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EXPERIENCE REPORT

Learning Health Systems

Development of a learning health system science competency assessment to guide training and proficiency assessment

Patricia D. Franklin[1] | Denise Drane[2] | Lauren Wakschlag[3] | Ronald Ackerman[4] | Abel Kho[5] | David Cella[1]

[1]Department of Medical Social Sciences, Northwestern University Feinberg School of Medicine, Chicago, Illinois, USA

[2]Program Evaluation Core & Searle Center for Advancing Learning and Teaching, Northwestern University, Evanston, Illinois, USA

[3]Department of Medical Social Sciences and Institute for Innovations in Developmental Sciences, Northwestern University Feinberg School of Medicine, Chicago, Illinois, USA

[4]Institute for Public Health and Medicine and Department of Medicine, Northwestern University Feinberg School of Medicine, Chicago, Illinois, USA

[5]Center for Health Information Partnerships, Northwestern University Feinberg School of Medicine, Chicago, Illinois, USA

Correspondence
Patricia D. Franklin, Department of Medical Social Sciences, Northwestern University Feinberg School of Medicine, 625 N Michigan Ave, Suite 2100, Chicago, IL 60611, USA.
Email: patricia.franklin@northwestern.edu

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Abstract

Introduction: Learning health systems (LHS) science is fundamentally a transdisciplinary field. To capture the breadth of the competencies of an LHS scientist, AHRQ and national experts defined a series of 42 competencies across seven domains that support success. Clinicians, researchers, and leaders who are new to the LHS field can identify and prioritize proficiency development among these domains. In addition, existing leaders and researchers will assemble teams of experts who together represent the LHS science domains. To serve LHS workforce development and proficiency assessment, the AHRQ-funded ACCELERAT K12 training program recruited domain experts and trainees to define and operationalize items to include in an LHS Competency Assessment to support emerging and existing LHS scientists in prioritizing and monitoring proficiency development.

Methods: Sequential interviews with 18 experts iteratively defined skills and tasks to illustrate stage in proficiency, and its progression, for each of 42 competencies in the seven LHS expertise domains: systems science; research questions and standards of scientific evidence; research methods; informatics; ethics of research and implementation in health systems; improvement and implementation science; and engagement, leadership, and research management. An educational assessment expert and LHS scientist refined the assessment criteria at each stage to use parallel language across domains. Last, current trainees reviewed and pilot tested the assessment and the LHS Competency Assessment was further refined using their feedback. The assessment framework was informed by Bloom's revised taxonomy of educational objectives (Anderson and Krathwohl, A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives, 2001) where learning progresses from recalling, defining, understanding, and awareness at the lower levels of the taxonomy, to applying and adopting and finally to creating, designing, and critiquing at the upper levels of the taxonomy. We also developed assessment criteria that could be used for longer term assessment of direct performance. Van der Vleuten et al. (Best Pract Res Clin Obstetr Gynaecol. 2010;24(6):703-719) define longer term direct assessment methods as assessment that occurs over a period ranging from

weeks to even years and involves multiple assessment methods and exposure to the learner's work over an extended period.

Results: This experience report describes the content of the LHS Competency Assessment. For each domain and competency, the assessment lists examples of evidence to support expertise at each level of proficiency: no exposure; foundational (awareness/understanding); emerging (early application); and proficient (application with a high level of skill). Trainees begin with baseline standard assessment tables, where they can indicate no exposure or mark the foundational and emerging skills with which they have competence. For domains where foundational and emerging skills have been achieved, users can move on to assessment tables that list evidence of proficiency.

Conclusion: The LHS Competency Assessment offers consistent, graded criteria across the seven LHS domains to guide trainees and mentors to evaluate progress from no experience to foundational knowledge, emerging proficiency, and proficiency. The assessment can also be used to design training and mentoring for those newly exposed to LHS science and for those with key expertise who wish to expand LHS expertise.

