and data exchange between different digital systems.	"I guess the barriers to that have been the fact that the medical record was designed as a clinical tool, not as a data capture tool." "I'm a fellow GP. I've only worked in three general practices. I recognize that, you know, the way that different practices function, the software that different practices use, are all very different in the in the way that that clinical workflow happens across different practices. And so, I guess the kind of fragmentation and complexity of primary care specifically, has been a real challenge."	Pilot dataset Enticott et al. (2021),⁴ Hardie et al. (2022), Zurynski et al.²⁰ Pilot dataset
	Lack of staff with data analytics experience	Data expertise and analytics not available in the organization to assist with LHS projects	Support the professionalization of the data analytics workforce; develop digital skills across the wider healthcare workforce.	Hardie et al. (2022)
Cultural and organizational challenges	Lack of organizational readiness	Organization does not understand the value of LHS and therefore does not drive systematic changes.	"The organizational readiness is a hurdle because everyone is so preoccupied with ED overcrowding, hospital being red every day, staff shortages."	Pilot dataset
	Cultural resistance to change	Different working cultures and priorities, particularly among established professionals. Resistance to adopting new approaches and technologies associated with LHS.	"I think maybe there's a cultural layer anyway, that this isn't something that requires or deserves effort above and beyond what is already part of our job description. And so certainly being able to advocate that the resources that it needs is somewhat challenging. It's probably the main barrier I can think of, other than the fact that we're also in a period of time where it's no one's priority."	Easterling et al.,²⁶ Ellis et al.,³ Enticott et al. (2021),⁴ Hardie et al. (2022), Steels et al. (2021) Pilot dataset
	Organization lacks capacity for innovation	Organization's capacity for innovation and its other priorities will influence its ability to develop a learning health system. Absence or lack of leadership buy-in and support for implementation.	"I don't think that there is that those structures set up to support kind of innovation across the primary care space more broadly." "I think that the big barrier, within primary care more broadly, to think about digital innovation is that is that...the rates of burnout and the hugely excessive workload precludes people from being able to think about innovation, because they're just struggling to keep their heads above water."	Easterling et al.,²⁶ Enticott et al. (2021),⁴ Foley & Vale,⁵ Hardie et al. (2022), Lindsell et al.,²⁸ McDonald et al.¹⁷ Pilot dataset
	Lack of support for teamwork and collaborative working	Siloed work environments hinder interdisciplinary collaboration, resulting in isolated efforts instead of integrated learning health system (LHS) practices. Hierarchical structures may impede the adoption of the collaborative and adaptive nature required for effective LHS implementation.	"I think the challenges and trying to...set up a learning community where you're trying to work out, you know, who were the people that I need to involve, who are the key stakeholders, they're people that you're not already connected to, it's...fragmented quite a lot."	Hardie et al. (2022), Steels et al. (2021), Zurynski et al.,²⁰ Pilot dataset

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TABLE 3 (Continued)

