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Lessons learned for public health workforce development: An evaluation of the centers for disease control and prevention's laboratory leadership service fellowship

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Abstract

The Centers for Disease Control and Prevention launched the Laboratory Leadership Service (LLS) Fellowship Program in July 2015 to develop public health laboratory (PHL) leaders who will improve PHL quality and safety. This article describes a retrospective, summative evaluation to determine the extent to which LLS has met its short-term goals for PHL workforce development. The evaluation relied on existing data from routine LLS data collection and reporting, supplemented with a new alumni survey. The purpose of the design was threefold: 1) to reduce data collection burden on program staff and participants, 2) to assess the value and limits of routine fellowship data for comprehensive public health workforce development program evaluation, and 3) to identify ways to improve LLS's routine data collections for program evaluation. We used descriptive statistics, qualitative analysis, and participatory methods (i.e., a data party) to analyze and interpret data. Results show LLS short-term outcome achievement and highlight opportunities for program improvement, particularly related to the design of certain training requirements and for future evaluations. Overall, the evaluation contributes to lessons learned for PHL workforce development efforts, including how routine data collections can contribute to comprehensive public health workforce development evaluations.

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CDC Disclaimer

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.evalprogplan.2022.102147.

CRediT authorship contribution statement

Caitlin McColloch: Conceptualization, Methodology, Formal analysis, Writing – original draft. **Meagan Davis:** Conceptualization, Supervision, Writing – review & editing. **Aufra Araujo**: Supervision, Writing – review & editing. **Shaniece Theodore**: Resources, Writing – review & editing. **Joi Barkley**: Resources, Writing – review & editing.: **Margaret Paek:** Conceptualization, Writing – review & editing. **Tara Henning:** Supervision, Writing – review & editing.

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Keywords

Program evaluation; Public health laboratory; Public health workforce; Training evaluation; Workforce development

1. Introduction

1.1. Background

Public health workforce development (PHWD) programs build and maintain a competent public health (PH) workforce (Baker et al., 2005; Koo & Miner, 2010; Office of Disease Prevention and Health Promotion, 2020; Thacker, 2009). Just as PH practitioners seek to implement evidence-based approaches to PH services and policies, PHWD programs should seek to implement evidence-based approaches to workforce development. Research has shown that effective PHWD programs are discipline-specific, competency-based, and focused on service learning, a type of experiential training that emphasizes a dual benefit to both learner and community where learning takes place (Furco, 1996; Koo & Miner, 2010; Ned-Sykes et al., 2015; Thacker, 2009).

Evaluations provide specific programmatic learning and improvement opportunities and, when shared, strengthen the PHWD evidence base by contributing lessons learned. Though valuable, evaluations require time and resources that are not always easily available to programs. PHWD program implementers can use data strategically collected throughout the program cycle to help ease evaluation data collection burden (Kane et al., 2000). This article describes an internal evaluation of the Laboratory Leadership Service (LLS) fellowship that used predominately existing data collected from routine fellowship data collections.

1.2. Program overview

The Centers for Disease Control and Prevention (CDC) started LLS after a series of laboratory safety incidents in 2014 highlighted needs for improved laboratory quality and safety practices (Centers for Disease Control and Prevention, 2014; External Laboratory Safety Working Group, 2015; Glynn et al., 2020; McCarthy, 2014). The goal of LLS is to develop future public health laboratory (PHL) leaders who demonstrate scientific excellence through leadership, high standards of laboratory quality and safety, and service. LLS is modeled after the long-standing Epidemic Intelligence Service (EIS) fellowship program (Thacker et al., 2001) and provides doctoral scientists two years of training and applied learning opportunities at a PHL, known as a host site. Any governmental (e.g., state, territorial, local, tribal) PHL can apply to serve as a host site. LLS classes are made up of 6–8 LLS fellows (LLSFs) with approximately 16% of eligible applicants accepted each year. Since its inception in 2015, 47 fellows have trained with LLS: 36 alumni and 11 currently in training.

LLS implementation includes four key activities outlined in Fig. 1 and described below.

Select and match fellows and host sites.—Fellows are selected based on eligibility and suitability criteria. Eligible applicants have a doctoral-level degree in a laboratory-

related discipline, a minimum of 2 years of postgraduate laboratory experience, and U.S. citizenship or permanent residency. Suitability of eligible applicants is determined through a rigorous application review and interview process. Among other criteria, suitable applicants should have a strong commitment to public service. Host sites are selected based on their ability to provide opportunities for the LLS fellow (LLSF) to complete 10 Core Activities of Learning (CALs) (Supplemental Table S1). Selected LLSFs and host sites are matched based on a combinatorial optimization algorithm.

Train fellows with a competency-based, service-learning curriculum.— Competencies provide an ideal framework for developing PHWD training (Ned-Sykes et al., 2015). A core component of LLS is its competency-based curriculum framed within the following six competency domains deemed critical for public health laboratory leadership:

I. Leadership and Management Skills;

II. Quality Management Systems;

III. Laboratory Safety;

IV. Applied Laboratory Research, Investigation, and Surveillance;

V. Informatics and Bioinformatics; and

VI. Communications.

The LLS competency domains focus on three foundational areas (Glynn et al., 2020):

1. *Leadership (domain I):* The laboratory safety and quality issues that prompted the creation of LLS highlighted the importance and need for laboratory leaders to promote a culture of safety and quality in agency laboratories (External Laboratory Safety Working Group, 2015). The Leadership and Management Skills domain (I) is intended to train LLSFs in leadership and management skills required to become public health laboratory safety and quality leaders.

2. *Laboratory safety and quality (domains II and III):* LLS was created specifically to address public health laboratory safety and quality needs. The Quality Management Systems (II) and Laboratory Safety (II) domains train fellows in best practices for laboratory safety and quality.