KEYWORDS
assessment, competency, curriculum, learning health systems

1 | INTRODUCTION

Learning health systems (LHS) science is fundamentally a transdisciplinary field. To capture the breadth of the competencies of an LHS scientist, AHRQ and national experts defined a series of 42 competencies across seven domains that could be used to design, implement, and evaluate training programs for LHS researchers.[1] Clinicians, researchers, and leaders who are new to the LHS field can use these competencies to identify and prioritize proficiency development. In addition, existing researchers and health system leaders may choose to assemble teams of experts who together represent the LHS science domains. To serve LHS workforce development and proficiency assessment for LHS scientists, faculty of an LHS training program recruited domain experts and trainees to design an LHS Competency Assessment to support emerging and existing LHS scientists in prioritizing and monitoring LHS proficiency development.

While there are multiple competencies in each LHS domain, training programs do not expect scholars to become proficient in every domain or competency. Rather, LHS scholars will focus their training on a few domains and several competencies within the domain. Every LHS trainee brings individual strengths; some scholars enter the program with proficiency in some competencies, while lacking exposure to other competencies or domains. The LHS Competency Assessment is designed to guide trainee and mentor planning across many years of an early LHS science career as proficiency evolves, including providing measurable benchmarks for individual career advancement plans.

Competencies are important for LHS workforce development as they define the knowledge- or skill-based assets that trainees should acquire during their training.[2] They are outcome focused rather than content focused.[3] Clearly defined competencies are needed to develop LHS training curricula. They allow program leaders to define learning objectives for trainees and to develop structured learning activities and experiences that will help trainees achieve the competencies. Criteria for assessing competencies are equally important for workforce development because they provide fixed and objective criteria for determining if trainees have acquired competencies at the desired standard of performance.[3,4] This obviously has practical importance, however, in their paper on assessment of clinical and translational medicine competencies, Dilmore et al. also note that there is an ethical imperative to evaluating competence.[14]

To serve LHS workforce development and proficiency assessment for LHS scientists the specific goals of this project were to (a) define distinct levels of LHS proficiency for each competency and (b) operationalize measurable criteria that could be used to differentiate between the levels of proficiency.

2 | METHODS

2.1 | Educational framework

Achieving competence is developmental and requires a gradual progression toward the integration of knowledge, skills, and attitudes. Competency-based education is a learning paradigm focused on describing and measuring what learners need to know and be able to do (outcomes), given the goals and mission of the program.

In this light, competencies define the knowledge, skills, and attitudes needed to function successfully within the discipline.[14]

Our assessment framework was informed by Bloom's revised taxonomy of educational objectives.[5] The taxonomy defines cognitive processes that underly learning. At the lower level of the taxonomy, learners remember (recognize, recall), and understand (eg, summarize, explain, interpret). These are the cognitive processes that underly the foundational mastery level of the framework. In the mid-level of the taxonomy, learners apply (execute, implement). This process underlies the application level of the framework. At the upper level of the taxonomy, learners analyze (eg, differentiate, attribute), evaluate, and create (eg, generate, plan, and produce).

We also aimed to develop an assessment framework that could be used for longer term assessment of direct performance. Van der Vleuten et al. define longer term direct assessment methods as assessment that occurs over a period ranging from weeks to even years.[6] This contrasts with assessment that occur at a single point in time. In addition, these authors note that assessment involves multiple assessment methods and exposure to the learner's work over an extended period. Our framework has 4 levels of mastery so that progress can be assessed over a timeline of months and/or years. Mastery is assessed using multiple forms of evidence from research study protocols to IRB submissions, to stakeholder meetings, to the trainee's mentored research project.

