Guide For e-Construction & Partnering
Training the 21st Century e-Construction Workforce

On-Ramp to **Innovation** every day counts

eCP
e-Construction and Partnering

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Summary

Digital technology changes how contractors and inspectors perform their work. At the same time, the construction workforce is losing experience and skill as a large wave of workers retires. Agencies can train inspectors and transfer institutional knowledge with a mentor-led, blended-learning approach. Blended learning uses guided self-study through documents and digital media. Agencies can invest in digital content that serves as job aids and online, on-demand training. Formal mentors would guide training, evaluate inspectors' progress, and provide expertise through remote support.

Audience

The primary audience for this guide is construction managers in State transportation departments, construction methods development/automation engineers, and resident engineers. The secondary audience includes managers in consulting firms that provide construction engineering and inspection services, construction technology vendors, and training providers.

Purpose

In 2016, a U.S. Domestic Scan team examined how State agencies develop and maintain a skilled construction inspection workforce (1). This guide incorporates a selection of the scan recommendations, specifically:

- Create a framework for a mentoring program.
- Consider blending various modes of training delivery.
- Test how inspectors apply knowledge, rather than how they recall data.
- Use instructors who have field experience.
- Explore using manuals and agency publications as training materials.
- Use technology to develop and deliver training more efficiently and effectively.
- Collaborate with industry to share resources.
- Take advantage of national training resources.
- Assign qualified staff to manage inspector training programs.

Justification

State construction departments have long faced issues with an aging workforce and struggles with retention and recruitment. A 2003 synthesis highlighted the aging workforce, the compensation gap between public and private sectors, and morale issues (2). Other issues from more than 15 years ago—a reduced pipeline of future hires, low unemployment rates, and an aging workforce—continue today.

Long-term efforts are underway to update the image of construction careers and to build a pipeline of future construction workers (3), but in the short term, agencies should look to better utilize their current staff, focus on retention and knowledge transfer, and take a broader view of their workforce.

As agencies increasingly rely on consultant inspection staff (4), they lose direct control of preparing a large segment of inspectors. Agencies can mitigate this challenge by supporting the construction workforce as a whole. This guide creates a framework for agencies to deploy their limited, highly skilled staff, placing more emphasis on providing support and mentoring and less emphasis on self-performing inspection services.

Digital technologies create an opportunity to mitigate the workforce challenges. State agencies can learn from the short-term strategies private organizations have used to overcome them. For example, contractors are taking advantage of mobile devices in the field to deliver and manage safety training with apps. Contractors have begun

to deploy technologies like small unmanned aerial systems, wearable devices, and augmented reality to improve workforce management, productivity, and safety (5). Viewing technology through this lens can help agencies screen and prioritize technologies to adopt as part of their e-Construction solution.

Approach

New high school and college graduates bring technology skills and aptitudes as so-called "digital natives." Blended learning, which combines text-based self-study with online curricula and self-assessment, is standard in modern school and college classrooms (6). With accessible blended learning content, mentors can guide new inspectors through just-in-time independent study. A mentor can also evaluate an inspector's competency through in-training assessment and serve as a resource for problem-solving on the jobsite.

Agencies can invest in documenting procedures into searchable, accessible job aids delivered through channels that inspectors can access on demand from the jobsite. With further investments in documentation, agencies can provide clear guidance for inexperienced inspectors to follow. Examples include inspection priorities and creating project-specific checklists that tie inspection priorities to project risks. These job aids also lay the foundation for implementing consistent and risk-based inspection practices.

Agencies can uncouple their training investments from individuals, who may leave the agency, and instead invest in training that serves a wide audience through online, on-demand channels. Agencies can control the inspector development curriculum by making the training available to a growing league of consultant inspectors. They can procure e-learning content from vendors to use economies of scale. Consistent processes enable agencies to allocate staffing resources more

dynamically to respond to fluctuations in resource needs across projects and the construction season.

Agencies can invest in building centralized resources to augment on-site resources, such as centralized staff who handle low-risk, routine documentation for multiple sites using real-time and recorded footage from remote camera feeds. This role is entry level and a gateway to inspection for office-based staff. Agencies can also utilize experts to support multiple sites remotely in a live, on-demand manner using video conferencing and provide oversight by monitoring remote cameras and intervening to provide support, training, and mentoring. This role extends the technical career path options while providing flexible, safe working conditions and satisfying, high-impact work.