3. *Current and emerging public health laboratory issues (domains IV, V, VI)*: The remaining three domains are additional areas deemed critical for laboratory safety and quality leaders based on the Competency Guidelines for Public Health Laboratory Professionals released by CDC and Association for Public Health Laboratories (Ned-Sykes et al., 2015).

Each competency domain consists of one or more competency, and there are 14 total competencies (Supplemental Table S2). LLS implements its curriculum through a series of didactic, classroom-based courses and experiential, service learning. The didactic curriculum is designed to provide balanced, comprehensive training across all competency areas over the two-year fellowship. The CALs are linked to the competency domains and serve as the framework for service learning. The CAL framework was revised for the 2016 class to make

improvements based on lessons learned from the first year (Supplemental Table S1). Service learning may also occur through field experiences where fellows provide short-term (1–3 weeks) onsite laboratory assistance to PH authorities.

***Facilitate a community of practice* (Wenger, 2009).—**LLSFs participate in didactic trainings together as a class and are strongly encouraged, but not required, to participate in a class project in which fellows work together to develop a product to aid, promote, or advance laboratory science in the PH community. LLS expects fellows to actively develop their practice together, see each other as valuable resources, and collectively contribute to improved PHL safety and quality practices because of these activities.

Collaborate with Epidemic Intelligence Service (EIS).—Collaboration between practitioners in laboratory and epidemiology is essential to an efficient PH infrastructure (Association of Public Health Laboratories, 2014; Baker et al., 2005). LLSFs and EIS officers receive side-by-side training to gain a shared understanding of each other's roles in their respective fields and how to improve laboratory-epidemiology collaboration.

According to LLS's theoretical framework and outlined in the LLS logic model (Fig. 2), successful implementation of these activities contributes to long-term outcomes such as an increase in the number of laboratory scientists advancing the science of laboratory safety and quality, more laboratory scientists in PHL leadership and management positions, and improved safety and quality practices and policies in PHLs. This theory is grounded in the understanding that a fellowship that is discipline-specific, competency-based, and focused on service-learning is effective for developing a robust workforce (Furco, 1996; Glynn et al., 2020; Koo & Miner, 2010; Ned-Sykes et al., 2015).

2. Methods

2.1. Evaluation design

This internal evaluation followed the steps and standards outlined in CDC's Framework for Program Evaluation (Centers for Disease Control and Prevention, 1999) and was considered a non-research activity by CDC's Institutional Review Board. An evaluator located in the organization that manages the LLS program led the evaluation. Key partners were engaged throughout each step and included LLS program staff, leadership, fellows, and alumni.

As a newly established program, organizational leadership was invested in understanding the program's effectiveness and potential areas for improvement early on. The evaluation purpose was to describe how LLS activities have been implemented and the extent to which short-term outcomes have been achieved. Data were gathered to answer four process and outcome evaluation questions (Table 1):

1. How have key program activities been implemented?
2. To what degree have fellows' and alumni's knowledge, skills, attitudes, and behaviors (KSABs) changed in line with expected outcomes?
3. To what degree do alumni's early career paths post-fellowship match with the program's expected career paths?

4. To what degree have host sites' KSABs for laboratory safety and quality changed in line with expected outcomes?

The first question focused on processes and sought to assess the four key activities described previously: select and match fellows and host sites; train fellows with a competency-based, service learning curriculum; facilitate a community of practice; and collaborate with EIS. Questions two through four focused on the degree to which LLS achieved the following short-term outcomes related to fellow, alumni, and host site KSABs at graduation and immediately postgraduation of each class (Fig. 2):

- Fellows acquire competencies, recognize their collective expertise, and have an increased understanding of the value in collaboration with epidemiologists;
- Alumni secure positions that fill PHL needs; and
- Host site staff gain and use knowledge and skills to improve laboratory safety and quality.

The evaluation was retrospective, summative, and was designed to primarily compile and summarize existing data to reduce data collection burden. Indicators were selected based on the extent to which they answered evaluation questions and on data availability (Table 1). A secondary goal of the evaluation was to assess this low burden evaluation design. Specifically, the LLS program wanted to better understand the value and limits of using routine fellowship data for comprehensive public health workforce development evaluation and how the program could improve these data collections for future program monitoring and evaluation. For LLS, routine fellowship data were administrative data (e.g., program records) and regular surveys of fellows and supervisors (e.g., didactic session feedback forms, exit surveys).

2.2. Data collection

The evaluation incorporated data from the 2015–2019 classes (years = class's program start). Outcome-level indicators were limited to graduated classes (2015–2017) at the time of the evaluation. Most data were collected through document review (Centers for Disease Control and Prevention, 2018) and existing LLS administrative and performance monitoring databases. An alumni survey provided new data for the evaluation. Table 1 provides a description of each data source and available data.

Program records collected through document review included activity reports, curriculum plans, course schedules, and alumni job reports. Program records were used to describe key program activity implementation and alumni jobs post-fellowship.

LLS administers routine surveys to participants throughout the fellowship. Routine survey data used in the evaluation included post-course surveys, fellow exit surveys, and supervisor surveys.

Post-course surveys: LLS sends post-course surveys to current fellows immediately following each required course. The surveys ask fellows about their experience in individual training sessions and the course overall, and their perception of relevance and value of the

training to their professional development. The LLS program uses these data to evaluate courses and to modify sessions as necessary.