Codes	Subcodes	Description	Typical exemplars	Literature or data justification
	Workflow disruption	Workforce challenges such as disruption of established clinical workflows, causing inconvenience and resistance. Lack of clarity on roles and responsibilities.	Stakeholders see LHS as just more administrative tasks and an additional burden to their workload.	McDonald et al., ¹⁷ Zurynski et al. ²⁰
	Supportive system competencies: Feedback mechanisms	Individuals express apprehension that providing feedback may result in negative actions or consequences directed towards them personally or professionally.	Hesitation to share constructive criticism due to concerns about retaliation. Fear that expressing concerns or suggestions may lead to negative repercussions. Reluctance to provide honest feedback due to perceived risks to individual standing or reputation.	McDonald et al., ¹⁷ Zurynski et al., ²⁰
	Absence of a culture of learning and improvement	Organizational culture does not support learning.	A lack of relevant evidence and information about how to translate research findings.	Foley and Vale, ⁵ Hardie et al. (2022)
	Poor communication channels	Lack of transparent and efficient communication channels for disseminating information related to LHS initiatives. Absence of evidence about LHS and what it is trying to achieve. Lack of clarity on LHS.	Communication enhancements, or clarification efforts required to ensure a more informed and aligned understanding of LHS principles and objectives. Promotion of communication with patients, research participants, and community at large.	Zurynski et al. ²⁰
	Lack of long-term sustainability and organizational commitment	Lack of clear vision and agreed set of objectives. Short-term nature of the program and lack of further investment.	Short-term contracts; lack of implementation of new governance structure; staffing shortages due to being unable to offer competitive salaries.	Steels et al. (2021)
Patient-centered care	Patients demonstrate a lack of active participation in their healthcare	Inability to meet patient expectations and satisfaction regarding care. Patients do not see the value in the aim of the project.	Patients do not initiate or respond to communications from healthcare providers regarding their health. Patients consistently miss scheduled appointments or follow-up visits.	Hardie et al. (2022), McDonald et al. ¹⁷
	Patients lack knowledge and technological skills	Patients required to access and understand health-related information and to understand and share information with an established system.	Insufficient training for patients, for example, lack of understanding on how to input data (e.g., telemonitoring).	Easterling et al., ²⁶ Ellis et al., ³ Hardie et al. (2022), McLachlan et al., ⁷ Zurynski et al. ²⁰
	Lack of trust in data security	Concerns about unauthorized access to healthcare data. Perceived risk of data breaches. Lack of confidence in data handling processes. Insufficient transparency in data security practices. Fear of data misuse.	Inadequate explanation of data usage in consent forms, particularly for re-use in research and quality improvement activities, may make patients more cautious about data collection and re-use, including for research purposes.	Zurynski et al. ²⁰
Resource constraints	Inadequate funding or resources	Unstable/unbalanced internal and external funding. Limited resources to invest in new technologies, training, development, deployment, or other resources required for LHS. Resource allocation challenges.	“The major barrier is funding. So, you know, this is not the first time that we’ve attempted to embed, choosing wisely into business as usual. And they’re really, you know, hospitals are a resource poor organization...And it’s really hard for people to understand the need to invest in this area and why it’s not just part of what we do every day.”	Easterling et al., ²⁶ Ellis et al., ³ Enticott et al. (2021), ⁴ Hardie et al. (2022), Lindsell et al., ²⁸ McDonald et al., ¹⁷ McLachlan et al., ⁷ Nash et al. (2022), Steels et al. (2021)

TABLE 3 (Continued)

Codes	Subcodes	Description	Typical exemplars	Literature or data justification
Skilled workforce for LHS work/ expertise	Time constraints	Includes delays in signing off on funding, contracts, allocation of funds, and putting staff in place. LHS timelines that are unresponsive to healthcare system needs, unrealistic to accomplish. Protected time not made available for staff to take part in LHS work. Difficulties achieving ambitious and innovative programs of work in restricted time frames.	“At some grades of work, that is really an issue because people are held accountable minute by minute. Certain grades, like mine... we work such flexible hours that, you know, we don't always acknowledge the fact that most of us do a lot of our non-clinical working at weekends... People have to be given the time to join in the community and be meaningfully engaged.”	Gould et al., ¹² McDonald et al., ¹⁷ Steels et al. (2021) Pilot dataset
	Difficulty getting specific approvals	Delays in funding, contracts, allocation of funds, or staff.	Lengthy ethics or waiting periods gaining necessary approvals, for example, data sharing.	Steels et al. (2021)
	Lack of specific training	Insufficient training and education on LHS concepts to equip staff with the necessary skills for LHS tasks and responsibilities can hinder adoption.	“We've got, you know, a lot of work to do on education of staff at various levels.”	Easterling et al., ²⁶ McDonald et al. ¹⁷ Participant 16
	Lack of availability of trained staff	May limit the ability for staff to participate in aspects of LHS, for example, data collection or translation.	Lack of trained staff, low staffing levels, limited data analysis skills.	Steels et al. (2021), Zurynski et al. ²⁰
Strategies	Improve digital and technology infrastructure	Establish a clear framework for how data are collected, managed, and used.	Process maturity assessment tools for technical infrastructure, aimed at the complex, constantly changing sociotechnical aspects of a learning health system.	Easterling et al., ²⁶ Enticott et al. (2021), ⁴ Foley & Vale, ⁵ Hardie et al. (2022), Lindsell et al., ²⁸ McDonald et al. ¹⁷
	Implement data security measures	Organization implements robust data protection and security measures to address privacy concerns.	Regularly update security protocols and conduct risk assessments to identify vulnerabilities. Development of data-sharing protocols.	Easterling et al., ²⁶ Enticott et al. (2021), ⁴ Foley & Vale, ⁵ Hardie et al. (2022), Lindsell et al., ²⁸ McDonald et al. ¹⁷
	Develop a digital transformation plan	Create a clear digital transformation roadmap outlining specific goals, milestones, and timelines. Align digital initiatives with organizational objectives and the evolving needs of healthcare delivery.	Support the development of new analytics and data tools; spread best practice for procuring and implementing digital tools.	Hardie et al. (2022)
	Meet interoperability standards	Facilitate the seamless exchange of patient information among different healthcare entities to enhance care coordination. Help providers to achieve interoperability standards.	An integrated, interoperable EHR system that supports the data requirements of multiple stakeholders. Improve adherence to interoperability standards.	Allen et al., ²⁵ Hardie et al. (2022)
	Build specialist capability	Develop training programs to enhance digital literacy and technology skills among healthcare staff. Foster a culture of continuous learning to keep employees abreast of technological advancements.	Build specialist analytic and data science capability. Employ specialist staff with the required data science skill set.	Hardie et al. (2022)