TABLE 1 Summary of the six-step competency assessment development process

1.	Panel of learning health systems experts assembled and includes multiple experts within each of the 7 LHS domains Development team outlines process for developing competency assessments with panel experts Development team and education expert discuss competencies and competency assessment with panel experts
2.	Development team convenes a 90-min brain-storming session with 7 sub-groups of the panel comprised of 3–4 experts for each domain Based on session recordings, development team creates first draft of competency assessments and shares them with the domain experts
3.	Domain experts revise competency assessments Development team refines competency assessments and shares with domain experts for their final revisions Development team makes final revisions for consistency across domains
4.	Competency assessments for 7 domains shared with the full expert panel for feedback Development team makes revisions
5.	Competency assessments shared with new cohort of trainees for feedback
6.	Development team makes final revision to competency assessments

2.2 | Competency assessment development team

ACCELERAT (A Chicago Center of Excellence for Learning Health Systems Research Training) is one of the 11 AHRQ-funded LHS training programs. (K12HS026385; 2019-2023) Participation in the K12 funding mechanism allows junior faculty committed to a career as an LHS scientist to dedicate 75% effort for a minimum of 2 y. While ACCELERAT is housed at Northwestern University Feinberg School of Medicine, the program invites scholar applications from across the Chicago region. LHS scholars complete a mentored research project while completing a training program that includes a core didactic series plus individualized training opportunities.

The development team for this competency assessment consisted of an expert in learning health systems research and an expert in higher education evaluation and assessment. The development team created the development process, identified experts to review draft competencies, conducted the expert panels, and drafted and refined the competencies.

2.3 | Competency assessment development process

We developed the competency assessments using an iterative process (Table 1). We identified a panel of 18 experts across the learning health science domains to develop the competency assessments, including research experts for each domain. The experts were members of the ACCELERAT executive committee for the training program, faculty who teach in the program, and experts from within the health systems that employed the trainees. Expert panels for domains 4 (informatics) and 5 (ethics) also included trainees who entered the training program with a high degree of expertise in those domains.

The competency development team co-facilitated an initial meeting with the director of the Northwestern University Searle Center for Advancing Learning and Teaching to explain what competencies are, how Blooms Revised taxonomy could be used as a means of distinguishing between levels of performance, and potential sources of evidence to assess competencies development. The process for developing the competency assessments was also discussed at the meeting.

Panels of 3-4 experts were convened for each competency domain. The expert panel then met with an expert in learning health systems research with broad expertise across all the domains and a specialist in higher education evaluation for a 90-min brainstorming session. During the sessions, experts described how they understood the competency, and how they would distinguish between someone with a very basic level of skill, someone whose skills were emerging and someone whose skills were proficient. The expert panel meetings were recorded, and notes were taken. Following the meeting, the evaluation specialist reviewed the meeting notes and recording and drafted criteria for the different levels of proficiency described during the meeting. The LHS expert edited the drafts, and the revised draft was shared with the expert team for additional edits. The revised draft

was then reviewed and edited by the development team again. Revised drafts were then shared with the expert panel for another round of feedback. The full expert panel discussed and advised on the definition of proficiency levels and provided final feedback on the assessment. Last, the draft competencies were reviewed by a new cohort of four ACCELERAT trainees to provide input on content and accessibility of the language for trainees.

TABLE 2 Definitions of the four levels of proficiency

Mastery level	Definition
No exposure	The trainee has not been exposed to the competency
Foundational	The trainee has an awareness of or basic understanding of the competency. The trainee demonstrates understanding by interpreting, classifying, summarizing, inferring, comparing, and explaining
Emerging	The trainee is in the early stages of applying the competency. The trainee can execute and implement
Proficient	The trainee is applying the competency to their research with a high degree of skill. The trainee can analyze, evaluate, and critique, integrate stakeholder perspectives and work successfully in complex systems

2.4 | Proficiency levels

Based on input from all domain experts, we chose four levels of proficiency: "no exposure," "foundational awareness," "emerging proficiency," and "proficient" (Table 2). The "no exposure" level of proficiency was created for trainees with no incoming awareness of the competency. The "foundational awareness" level is associated with awareness or understanding of the concepts and skills. This awareness is often gained through didactic learning (seminars, workshops, and coursework) in the training program but may also be acquired through one-to-one feedback and discussions in research in progress meetings or with mentors. Trainees demonstrate their understanding during discussions, workshop activities, and course assignments through behaviors such as summarizing, explaining, and comparing. The emerging level is associated with application of knowledge and concepts and skills to the trainee's own research. Trainees design, create, and make decisions but with minimal input from stakeholders. Completion of a mentored research project may demonstrate emerging skills in some LHS domains.