Fellow exit surveys: Fellow exit surveys are used to understand LLSFs' overall fellowship experience and to assess changes in fellows' knowledge, skills, attitudes, and behaviors because of their fellowship participation. Fellows are asked to holistically assess the value of the different aspects of their training (e.g., didactic courses, field experiences, peer-to-peer learning) considering their overall experience, and to retrospectively rate their skill level before and after LLS for each competency across the six LLS competency domains. Skill levels are defined as:

- Beginner: I might have received some classroom or on-the job training but have limited experiential knowledge and would need guidance or oversight to perform a task, behavior, or function.
- Competent: I can see how actions fit into the context of the laboratory's goals and plans. I can perform a task, behavior, or function with a high degree of independence.
- Proficient: I understand how situations and actions fit into the context of the laboratory's long-term goals and mission. I have developed sufficient mastery to integrate or design a new task, behavior, or function.
- Expert: I integrate systems thinking, collaborative relationships, and available resources to achieve the laboratory's mission. I have acquired mastery to design new strategies, policies, tasks, behaviors, and functions that support quality operations.

These retrospective pre/post data are used to inform evaluation question two.

Supervisor exit surveys: Supervisor surveys provided data on supervisors' experiences with LLS and perceived benefits to the host site. Each fellow is assigned at least two supervisors: a primary and secondary. All supervisors received the supervisor survey. These data were used to inform evaluation question four.

Finally, LLS conducted an alumni survey in March 2019 for this evaluation. The alumni survey purpose was to understand to what extent fellows had used what they learned in LLS as alumni. Only LLSFs that had been alumni for at least one year participated in the survey (Table 1). These data informed evaluation questions two and three.

2.3. Data analysis and interpretation

Most data were analyzed using descriptive statistics, such as counts and proportions. We used self-reported skill-level (i.e., beginner, competent, proficient, or expert) per competency (n = 14) before and after LLS to assess LLSF growth. We aggregated LLSF self-reports per skill-level for domains with more than one competency. Domains with more than one competency include I: Leadership (n = 3), III: Laboratory Safety (n = 3); IV: Applied Laboratory Research, Investigation, and Surveillance (n = 4); and V: Informatics and Bioinformatics (n = 2).

Participatory data interpretation was used to engage partners with analyzed data (Pankaj & Emery, 2016). LLS program staff, leadership, and alumni participated in a data party, which is a participatory data interpretation event to produce key findings and recommendations based on a critical review of the data.

3. Results

Results are grouped by evaluation focus: processes and outcomes.

3.1. LLS processes

Selection & match: Selection outcomes are shown by class (Table 2). According to data available at the time of this evaluation, the number of LLSF applications received has increased with each class since the 2017 class. A 52% increase was reported in the number of eligible applicants from the 2018 class (n = 31) to the 2019 class (n = 47). From the last three classes (2017–2019), 20 of 21 fellows matched with their first or second choice host site, and all host sites (n = 21) matched with their first or second choice candidate.

Training design & implementation: Table 2 shows LLS training completion rates by class. One fellow from the 2017 class resigned from LLS after year one and was not considered a graduate for this evaluation. All graduates (n = 21) participated in all required didactic trainings, activities, and conferences. Twelve of 21 of graduates completed all CALs. Nine graduates completed all but CAL 7, which is to write and submit, as first author, a scientific manuscript for a peer-reviewed journal.

According to post-course survey and exit survey responses (Table 3), fellows agreed that what they learned in the courses was valuable to their professional development immediately following the course and many months after the course at graduation. All but one LLSF (n = 20) reported satisfaction with their overall training experience at graduation. Alumni (n = 14) reported that all LLS competency domains are “a little”, “somewhat”, or “very much” relevant to their jobs post-fellowship. According to alumni, domain VI: Communications is the most relevant, with 12 alumni having reported the domain is “very much” relevant; domain V: Informatics and Bioinformatics was the least relevant, with one alum having reported the domain is “very much” relevant. All alumni survey respondents expect their LLS experience to positively affect their career progression; three expect a “moderate positive impact” and 11 expect a “substantial positive impact” to their careers because of LLS.

Community of practice: In addition to 100% participation in the didactic trainings, 20 of 21 graduates participated in an optional class project. One of the goals of the class project is to facilitate peer-to-peer learning and encourage fellows to recognize their collective expertise. Half (7/14) of alumni survey respondents reported that the peer-to-peer learning aspect of their LLS experience “very much” prepared them for their current position postgraduation.

Collaboration with EIS: The proportion of total joint LLS-EIS didactic training sessions increased by 50% from 28% in 2015 (30/106) to 42% in 2018 (49/117). LLSFs from the

classes of 2015–2017 participated in a total of 29 field activities; 48% included an EIS officer.

3.2. LLS outcomes

Fellow knowledge, skills, attitudes, and behaviors: Table 4 illustrates how, overall, LLS fellows reported to be more skilled in the LLS competency domains after LLS compared to before LLS. The table summarizes the fellows' self-reported skill-levels (i.e., beginner, competent, proficient, and expert) for all 14 competencies before and after LLS per competency domain. As described in Table 4, LLSFs started the fellowship most competent in domain IV: Applied Laboratory Research, Investigation, and Surveillance, which had the highest proportion of self-reported skills at the competent, proficient, and expert levels before LLS (51 of 84). Consequently, this was one of the domains with the least growth in proficient or expert-level skills (54% overall). Although most fellows reported to be at least competent in domain V: Informatics and Bioinformatics after LLS (fellows self-reported as at least competent 38 of 42 times), this domain had the lowest growth in proficient- or expert-level skills overall (43%). LLSFs had the highest growth potential, and indeed the highest growth in, domains III: Laboratory Safety (90% overall growth) and II: Quality Management Systems (86% overall growth). Though not shown in the table, reported growth in at least proficient skills increased in each domain with each class except for domain III: Laboratory Safety for which the 2016–2017 classes reported 100% growth. The number of LLS graduates that reported to be at least competent (i.e., competent, proficient, or expert) in all six competency domains increased from 1 of 21 graduates before LLS to 18 of 21 graduates after LLS.

In total, 20 of 21 graduates reported that it was valuable or extremely valuable to reach out to other LLSFs for resources, information, or input on their work during the fellowship (Table 3). Among the 20 graduates who participated in a class project 17 reported having a better understanding of other LLSFs' expertise after project participation and 18 reported growth in their own expertise. Seven of 14 alumni who responded to the survey reported finding value in collaboration with other LLS alumni post-LLS.