Introduction

Historically, agencies used in-house trainers and maintained their own curricula. Agencies report having sufficient access to training materials. However, some States have noted they do not have enough experienced instructors. Some have used consultant inspectors to deliver training, while one is exploring using retirees as mentors. Many agencies now use online training materials. Some are developing their own, while others are using external training vendors (1).

Agencies have invested in placing manuals, specifications, and job aids online (1). Inspectors use eConstruction technology to access job aids from the jobsite. Blended learning uses guided self-study through documents and digital media. States could use these job aids and online training resources in a blended learning program by providing a formal mentor to guide inspectors. The mentor could also provide remote support and monitor inspectors' progress acquiring competencies.

Some States make their training available to consultant inspectors (1). Other States work with their consultant and contractor partners to develop inspector training (7). These approaches yield consistent inspection and documentation procedures and allow for cost sharing.

This guide provides a framework for a mentor-guided, blended-learning training program. This framework is accessible to the digital native generation, is appropriate for adult learners, and accommodates just-in-time delivery. Through mentoring, institutional knowledge flows from experienced to new inspectors. The mentor relationship also mitigates risks associated with inexperienced inspectors. The mentor can evaluate an instructor's performance and guide him or her toward e-learning and job aids to prepare for upcoming inspection activities.

Components of a Successful Training Program

There are four main components of a successful inspector training program. It should be feasible, reliable, aligned to other agency objectives, and consistent with effective adult learning approaches. The feasibility of the program includes cost, resourcing, and technical workability, as well as the agency's ability to deliver the program in a safe manner. Safety is especially important when taking into consideration how the inspector will engage with technology on the jobsite, whether to access support from the mentor, use job aids, or view short instructional videos (also called micro-learnings).

For the training program to be reliable, it should satisfy the conditions of completeness, efficacy, and validity in its assessments. The content available should serve the full range of inspector training requirements. The materials should be prepared in a way that delivers the intended learning outcomes effectively. Many States already have access to libraries of complete and effective learning materials but are interested in improving how inspectors' competencies are assessed (1).

The training program should be implemented in a manner that supports other related agency objectives. These may include increasing digital delivery process improvements, fostering a more diverse workforce, improving staff retention, capturing and transferring institutional knowledge, adopting risk-based inspection, and so on. These parallel objectives should be identified so they can be considered when determining how to fund or justify changes to the inspector training program.

Finally, the training program should be consistent with the hallmarks of effective adult learning delivery identified in Figure 1. Adult learners are more successful when the learning can be self-directed with a clear, beneficial outcome for the learner—such as progress toward goals on a clearly defined career path. The training materials should also be relevant to the learner's job and task-oriented.

Self-Directed   Relevant   Task-Oriented   Clear Benefit

Figure 1: *Hallmarks of successful adult learning.*

Framework for Blended Learning

Figure 2 identifies the four components of a blended learning framework for inspector training. The first component is a mentor. Through blended learning, the mentor's role shifts from imparting knowledge to curating engaging learning experiences for the trainees. The second component is the documentation that provides text-based technical content and job aids. The third component is the technology through which trainees access learning materials and communicate with the mentor. The fourth component is the e-learning material for just-in-time training and micro-learning delivery.

| Mentor | Documentation | Technology | e-Learning |
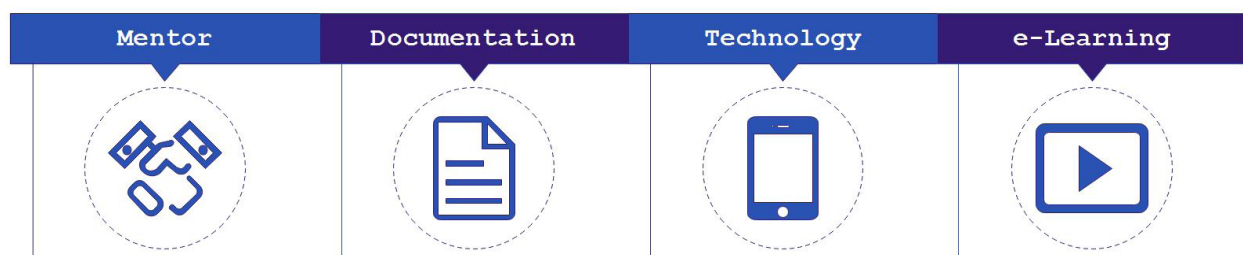
Figure 2: *Four components of a blended learning framework.*