Work products from courses: assignments, projects, exams, peer review work

Research in Progress Meetings: presentations, discussions with faculty & peers during meetings

IRB Submissions: study protocol, IRB protocol, IRB Consent form, revisions of protocols and forms with annotations explaining how revisions improve quality

Research/Quality Improvement Projects: group charters and protocols, revisions with annotations to explain revisions, project data, analysis of project data, project report

Informatics: Electronic health data requests, data curation, use of data standards

Statistical analyses and Modeling: models developed/applied/critiqued in own research

Grants: grant draft, revised grant draft with annotations explaining improvements, submitted grant

Publications: draft manuscripts, manuscripts submitted

Conference Materials: conference submissions, abstracts, posters, slides

Meetings: stakeholder meeting minutes and products, committee meetings, quality committee meetings, health system meetings

Presentations: given at program research in progress meeting presentations, conferences, stakeholder meetings, health system meetings

Social Media: blogs, social media posts, tweets, visual abstracts

FIGURE 1 Illustrative sources of evidence for trainee proficiency self, mentor, or program assessment

TABLE 3 Sample competency assessments for each of the 7 learning health systems (LHS) domains

No exposure	Foundational	Emerging	Proficient
Domain 1: Systems science			
Competency 1: Demonstrate knowledge of how systems theories can be used to understand how the interactions of the parts of health systems operate to produce value for stakeholders			
No exposure	1A. Aware of potential external and internal factors that may influence an *intervention* in the health system and how to recognize them	1B. Identifies both internal and external system determinants that can influence the impact of an intervention to be deployed	1C. Designs a complex health intervention study that measures the contribution of multilevel determinants on outcome as measured by process/use measures
Domain 2: Research questions and standards of scientific evidence			
Competency 1: Demonstrate the ability to compose feasible and timely research questions and hypotheses, incorporating stakeholder priorities, to generate evidence that informs meaningful clinical and policy decisions			
No exposure	2A. Aware that research questions can be constructed in collaboration with stakeholders	2B. Constructs research questions mainly in isolation based on literature and clinical knowledge	2C. Constructs and refines research questions in collaboration with stakeholders
Domain 3: Research methods			
Competency 2: Demonstrate the ability to develop an appropriate observational, quasi-experimental, or experimental study design while mitigating threats to internal and external validity for research that is minimally disruptive to operations in real world health systems and practices			
No exposure	3A. Understands how stakeholder involvement can enhance study procedures and successful study conduct	3B. Accurately assesses the feasibility of conducting the study protocol including consideration of workflow, issues re: randomization, anticipation of the stakeholders who need to be engaged	3C. Study protocol exhibits evidence of substantive involvement of stakeholders/ community in the study design and issues such as workflow and randomization
Domain 4: Informatics			
Competency 1. Demonstrate the ability to use data derived from electronic health records and other clinical information sources for research and quality improvement			
No exposure	4A. Knows the range of questions that can be addressed with real world data	4B. Constructs questions that can be addressed using existing informatics tools and data sources	4C. Translates a research question into the vocabulary and specifications that a data analytics team can execute, while providing important clinical and research context
Domain 5: Ethics of research and implementation			
Competency 4: Demonstrate the ability to identify and minimize potential conflicts of interest in the design, conduct, and reporting of research conducted in health systems			
No exposure	5A. Aware of the range of conflicts of interests	5B. Identifies one's own conflicts of interest	5C. Identifies own conflicts of interest and conflicts of interest relating to those of stakeholders. Discloses and minimizes them
Domain 6: Improvement and implementation science			
Competency 1: Demonstrate the ability to employ specific quality improvement methods to reduce avoidable variation and improve performance in clinical processes and outcomes in routine practice			
No exposure	6A. Recognizes an opportunity to reduce variation in care delivery and/or to improve outcomes	6B. Identifies unnecessary variation in care delivery, patterns/themes and causes of variation and/or suboptimal performance	6C. After identifying potentially avoidable variation or suboptimal performance in care delivery, identifies stakeholders involved in care, collaborates to establish a team charter and measurable objectives
Domain 7: Engagement, leadership and research management			
Competency 7.6: Demonstrate the ability to implement protocols aligned with health systems operations and integrated into clinical settings, including engaging clinicians in the research process			
No exposure	7A. Understands the roles research partners play, including clinicians and other stakeholders, but major decisions are made without input	7B. Roles and decision-making authority of research partners, including patients and other stakeholders, are defined and clearly stated. Major decisions are communicated to all stakeholders	7C. Roles and decision-making authority of research partners, including patients and other stakeholders, are defined *collaboratively* and clearly stated. Major decisions are made *inclusively* and communicated to all stakeholders