In total, 18 of 21 graduates reported that they have a better understanding of how to foster collaboration between epidemiologists and laboratory professionals because of their work with EIS officers during LLS. Additionally, 15 reported that they are more likely to seek out collaboration with an epidemiologist in the future compared with when they entered LLS, but 6 reported no change in likelihood. Only 5 of alumni survey respondents reported finding value in collaboration with epidemiologists post-LLS.

Alumni jobs: All LLS graduates (n = 21) were employed within one month of finishing the program. Overall, 18 graduates accepted positions in PHLs. Alumni employment settings include CDC (n = 15), domestic government (n = 3), nonprofit (n = 2), and industry (private, nonclinical) (n = 1).

Alumni responsibilities: Of the 14 alumni survey respondents, 100% reported to be in a position of technical responsibility. Although only three reported to have official supervisory responsibility in their job post-graduation, at least 9 alumni report that they exercise a

great deal of leadership in various types of roles: influence on policy (n = 10), formal decision-making (n = 9), and opportunities to represent their organization (n = 10). These numbers do not include the LLS alum who served as Acting LLS Program Lead during this evaluation and did not complete the alumni survey. Examples of alumni's current position titles include Branch Project Manager, Senior Research Safety Manager, and Quality and Compliance Team Lead.

Benefits to host site staff: All supervisor survey respondents (n = 23) reported that their LLSF contributed to laboratory quality and safety at their host site (Table 3). Open-ended supervisor survey responses indicate that LLSFs developed laboratory quality systems, improved laboratory safety policies and procedures, and contributed to the PHL knowledge base by conducting relevant research. In total, 20 of 23 supervisors agreed that their team has gained knowledge or skills because of hosting their LLSF. Fewer supervisors reported that hosting their LLSF had changed the way they or their team members approached laboratory quality (n = 17), safety (n = 16), or management (n = 15).

4. Discussion

4.1. Lessons learned

This evaluation revealed the LLS program's initial success in training highly qualified doctoral scientists in competencies that contribute to the improvement of PHL quality and safety programs in their host sites and to their careers as laboratory leaders.

Evaluation question 1: How have key program activities been implemented?— The program keeps a detailed record of the selection, match, and training processes and outcomes for each cohort. These reports include a descriptive critical review of the data (i.e., extent to which the program met targets, strengths and weaknesses of approaches, and planned improvements for future cohorts), and were extremely valuable in evaluating and making sense of data over time. Findings showed that LLS's selection and match processes resulted in fellows matched to PHLs that provide service-learning opportunities. Training completion rates highlight gaps in the curriculum and CAL requirements that should be addressed for future cohorts. Only 57% of fellows completed all CALs, which was primarily attributable to LLSFs who were unable to complete CAL 7 (i.e., write and submit, as first author, a scientific manuscript for a peer-reviewed journal). Several factors present a challenge for completing this CAL, including fellows' reliance on their host sites for publishable projects, time required for internal clearance of manuscripts, or prioritization of other CALs that provide new learning experiences. CAL 7 requirements were revised for the 2021 class to require interim manuscript deliverables over the course of the fellowship and a final draft as the CAL deliverable.

Perceived utility or relevance of training is another indicator of training design and implementation effectiveness (CDC, n.d.-b; Renta-Davids et al., 2014). LLS collects these data immediately after the course and many months after the course when the program expects that fellows have had the opportunity to apply what they learned to their work. This delayed follow up is important to assess learning transfer and training effectiveness (CDC, n.d.-a). Post-course survey results and curriculum-related exit survey results indicate that

fellows perceive their LLS training as useful. Additionally, the fact that alumni reported that LLS competencies are relevant to their jobs post-LLS suggests that LLS training is useful beyond graduation. The LLS program seeks to improve its routine data collection related to training effectiveness by incorporating 3–6-month course follow-up surveys to monitor and assess information retention and application.

Evaluation question 2: To what degree have fellows' and alumni's knowledge, skills, attitudes, and behaviors (KSABs) changed in line with expected outcomes?—Findings indicate progress in achieving LLS's intended short-term outcomes. LLS expects its graduates to acquire competencies deemed critical for public health laboratory leadership after participating in the fellowship. Self-reported skill-level before and after LLS suggest that LLSFs graduate the program more skilled in these competencies than when they entered the program. All LLSFs graduated at least mostly competent across all LLS competency domains, though skill-level growth varied (Table 4). In fact, LLSFs grew the most in competencies related to laboratory safety and quality, a reassuring finding given that the program was initially launched to address agency workforce training and competency needs in these areas. It is not surprising that skill growth was low in domain IV: Applied Laboratory Research, Investigation, and Surveillance (i.e., laboratory bench skills) compared to other domains because growth is limited by the fact that fellows tended to enter the program with higher-level skills (i.e., proficient or expert) in this domain. This is not the case, however, for domain V: Informatics and Bioinformatics. While most reported skill-levels within this domain at graduation were at least competent, domain V: Informatics and Bioinformatics saw the least growth in proficient- or expert-level skills. This evaluation did not assess why growth in this domain was low or why it increased with each cohort; however, these are interesting findings that merit further investigation. For example, to what extent are host sites able to provide experiential training opportunities related to the competencies in this domain compared to the other domains? How has the role of informatics and bioinformatics to PHL safety and quality work changed since 2015?

Another intended short-term outcome is that graduates increase their understanding of the value of laboratory-epidemiology collaboration. LLSFs perceive value in collaboration with their LLS peers and with epidemiologists at graduation, although less so after graduation as alumni. Interpretation of these data is challenging because of the limited sample size; however, alumni may perceive less value in collaboration with epidemiologists if it is not an aspect of their job. LLS expects this to change because we have already anecdotally seen more and improved laboratory-epidemiology collaboration during CDC's response to the COVID-19 pandemic.