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TABLE 3 (Continued)

Codes	Subcodes	Description	Typical exemplars	Literature or data justification
Supportive organizational culture with visible leadership	Improve data access and availability	Access to real time, secure data with integrated data infrastructures, and EHR interoperability	Good quality and reliable research data are necessary for LHS—for example, extraction and application. All aspects of care including safety, quality, processes, costs, and outcomes are recorded and available to stakeholders (patients, health professionals, managers) to improve patient care and decision-making.	Easterling et al., ²⁶ Ellis et al., ³ Gould et al., ¹² McDonald et al., ¹⁷ Nash et al. (2022), Zurynski et al. ²⁰
	Undertake assessment of organizational readiness	Evaluate the organization's readiness for LHS—define purposes and scope, establish criteria, engage stakeholders. Evaluate leadership commitment, staff competence, organizational culture, and technological infrastructure.	Identify strengths, weaknesses, and areas of opportunity. Establish mechanisms for ongoing monitoring of readiness levels.	Foley and Vale ⁵
	Develop organizational goals and incentives	Organizational policies incentivize LHS activities. Explicit document outlining goals, priorities, and actions; a strategic direction. Provide vision and leadership.	Policies actively encourage ongoing evaluation of care given and improvement of processes and support the provision of high-value care and reduction in wasteful practices.	Easterling et al. (2022), ²⁶ Enticott et al. (2021), ⁴ Foley and Vale, ⁵ Zurynski et al. ²⁰
	Implement organizational behavior change	Organizations need to change what they are doing—often requires purposeful intervention to align with principles and goals of a LHS.	Shared ways of thinking/assumptions; values and beliefs. Unconscious underpinnings of daily practice.	Foley and Vale (2022) ⁵
	Develop awareness campaigns	Develop a clear narrative on why LHS matter and the impact they could have.	Leadership promotes the benefits and principles of LHS to enhance understanding and buy-in.	Hardie et al. (2022)
	Improve integration with current workflows	Appropriate staffing to assist with workflow.	Organization ensures that the LHS fits seamlessly into existing practices to reduce resistance and friction.	McDonald et al. ¹⁷
	Engage LHS champions	Identify and support individuals who are passionate about LHS to influence colleagues.	Engage change champions and advocates to drive acceptance and reduce user frustration.	Easterling et al. (2022) ²⁶
	Develop an implementation strategy	Package of evidence-based interventions to overcome barriers to successful implementation. LHS tested in smaller settings to gather feedback and make necessary adjustments.	Staged implementation processes and learning from facilities that have implemented EHR/LHS systems	Foley & Vale, ⁵ McLachlan et al. ⁷
	Encourage stakeholder collaboration	Organization encourages collaboration and supports engagement between all key stakeholders.	Cross-institutional collaboration with shared goals supported by structured interactions creates a strong framework for learning.	Easterling et al. (2022), ²⁶ Enticott et al. (2021), ⁴ McDonald et al., ¹⁷ McLachlan et al., ⁷ Zurynski et al. ²⁰
	Comprehensive evaluation	Collect data and analyze results to evaluate initiatives from the outset. Describes initiative activities and their relationship to outcomes.	Formative evaluations from the project start that clearly define the population of interest, core intervention components, or meaningful metrics.	Allen et al. ²⁵
	Provide feedback mechanisms	Establish channels for regular feedback from all stakeholders to continuously refine and improve the system.	Consultation on the content, methods, design, implementation, metrics, or evaluation of LHS projects.	Allen et al. ²⁵
	Ensure consumer co-design	Involve consumers in the design, development, and implementation of LHS.	Providers, participants, and patients collaborate to design care based on evidence and stakeholder needs by using pragmatic, timely, and flexible methods.	Allen et al., ²⁵ Easterling et al. (2022), ²⁶ Foley & Vale, ⁵ Lindsell et al., ²⁸ McDonald et al. ¹⁷