"Proficient" involves application, but with a high degree of skill. Trainees who are proficient conduct their work within complex systems with diverse stakeholders. They design, create, and make decisions in collaboration with stakeholders and demonstrate a high degree of flexibility. Trainees may demonstrate their proficiency through successful completion of a mentored research project, meetings, and interactions with stakeholders. Figure 1 provides examples of evidence for trainee proficiency.

The competency framework rests on the assumption that competencies will be assessed via multiple streams of information. Potential sources of evidence available in the program were identified by the development team and shared with the expert panel during the initial meeting. These included traditional training program work products such as course assignments, research in progress meetings and conferences presentations, grant proposals, and manuscripts, but also included work products specific to learning health systems training programs such as quality improvement projects, informatics requests, and conversations and interactions in stakeholder and health systems meetings.

3 | RESULTS

We developed assessment criteria for all competencies within each of the seven LHS domains. For each domain and competency, the assessment lists examples of evidence to support expertise within the level of proficiency: no exposure; foundational (awareness/ understanding); emerging (early application); and proficient (application with a high level of skill). Sample competency assessments for each domain are presented in Table 3. The number of assessment criteria (n) varied for each domain (Domain 1 n = 11; Domain 2 n = 12; Domain

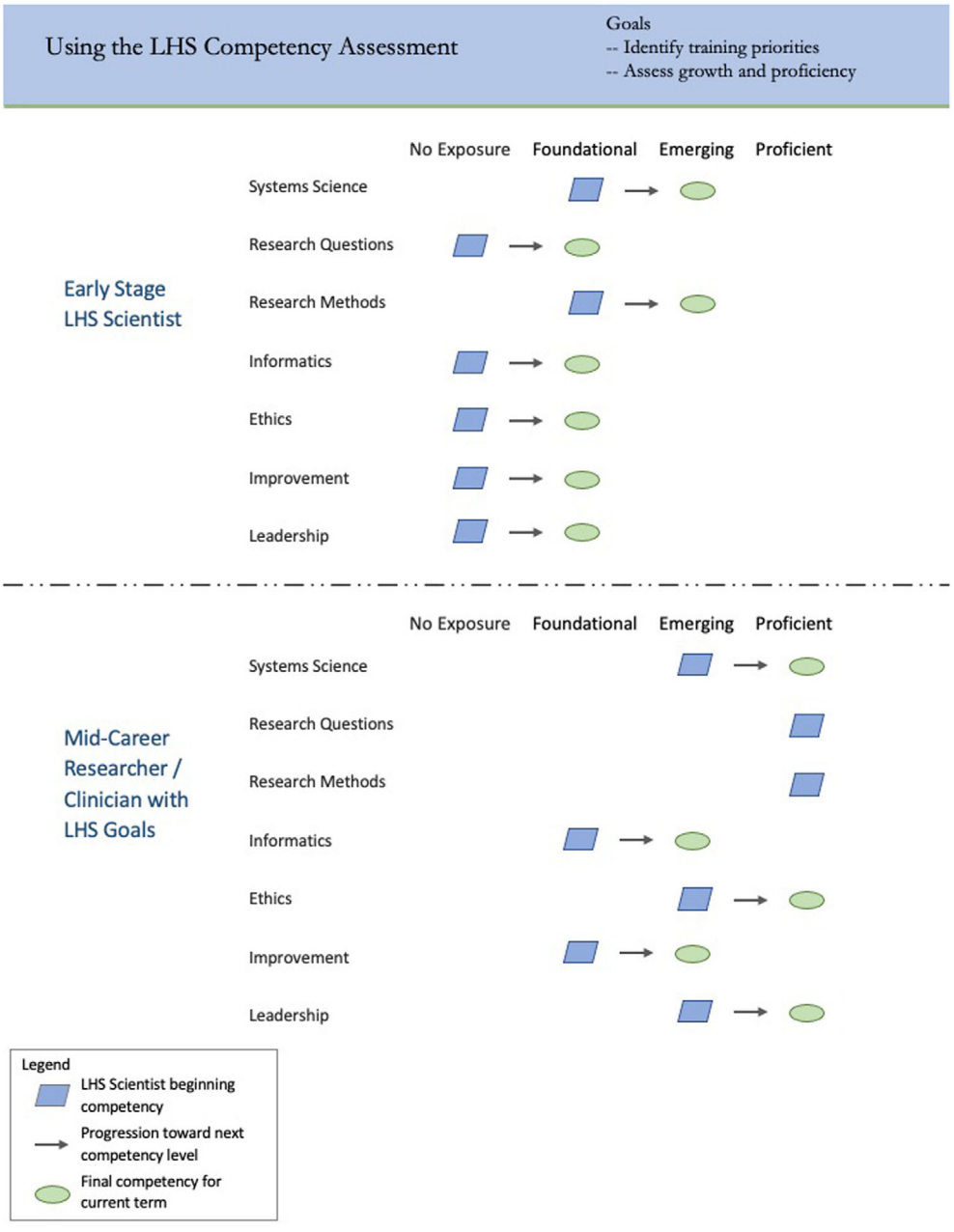

FIGURE 2 Using learning health systems competency assessment

3 n = 15; Domain 4 n = 12; Domain 5 n = 4; Domain 6 n = 10; Domain 7 n = 10).

We organized the assessment criteria into Assessment Tables (Supporting information). Users begin with baseline standard assessment tables, where they can indicate no exposure or mark the foundational and emerging skills with which they have competence. For domains where foundational and emerging skills have been achieved, users can move on to assessment tables that list evidence of proficiency.

4 | DISCUSSION