Evaluation question 3: To what degree do alumni's early career paths post-fellowship match with the program's expected career paths?—LLS also expects its fellows to accept PHL leadership positions immediately post-fellowship. One of the main objectives of LLS as a PHWD program is to add competent PHL professionals who can effectively lead PHL safety and quality initiatives to the PH workforce. The LLS program's post-fellowship employment target was for at least 85% of graduates to accept a position in government public health. So far, this target has been met with the classes of 2015–2017:

all 21 LLS alumni secured a job within one month of graduation and almost all (18 of 21, or 86%) were employed in government PH. In terms of leadership, LLS alumni accepted positions of leadership, though some less formal than others. LLS plans to incorporate an alumni survey to the program's routine data collections for performance monitoring and will continue to track alumni positions to monitor this trend.

Evaluation question 4: To what degree have host sites' KSABs for laboratory safety and quality changed in line with expected outcomes?—In terms of benefits to host sites, supervisors reported to have gained knowledge and skills for laboratory safety and quality after hosting their fellow; however, fewer supervisors reported operational changes in their laboratories. LLS does not collect baseline data on host site capacity and does not know host sites' capacity for change. Additionally, among supervisors who did report operational changes in their laboratories, the extent and sustainability of reported changes is unclear. These uncertainties merit further evaluation.

Finally, an important lesson learned from this evaluation is the importance of strategic, routine data collected as part of program implementation and the feasibility of conducting a comprehensive, informative evaluation that relies almost exclusively on these data. LLS prioritized strategic performance monitoring since its inception, including designing routine data collections that are equally useful for program implementation as evaluation. This approach maximizes use of existing data strategically collected to meet multiple needs. There are limitations with this approach, however, depending on the type, scope, and quality of data available, and it is important to consider the types of evaluation questions this design approach can answer. For example, a fifth evaluation question intended to assess the extent to which the LLS community of practice provides enhanced expertise to CDC could not be fully assessed with LLS's existing data and new data collection would have required substantial effort. Additionally, the phrase 'as a result of the program' was originally included in evaluation questions two and four. However, this phrase was removed from both questions because it was not possible to establish attribution with sufficient rigor. Often, as in the case of this evaluation, routine data are only available for the program participants, and therefore, cannot be used to determine impact or causality (i.e., what would have happened in the absence of the program). Though limited in scope, this evaluation helped to identify potential areas of LLS program and data collection improvement as well as resulted in an inventory of existing data and data collections that may be useful for future impact evaluations.

4.2. Limitations

One major limitation of this evaluation is that competency assessment is challenging and often relies on subjective data (Baker et al., 2005; Koo & Miner, 2010). LLSFs may have a skewed perception of their competency, which confounds assessment of skill growth. To address this, LLS implemented CAL rubrics with the 2017 class that measures CAL completion quality as an indicator of competency. Supervisors score their fellow's performance of each CAL based on the criteria in the rubric, review the score with the fellow, then submit the rubric to the LLS program. Future evaluations will assess rubric effectiveness.

Another limitation is that LLS class sizes are small, which makes data interpretation challenging and limits conclusions to trends that should be monitored as future class sizes are expanded. Among an already limited sample size, the supervisor survey response rate was low. Therefore, results may not accurately represent the perspectives of all LLS supervisors.

While there are benefits to internal evaluations (e.g., more economical, evaluators have existing familiarity with the program and its information needs), we must acknowledge their limitations. One of the main limitations of internal evaluations is the increased potential for biased reporting and interpretation of results in favor of the program. We believe this evaluation produced an honest representation of the program. However, we do recognize the threat to objectivity as a limitation and encourage LLS to consider evaluations external to the agency in the future, especially for impact evaluations.

5. Conclusion

LLS is a robust, data-driven PHWD program that strengthens PHL's workforce by preparing laboratory professionals to be PH leaders. Data collected as part of a routine, strategic performance monitoring system are valuable for LLS program evaluation and ensure the program adapts to meet changing needs. This is especially important and relevant now as the LLS class of 2022 is expected to at least double the average historical class size because of new funding opportunities. The scope of an evaluation that relies solely on these data collections will depend on the type and extent of data available. Programs should prioritize routine data collections based on identified information needs, program capacity, and participant burden. The LLS program prioritizes frequent surveying of participants to continually monitor and improve the LLS fellowship experience. The findings from this evaluation provide an example of how implementers of public health workforce development programs can use routine data collections for comprehensive evaluation, and contributes lessons learned to improve PHWD efforts.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Abbreviations:

PHWD	Public Health Workforce Development
PH	Public Health
LLS	Laboratory Leadership Service
PHL	Public Health Laboratory
CDC	Centers for Disease Control and Prevention
EIS	Epidemic Intelligence Service
LLSF	Laboratory Leadership Service Fellow
CAL	Core Activity of Learning