TABLE 3 (Continued)

Codes	Subcodes	Description	Typical exemplars	Literature or data justification
	Motivate staff and providers	Empowering health professionals with quality improvement ideas enhances project motivation more effectively than input solely from managerial staff	"I think things that come from the bottom-up is the stuff that gets people the most excited. I can come in and say [management] want us to capture X, Y, and Z, and it feels like another job. But if somebody [on the frontline team] says, 'I'm really curious about this clinical issue,' and everybody gets excited, that doesn't feel like another job."	Easterling et al. (2022), ²⁶ Enticott et al. (2021), ⁴ Foley & Vale, ⁵ Nash et al. (2022)
Organization invests sufficient resources/sustainable funding	Provide support and resources	Provision of resources—technical, support, or funding to: improve digital maturity, build specialist data science capability, help providers meet interoperability standards, and build capability to implement improvements to care.	Sufficient and stabilizing funding from internal or external sources.	Allen et al., ²⁵ Enticott et al. (2021), ⁴ Hardie et al. (2022), Gould et al., ¹² Hardie et al. (2022), Lindsell et al., ²⁸ McLachlan et al. ⁷
	Provide time and flexibility	Organization provides sufficient time and flexibility to engage in LHS activities.	Organization provides protected time for quality improvement/research.	Enticott et al. (2021), ⁴ Hardie et al. (2022), McDonald et al. ¹⁷
Skilled workforce for LHS work/expertise	Foster a culture of continuous learning and improvement among staff at all levels	Implementation of staff training, skill building, and support to enable continuous refinement of processes and system improvements. Ensure staff understand how new systems contribute to quality improvement and promoting a science-literate workforce.	Provision of general training and tailored skill training (e.g., EHR-specific, computer skills, clinical workflows, implementation, and use of LHS).	Easterling et al. (2022), ²⁶ Hardie et al. (2022), McDonald et al., ¹⁷ McLachlan et al. ⁷
	Ensure a multidisciplinary team	Developing a LHS is a multidisciplinary endeavor.	Team could be made up from a mix of employed, contractors, and consultants; other staff may be employed by suppliers and platform providers. Leadership is especially important.	Foley & Vale ⁵

Abbreviation: LHS, Learning health system.

TABLE 4 Macro (policy)-level codes.