Over the past decade, training in health-related fields has shifted toward competency-based models.[7,15] In addition to medicine and nursing, disciplines including epidemiology[8] and health systems research[9] have devoted time and resources to studying the core skills and knowledge that trainees require to succeed in the professions. For translational science, which is also a transdisciplinary field, experts have also defined competencies (EATRIS C-COMEND, 2016) and characteristics[10] that complement discipline-specific expertise. Similarly, the AHRQ-defined competencies for learning health system science provide a framework for training and proficiency assessment for emerging LHS scientists.

We operationalized assessment criteria for the seven initially defined LHS competency domains. The progression from foundational to emerging to proficient involves a progression from "awareness" to "application" to "application with a high degree of skill." Application with a high degree of skill involves the ability to apply the competency in complicated settings or projects (see 1C), high level application/integration of patient-centered outcomes skills (see 2C, 3C, 6C, 7C), or the ability to work with professionals in the health system at a high level (4C) or the ability to address complex problems (5C). In the development sessions, experts across LHS domains discussed that emerging proficiency can be differentiated from proficiency because the latter requires active engagement of diverse stakeholders ranging from health system leaders and policy makers to clinicians and clinic staff to patients. The varied backgrounds and perspectives of these stakeholders must be considered when refining LHS research questions, implementing novel interventions, and evaluating associated health outcomes and health system impact. The expertise to respectfully solicit diverse stakeholder opinions, define a nuanced consensus, implement new procedures, and evaluate the impact requires practice across many years. Overall, the goal is for LHS trainees to progress toward a greater proficiency in leadership and systems thinking, meaning they can distinguish and understand relationships among parts of a health system and can apply tools to understand and solve complex problems to improve healthcare delivery and health outcomes.[11]