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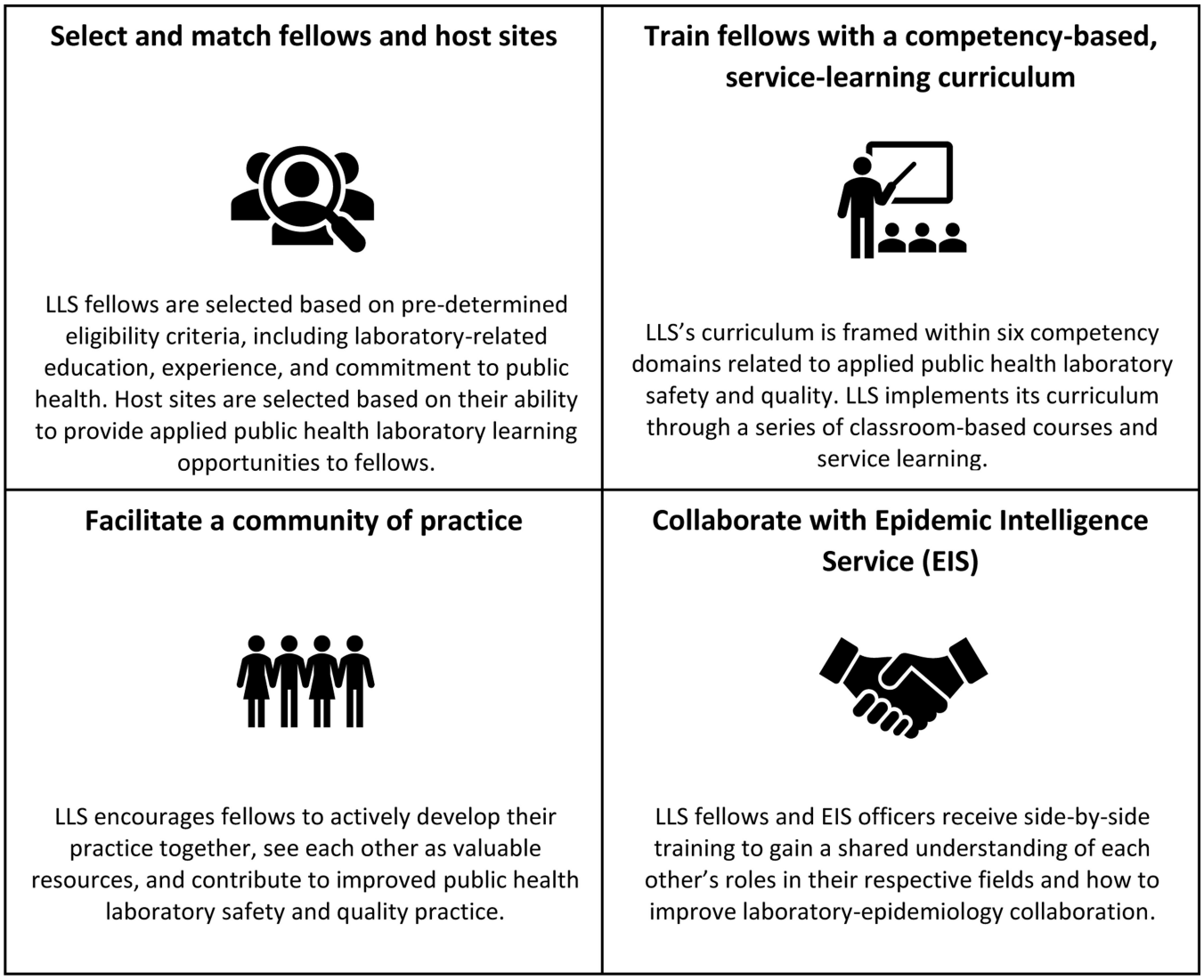
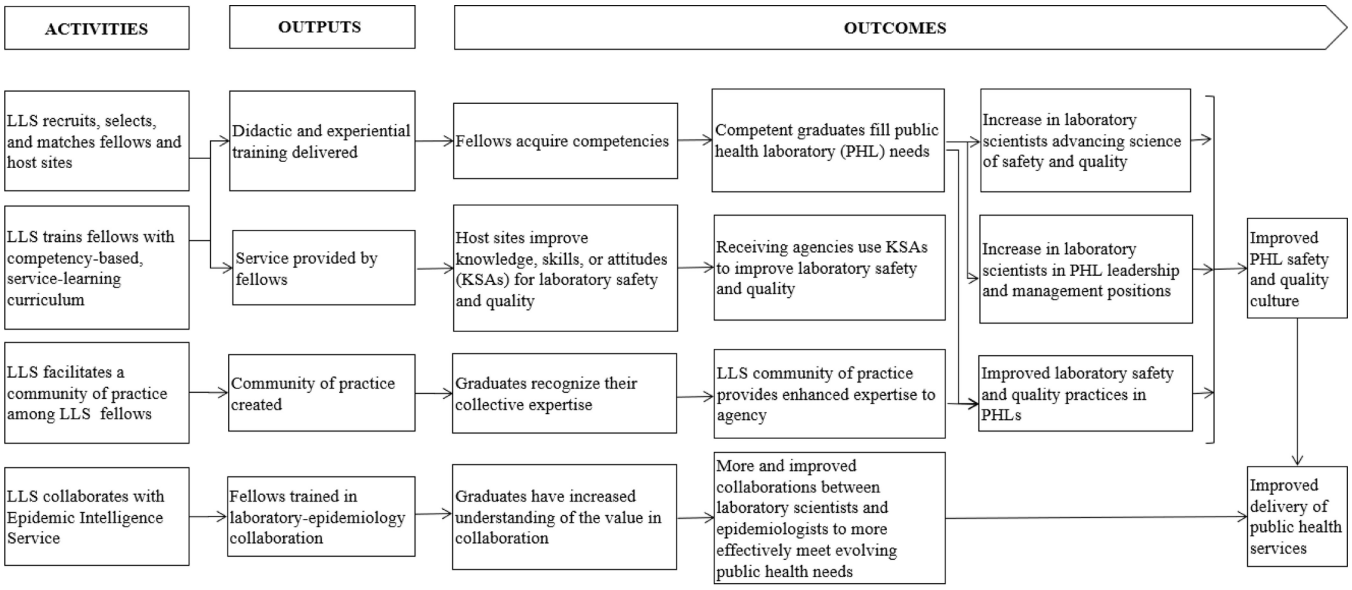


Figure 1.
Laboratory Leadership Service (LLS) Fellowship Program key activities



Context and assumptions: Public health and laboratory (lab) communities (e.g., labs/employers, students/potential fellows) recognize LLS as value-added. Jobs are available for graduates entering the workforce (i.e., the types of positions in career path exist and are hiring).