Codes	Subcodes	Description	Typical exemplars	Literature or data justification
Enablers				
Suitable digital and technology infrastructure	Appropriate industry data standards and frameworks	Industry standards for data formats, quality metrics, and best practices	Further develop interoperability standards and support services to meet them.	Hardie et al. (2022)
	Supportive data legislation	Policies that promote data sharing and interoperability	“Governance structures that enable routine sharing of patient clinical data, including consistent regulations across health system sectors (e.g., between local jurisdictions, states, and territories, or between private and public institutions), would help with information dissemination.”	Zurynski et al. ²⁰
National or regional initiatives.		Government-led initiatives or campaigns promoting LHS can drive awareness and prioritize its implementation.	Initiatives for providers and local systems that support the embedding, adaptation, and refinement of new service models.	Hardie et al. (2022)
Provision of funding		Invest in improvement capabilities required; improve digital maturity and help create infrastructure; build specialist analytic and data science capability; help providers meet interoperability standards.	Targeted funding facilitates the uptake of research discoveries in the clinical setting while ensuring that ethical, legal, and social obligations are met.	Hardie et al. (2022), Zurynski et al. ²⁰
Collaborative networks		Networks or consortiums of health institutions, policymakers, and technology providers can facilitate knowledge exchange and collaborative efforts.	Leaders, health professionals, researchers (mutual trust); executive sponsors (make things happen); physicians as leaders and members of multidisciplinary improvement teams.	Gould et al. ¹²
Public awareness and support		A well-informed public that understands and supports LHS.	Recognize the importance of public trust in the handling and sharing of data. Public engagement into policies and practices.	Hardie et al. (2022)
Barriers				
Regulatory, governance, and policy restrictions	Legal/ethical issues	Burdensome regulations; ethics/research approval; intellectual property rights.	Ethics committee approval processes reduce the amount and type of patient data available for research.	Zurynski et al. ²⁰
	Complexity and inconsistency of regulations	National or regional policies and regulations might limit data sharing or impose bureaucratic hurdles that stymie the flexibility required for LHS.	“It seems that no current legislation adequately contemplates or addresses general liability or duty of care issues arising from use of the multitude of eHealth products.”	McLachlan et al., ⁷ Zurynski et al. ²⁰
Lack of standardization		The absence of industry-wide standards for health data formats, interoperability, or quality metrics can hinder the scalability and integration of LHS.	Electronic data do not always meet quality standards, for example, data can be incomplete or captured incorrectly.	Hardie et al. (2022), McDonald et al. ¹⁷
Funding limitations		National- or state-level funding might not prioritize or adequately support LHS initiatives.	Provide longer-term funding to help the least mature organizations and systems.	Hardie et al. (2022)
Diverse stakeholder interests		Differing priorities among policymakers, payers, providers, and the public can make consensus-building challenging.	Consensus can be hard to achieve when learning communities are diverse in backgrounds, organizational approaches, and culture.	Foley & Vale, ⁵ Hardie et al. (2022)
Political pressures		Implementation of therapies or technologies with little or uncertain evidence.	Lack of availability of evidence or lack of guidance on translating evidence.	Ellis et al. ³
Concerns related to data security		At a macro-level, concerns about patient data privacy and potential misuse can influence public perception and acceptance.	Data breaches may make patients more cautious about data collection and re-use, including for research purposes.	Ellis et al., ³ Zurynski et al. ²⁰

TABLE 4 (Continued)

Codes	Subcodes	Description	Typical exemplars	Literature or data justification
Strategies				
Engagement in policy advocacy		Engage in advocacy efforts to influence health policy, promoting the importance and benefits of LHS.	Engage patient and public trust. Develop a clear narrative on why LHS matter and the impact they could have.	Hardie et al. (2022)
Facilitation of stakeholder collaboration		Establish regular dialogue and collaboration platforms among health institutions, tech providers, policymakers, and the public. Raise public awareness of the value of participating in research.	Enable and promote collaboration across stakeholders; create and harness networks.	Gould et al., ¹² Hardie et al. (2022), McDonald et al. ¹⁷
Creation of public awareness campaigns		Launch campaigns to educate the public on LHS's benefits, addressing concerns and highlighting success stories	Develop a clear narrative on why LHS matter and the impact they could have.	Hardie et al. (2022)
Development of research and pilot programs		Fund and promote research or pilot programs that can provide evidence of LHS's efficacy and benefits.	Financial protected longer-term funding for development and deployment.	Enticott et al. (2021), ⁴ Hardie et al. (2022)
Standards development		Support efforts to develop industry standards for data sharing, interoperability, and other LHS components.	Help providers meet interoperability standards, improve digital maturity, and help create infrastructure.	Hardie et al. (2022)
Provide funding and incentive mechanisms		Create funding opportunities or financial incentives for institutions that adopt or innovate within the LHS framework	Regulatory oversight and targeted funding facilitate the uptake of research discoveries in the clinical setting while ensuring that ethical, legal, and social obligations are met. "Financial incentives have been suggested to reward health systems and researchers that facilitate data sharing, increase access to data-sharing programs, and improve adherence to interoperability standards, as well as to entice patients to share data or participate in research."	Hardie et al. (2022) Zuryński et al. ²⁰
Ensure continuous evaluation and results dissemination		Regularly evaluate the progress, challenges, and outcomes of LHS initiatives to refine strategies and policies accordingly.	Sharing results (processes and outcomes) of LHS projects to further emphasize LHS concept, via internal and external communications.	Allen et al. ²⁵

Abbreviation: LHS, Learning health system.