The LHS Competency Assessment can be used as a self-assessment or in conversation with a mentor or supervisor. Completing the assessment encourages trainees to participate actively in monitoring skill growth and assuming responsibility for achieving competence.[3] Users can complete a baseline assessment for all domains, identify the domains within which they would like to develop proficiency, and then move to the proficiency tables for the domains that are an area of emphasis to identify competencies that have been met. The assessment can be useful if repeated biannually during the training period and at least annually during the early years of an emerging LHS science career.

The sheer number of competency assessment criteria may appear to be overwhelming. However, in learning health systems training programs, the goal is not for trainees to become proficient in every competency, but for them to identify a few competencies in which they want to become proficient and others where they want to have emerging or foundational skills. The expected level of competence in each educational domain, however, is a topic for each training program to address with trainees.[2]

We anticipate that the LHS competency assessment will clarify the skills that align with each competency and illustrate how the distinct levels of expertise can be differentiated for both the trainee and mentor. The operational definitions use tasks and expertise to illustrate progression from foundational skills to proficiency. Items were selected to provide the trainee with a tangible idea of what skills and expertise they should be developing within each domain. The specificity of the competency assessments enables mentors to provide mentees with highly specific external feedback which is critical to the success of competency-based education.[3] In addition, the explicit assessment criteria make it easier for mentors and mentees to set goals and to identify activities that will help mentees reach the next level of proficiency. Mid-career or senior researchers who hope to develop new skills aligned with LHS science can also use the assessment to identify gaps in proficiency. Figure 2 illustrates how both a trainee new to the LHS field and a mid-career researcher may use the LHS competency assessment to establish and monitor learning goals.

We recognize that LHS scientists require ongoing practice while engaged in complex research and improvement activities in order to become proficient in some competencies. Thus, the LHS scientist with emerging proficiency requires the availability and partnership of a healthcare delivery system that shares the LHS values. Ongoing skill refinement in some domains, particularly in leadership and systems science, may emerge over time while some of the specific content knowledge domains may be mastered through training and early application.

A potential limitation of the LHS competency assessment is that the items were developed by experts at one LHS training center. Although the 18 participants spanned many areas of expertise and had trained and worked in different healthcare systems across the nation, all participated in the same LHS training program. It is possible that this may have resulted in a narrow perspective with uneven focus on components of LHS science. For example, we noted earlier that proficiency in a particular competency often involved high level integration of patient-centered outcomes research, a specific expertise of this program. It is possible that experts from other training programs may balance assessment criteria differently. In addition, involving a greater number of experts may have resulted in different assessment criteria. Some groups who have developed competencies have obtained feedback from several hundred members of professional associations.[12] Obtaining feedback from a wider range of LHS experts may be an appropriate next step in our competency assessment development process. To simplify assessment of trainee progress, we applied only four levels of competence across the many domains. For example, within the foundational level, both awareness of a concept and understanding

it - two distinct steps in mastery- are grouped together. Finally, as additional LHS competencies are named, the competency assessment will be expanded. For example, in summer 2022 and after this assessment was defined, AHRQ and LHS training leaders defined an eighth domain addressing equity and justice competencies.

We note that conceptual critiques of competency-based medical education also apply to competency-based assessment in LHS. These include epistemological critiques such as "competency is socially constructed and reflective of dominant values and power relations" and "the learning process is as important as learning outcomes" and "competence is not solely individual, but also collective," along with behaviorist critiques such as "competency cannot be broken down into discrete elements," "it is not possible to define all necessary competencies" and "not all aspects of competencies are observable and measurable."[13] Thus, the LHS competency assessment will and should evolve as experience deepens with both the concept and application of learning health systems science in real-world healthcare delivery settings. The present work is an essential step toward advancing the LHS field by providing objective, measurable criteria for achieving competence.