Figure 2.
Laboratory Leadership Service (LLS) Fellowship Program Simplified Logic Model

Table 1.

2019 Laboratory Leadership Service (LLS) program evaluation questions mapped to indicators and data sources.

Evaluation Question	Indicators	Data Source	Data Collection Method	Class data available	N0.	Response Rate
1. How have key program activities been implemented?	• Eligible fellow applications • Final class composition • Match quality • Training completion • Fellow & alumni perception of training • Cohort-based activities • Joint LLS-EIS * training	Fellow exit survey	Existing LLS database	2015–2017	21	95%
		Summer course survey	Existing LLS database	2015–2018	28	100%
		Fall course 1 survey	Existing LLS database	2015–2018	27	96%
		Fall course 2 survey	Existing LLS database	2016–2018 †	20	100% ‡
		Alumni survey	Online survey launched March 2019	2015–2016 §	14 //	100%
		Program records	Document review	n/a	n/a	n/a
2. To what degree have fellows' and alumni's knowledge, skills, attitudes, and behaviors changed?	• Competency acquisition • Perception of the value in collaboration with LLS peers and epidemiologists • Attitude toward collaboration with peers and epidemiologists post-LLS	Fellow exit surveys **	-	-	-	-
		Alumni survey **	-	-	-	-
3. To what degree do alumni's jobs post-fellowship match with LLS's expected career paths?	• Post-fellowship activities	Program records **	-		-	-
		Alumni survey **	-		-	-
4. To what degree have host sites' knowledge, skills, attitudes, and practice for laboratory safety and quality changed?	• Fellow contributions to the host site • Perceived value of hosting a fellow	Supervisor surveys	Existing LLS database	2015–2017	23	51%

* Epidemic Intelligence Service

† LLS implemented Fall course 2 starting with the Class of 2016.

‡ Denominator includes fellows that were participating in LLS at the time of the course. One fellow left the program after year one and is not included in the denominator.

§ Only graduates that had been alumni for at least one year participated in the survey. The survey sent before the 2017 class completed one-year post-graduation.

// The LLS alumnus who served as interim LLS Program Lead during this evaluation was excluded from the survey to reduce bias.

** Data collection method, class data available, N0, and response rate the same for Evaluation Question one.

Table 2.

Laboratory Leadership Service (LLS) selection outcomes and training completion rates by class.

	2015*	2016	2017	2018	2019	Total
Selection Outcomes						
Applications received	-	44	39	42	53	178
Eligible applicants†	-	29	31	31	47	138
Candidates interviewed	10	15	12	9	16	62
Candidates matched‡	7	8	7	6	8	36
Training Completion Rates						
Final Graduates§	7	8	6	n/a	n/a	21
Completed didactic training requirements	7	8	6	n/a	n/a	21
Completed experiential training requirements (CALs‖)	4	4	4	n/a	n/a	12
CAL completion (2016–2017 CAL / 2015 CAL)	**2015 (n = 7)**	**2016 (n = 8)**	**2017 (n = 6)**	-	-	**Total**
CAL1: Conduct applied laboratory research	7	8	6	-	-	21
CAL2: Conduct a safety risk assessment	7	8	6	-	-	21
CAL3: Evaluate a quality management system	7	8	6	-	-	21
CAL4: Incorporate bioinformatics principles	7	8	6	-	-	21
CAL5: Give a 10–20-minute presentation	7	8	6	-	-	21
CAL6: Give a 30-minute presentation	7	8	6	-	-	21
CAL7: First author a scientific manuscript	4	4	4	-	-	12
CAL8: Laboratory operations management / First author public health update	7	8	6	-	-	21
CAL9: Communicate to external lay audience / First author scientific abstract	7	8	6	-	-	21
CAL10: Provide service to the agency / Communicate to external lay audience	7	8	6	-	-	21
CAL11: n/a / Provide service to the agency	7	n/a	n/a	-	-	7**
Participated in a class project (not a requirement)	6	8	6			20

*The overall selection process for the 2015 class was different than other classes given a shortened recruitment and selection timeline.

†Number of complete applications meeting eligibility criteria

‡Number of fellows at the start of the fellowship

§Number of fellows that completed the fellowship

‖Core Activity of Learning. The CALs for the 2015 class are different because the CALs were revised to make improvements based on lessons learned from the first year (see Supplemental Digital Content Table S1).

**Denominator includes only the 2015 class

Table 3.

Laboratory Leadership Service (LLS) close-ended survey responses.