TABLE 5 Codes at each level of the healthcare system.

Contributing factors	Level of healthcare system		
	Micro (individual)	Meso (organizational)	Macro (policy)
Enablers			
Skillset to undertake LHS work	x		
Mindset	x		
Personal attributes	x		
Suitable digital and technology infrastructure		x	x
Organizational culture		x	
Patient-centered care		x	
Investment of sufficient resources/sustainable funding		x	x
National or regional initiatives			x
Collaborative networks			x
Public awareness and support			x
Barriers			
Insufficient skillset to undertake LHS work	x	x	
Non-adaptive mindset	x		
Personal attributes: areas for growth	x		
Appropriate digital and technology infrastructure		x	x
Cultural and organizational challenges		x	
Patient-centered care		x	
Funding limitations/resource constraints		x	x
Regulatory, governance, and policy restrictions			x
Lack of standardization			x
Diverse stakeholder interests			x
Political pressures			x
Strategies			
Implement structured patient engagement processes	x		
Cultivate mindsets and skills important to LHS	x		
Seek appropriate support as required	x		
Protect time available to work on LHS activities	x		
Develop skillset for LHS work		x	
Improve digital and technology infrastructure		x	
Supportive organizational culture with visible leadership		x	
Investment of sufficient resources/sustainable funding		x	x
Engagement in policy advocacy			x
Facilitation of stakeholder collaboration			x
Creation of public awareness campaigns			x
Development of research and pilot programs			x
Standards development			x
Ensure continuous evaluation			x

Abbreviation: LHS, Learning health system.

codebook in existing literature and analysis by a coding team enhanced its validity and inter-coder agreement. The team approach included training and familiarization with the data. The use of pilot test data from interviews with current healthcare professionals

undertaking an LHS fellowship allowed for ongoing refinement and adaptation of the codebook as new insights emerged. The diversity of health professionals of fellowship participants increased the generalizability of the results across various Australian healthcare settings.

However, the codebook needs testing in different settings and with different populations, to assess its validity and reliability. Notably, the studies incorporated into the framework were primarily conducted in high-income countries. This limitation suggests the need for targeted research in low- and middle-income countries (LMICs) to understand how the coding scheme may or may not extend to LHS evaluation in those contexts. Supporting work on LHS implementation in LMICs could help determine the applicability of the current codebook and potentially reveal additional barriers, enablers, and strategies specific to these settings.

6 | CONCLUSION

This study described the development of a codebook for identifying barriers, enablers, and strategies related to implementation of learning health systems. Addressing a knowledge gap, the codebook provides a structured approach for understanding the factors influencing LHS implementation at micro-, meso-, and macro-levels of healthcare systems. By situating our framework in relation to CFIR, and LHS maturity models and grids, we aim to demonstrate its complementary nature and relevance, encouraging its adoption and iterative enhancement by the research community. The codebook facilitates effective analysis and understanding, providing practical insights for policy-makers, healthcare practitioners, and researchers. Its iterative development process ensures that the codebook will continue to evolve based on new data and emerging research, contributing to the ongoing improvement of healthcare systems and the realization of LHS capabilities.

ACKNOWLEDGMENTS

The authors would like to thank the LHS fellows and funding from the University of Melbourne Duncan Leary Trust.

FUNDING INFORMATION

This study received funding from The Duncan Leary Bequest.

CONFLICT OF INTEREST STATEMENT

The authors declare no potential conflict of interest.

ETHICS STATEMENT

This study received ethics approval from the Office of Research Ethics and Integrity, University of Melbourne, reference code 2024-24432-49149-8.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Shaw L, Perrier M, Tahmasebian K, et al. Developing a codebook to characterize barriers, enablers, and strategies for implementing learning health systems from a multilevel perspective. *Learn Health Sys*. 2025; 9(2):e10452. doi:[10.1002/lrh2.10452](https://doi.org/10.1002/lrh2.10452)