5 | CONCLUSION

This initial LHS Competency Assessment has the potential to guide and enhance the objectivity and consistency of trainee and mentor assessment of progress from no experience to foundational knowledge, emerging proficiency, and proficiency across the seven LHS domains. The assessment can also be used to identify training and mentoring priorities for those newly exposed to LHS domains. For those with research expertise and wishing to expand LHS skills, the LHS Competency Assessment can help to identify opportunities to attain a higher level of competence or broaden skills in new domains. Finally, the sample skills within the assessment can inform LHS training program didactic components to assure all participants master foundational skills across LHS domains while defining opportunities to continually expand proficiency in priority domains.

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ORCID

Patricia D. Franklin https://orcid.org/0000-0002-4441-0533
Denise Drane https://orcid.org/0000-0001-9763-3928
Lauren Wakschlag https://orcid.org/0000-0001-9511-2299
Ronald Ackerman https://orcid.org/0000-0002-4038-1966
Abel Kho https://orcid.org/0000-0003-1993-5634
David Cella https://orcid.org/0000-0002-9881-4541

REFERENCES

1. Forrest CB, Chesley FD Jr, Tregear ML, Mistry KB. Development of the learning health system researcher Core competencies. *Health Serv Res*. 2018;53(4):2615-2632. doi:10.1111/1475-6773.12751
2. Forrest CB, Martin DP, Holve E, Millman A. Health services research doctoral core competencies. *BMC Health Serv Res*. 2009;9:107. doi:10.1186/1472-6963-9-107
3. Gruppen L. Competency-based education, feedback and humility. *Gastroenterology*. 2014;148(1):4-7. doi:10.1053/j.gastro.2014.11.021
4. Searle J. Defining competency: the role of standard setting. *Med Educ*. 2000;34:363-366.
5. Anderson LW, Krathwohl DR, eds. *A taxonomy for learning, teaching, and assessing: a revision of bloom's taxonomy of educational objectives*. Boston: Allyn and Bacon; 2001.
6. Van der Vleuten CPM, Schuwirth LWT, Scheele F, Driessen EW, Hodges B. The assessment of professional competence: building blocks for theory development. *Best Pract Res Clin Obstet Gynaecol*. 2010;24(6):703-719.
7. Verderame MF, Freedman VH, Kozlowski LM, McCormack WT. Competency-based assessment for the training of PhD students and early-career scientists. *Elife*. 2018; (7):e34801. doi:10.7554/eLife.34801
8. Hlaing WM, Schmidt RD, Ahn S, Samet JM, Brownson RC. A snapshot of doctoral training in epidemiology: positioning us for the future. *Am J Epidemiol*. 2020;189(10):1154-1162.
9. Burgess JF, Menachemi N, Maciejewski ML. Update on the health services research doctoral core competencies. *Health Serv Res*. 2018; 53:3985-4003.
10. Gilliland CT, White J, Gee B, et al. The fundamental characteristics of a translational scientist. *ACS Pharmacol Transl Sci*. 2019;2(3):213-216. doi:10.1021/acsptsci.9b00022
11. Peters DH. The application of systems thinking in health: why use systems thinking? *Health Res Policy Sys*. 2014;12:51. doi:10.1186/1478-4505-12-51
12. Ablah E, Biberman DA, Weist EM, et al. Improving global health education: development of a Global Health competency model. *Am J Trop Med Hyg*. 2014;90(3):560-565. doi:10.4269/ajtmh.13-0537
13. Boyd VA, Whitehead CR, Thille P, Ginsburg S, Brydges R, Kuper A. Competency-based medical education: the discourse of infallibility. *Med Educ*. 2018;52(1):45-57. doi:10.1111/medu.13467
14. Dilmore TC, Moore DW, Bjork Z. Developing a competency-based educational structure within clinical and translational science. *Clin Transl Sci*. 2013;6(2):98-102.
15. Pock AR, Pangaro LN, Green CB, Laughlin L. Undergraduate medical education: past, present, and future. *Mil Med*. 2013;178(5):474-478. doi:10.7205/MILMED-D-12-00456

SUPPORTING INFORMATION

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

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