Question	Response options	Responses No.
Fellow Exit Survey (n = 21)		
How would you rate the value of the Summer Course? By value, we mean how the training activity increased your competence and skills in LLS competency domains	Valuable/Extremely Valuable Somewhat Valuable Not at all Valuable	20 1 0
How would you rate the value of the Fall Course? By value, we mean how the training activity increased your competence and skills in LLS competency domains	Valuable/Extremely Valuable Somewhat Valuable Not at all Valuable	18 2 1
I am satisfied with my overall LLS experience.	Agree Strongly Agree Disagree/Strongly Disagree	20 1
Overall, how valuable has it been to reach out to other LLS fellows?	Valuable/Extremely valuable Somewhat/Not at all valuable	20 1
After participating in a class project, I have a better understanding of other LLS fellows' expertise.	Agree/Strongly Agree Disagree/Strongly disagree	17 * 3 *
After participating in a class project, I gained added expertise as a result of collaborating with other Centers, Institutes and Offices outside of my host site. †	Agree/Strongly Agree Disagree/Strongly Disagree	18 * 2 *
Compared to when you entered LLS, how likely are you to seek out collaboration with an epidemiologist in the future?	More Likely Less Likely No Change	15 0 6
Because of my work with EISOs ‡, I have a better understanding of how to foster collaboration between laboratory professionals and epidemiologists.	Agree/Strongly Agree Disagree/Strongly Disagree	18 3
Summer Course Survey (n=28)		
What I learned in the course was valuable to my professional development	Agree/Strongly Agree Disagree/Strongly Disagree	28 0
Fall Course 1 Survey (n=27)		
What I learned in the course was valuable to my professional development.	Agree Strongly Agree Disagree/Strongly Disagree	26 1
Fall Course 2 Survey (n=20)		
What I learned in the course was valuable to my professional development.	Agree/Strongly Agree Disagree/Strongly Disagree	19 1
Supervisor Survey (n=23)		
I would recommend participation as an LLS host site to other public health laboratories.	Agree/Strongly Agree Disagree/Strongly Disagree	23 0
Your LLS Fellow supported the development of laboratory safety in the laboratory.	Agree/Strongly Agree Disagree/Strongly Disagree	23 0
Your LLS Fellow supported the development of laboratory quality in the laboratory.	Agree/Strongly Agree Disagree/Strongly Disagree	23 0
My team has gained knowledge or skills as a result of participating in the LLS Program.	Agree/Strongly Agree Disagree/Strongly Disagree	20 3
Hosting an LLSF changed the way I or my team members approach laboratory safety.	Agree/Strongly Agree Disagree/Strongly Disagree	16 7
Hosting an LLSF changed the way I or my team members approach laboratory quality.	Agree/Strongly Agree Disagree/Strongly Disagree	17 6
Hosting an LLSF changed the way I or my team members approach laboratory management.	Agree/Strongly Agree Disagree/Strongly Disagree	15 8
Alumni Survey (n=14)		

Question	Response options	Responses No.
How valuable has collaboration post-LLS graduation been with other LLS alumni?	Valuable/Extremely Valuable Somewhat/Not at all Valuable Not applicable Did not answer question	7 3 1 3
How valuable has collaboration post-LLS graduation been with epidemiologists?	Valuable/Extremely Valuable Somewhat/Not at all Valuable Not applicable Did not answer question	5 4 2 3
How do you expect your LLS experience to impact your overall career progression?	Negative impact No impact/Minimal positive impact Moderate positive impact Substantial positive impact	0 0 3 11
How relevant are leadership and management skills (competency domain I) to your current position?	Very much A little/Somewhat Not at all	11 3 0
How relevant are quality management systems skills (competency domain II) to your current position?	Very much A little/Somewhat Not at all	9 4 1
How relevant are laboratory safety skills (competency domain III) to your current position?	Very much A little/Somewhat Not at all	5 8 1
How relevant are applied laboratory research, investigation, and surveillance skills (competency domain IV) to your current position?	Very much A little/Somewhat Not at all Did not answer question	5 7 1 1
How relevant are informatics and bioinformatics skills (competency domain V) to your current position?	Very much A little/Somewhat Not at all	1 9 4
How relevant are communication (oral and written) skills (competency domain VI) to your current position?	Very much A little/Somewhat Not at all	12 2 0

*Denominator includes only those that participated in a class project (n=20).

†Question in the 2015 class survey: “I have increase competence and skills in LLS competency domains.

‡Epidemic Intelligence Service Officers

Table 4.

Laboratory Leadership Service (LLS) fellows (classes of 2015–2017) self-reported skill-level for each LLS competency aggregated by LLS competency domains before and after LLS, and the growth in the number of fellows that reported proficient- or expert-level skills before and after LLS per domain.

Classes of 2015–2017 (n = 21)											
Competency (C)*	Before LLS					After LLS					Growth in proficient or expert
	Beginner	Competent	Proficient	Expert	Row Total	Beginner	Competent	Proficient	Expert	Row Total	
C1	14	7	0	0	21	0	3	12	6	21	
C2	16	2	3	0	21	0	3	12	6	21	
C3	9	5	4	3	21	0	3	7	11	21	
Domain I.† Total	**39**	**14**	**7**	**3**	**63**	**0**	**9**	**31**	**23**	**63**	**70%**
C4	15	4	2	0	21	0	1	8	12	21	
Domain II.‡ Total	**15**	**4**	**2**	**0**	**21**	**0**	**1**	**8**	**12**	**21**	**86%**
C5	17	4	0	0	21	0	2	9	10	21	
C6	16	5	0	0	21	1	1	11	8	21	
C7	15	6	0	0	21	1	1	11	8	21	
Domain III.§ Total	**48**	**15**	**0**	**0**	**63**	**2**	**4**	**31**	**26**	**63**	**90%**
C8	8	7	5	1	21	1	1	11	8	21	
C9	4	6	8	3	21	2	0	7	12	21	
C10	7	5	6	3	21	1	2	9	9	21	
C11	14	7	0	0	21	1	5	10	5	21	
Domain IV.‖ Total	**33**	**25**	**19**	**7**	**84**	**5**	**8**	**37**	**34**	**84**	**54%**
C12	12	8	1	0	21	2	7	10	2	21	
C13	12	7	1	1	21	2	10	6	3	21	
Domain V. ** **Total**	**24**	**15**	**2**	**1**	**42**	**4**	**17**	**16**	**5**	**42**	**43%**
C14	10	9	1	1	21	0	3	10	8	21	
Domain VI.¶ Total	**10**	**9**	**1**	**1**	**21**	**0**	**3**	**10**	**8**	**21**	**76%**

* For a complete list of competencies see Glynn, M.K., Liu, X., Ned-Sykes, R., Dauphin, L.A., & Simone, P.M. (2020). Meeting an Urgent Public Health Workforce Need: Development of the CDC Laboratory Leadership Service Fellowship Program. *Health Security, 18*, 418–423.

† Leadership & Management Skills

‡ Quality Management Systems

§ Laboratory Safety

‖ Applied Laboratory Research, Investigation, and Surveillance

[**] Informatics & Bioinformatics

[¶] Communications