Mentor

Workforce issues are such that agencies should balance the need for new inspectors to be active on the jobsite with the risks arising from their potential competency gaps. Formal mentoring is a way to manage the risks proactively while facilitating training through blended learning and signing off on the competencies as the inspector demonstrates them. The roles of the mentor include the following:

- Guide the inspector to plan the week ahead (e.g., checklists, documentation).
- Guide the inspector through just-in-time e-learning.
- Review work to verify competency acquisition.
- Support the inspector's ability to solve problems on the jobsite.

Documentation

Job aids, such as inspection checklists and quality assurance-critical requirements, form the foundation of risk-based inspection protocols (8). They are also effective tools for guiding inspectors through a consistent approach to executing daily and weekly tasks. When the job aids can be hyperlinked to electronic documents, such as the specification, construction manual, or e-learning and micro-learning resources, they provide a form of just-in-time self-study. Key elements include the following:

- Searchable electronic documents tailored to the project.
- Easy-to-use user interface.
- Clear prioritization and risk designations.
- Protocols to escalate urgent, high-impact issues.

Technology

Blended learning requires technology to access the learning materials and communicate with the mentor. Technology also affords an opportunity to use in-training evaluation. An assessor can remotely observe inspectors at work to evaluate their core competencies. Body-worn cameras provide an opportunity to record walk-through materials that can be used for assessment or training later. The minimally sufficient technology resources for blended learning include the following:

- Mobile devices with photo and video recording.
- Internet connection.
- Document viewing app with search function.
- e-Learning viewing app with search function.

e-Learning

e-Learning refers to delivering training electronically. Usually, e-learning materials deliver training using a combination of electronic media, such as videos, documents, audio files, and online tests. Using elearning, inspectors can access training anywhere they have the necessary technology. e-Learning materials span short micro-learning resources to in-depth, asynchronous courses. New inspectors benefit from e-learning resources with the following characteristics:

- Clearly defined core competencies aligned to career development.
- Online, on-demand training materials that can be completed asynchronously.
- Content ranging from short micro-learning to robust Web-based training.
- Easy access to approved content for short how-to and procedure guides.

Implementation

The blended-learning training framework employs a combination of regularly scheduled mentoring meetings and e-learning, accesses job aids and micro-learning via technology, and relies on mentors for ad hoc support. Agencies have limited training resources and need strategies that yield the highest impact for each man-hour and dollar spent. The following sections identify strategies agencies can consider to leverage economies of scale, focus their resources on content that is unique to them, and formalize the channels that have historically passed institutional knowledge from one generation to the next.

Formalize Mentoring

Many agencies already provide informal or opt-in mentoring programs. These usually involve pairing new and experienced inspectors on a jobsite (1). However, mobile devices create an opportunity to implement the mentoring relationship virtually, rather than relying on co-location. In a virtual mentoring relationship, the mentor could be physically located anywhere, which creates an opportunity to extend the workforce. The Virginia Department of Transportation (DOT) is experimenting with using retired construction staff as mentors to foster the transfer of institutional knowledge (1). The formal mentor serves four roles, as shown in Figure 3. The following sections describe these roles.

Routine Meetings   Progress Reviews   Competency Evaluations   On-call Support

Figure 3: *Four roles of a formal mentor.*

Routine Meetings

An inspector would check in with the mentor daily, weekly, or monthly, depending on individual needs. Routine meetings, conducted over the phone or with screen sharing, should last for 30–60 minutes. For the less experienced inspectors, the mentor would use these sessions to do the following:

- Discuss the inspector's recent activities and provide guidance on any outstanding issues.
- Discuss the inspector's upcoming tasks and recommend job aids and e-learning content.
- Provide ongoing feedback to reinforce the inspector's on-the-job training and e-learning.

Progress Reviews

Progress review meetings track the mentee's core competency development toward career progression goals. The mentee will acquire skills asynchronously, with seasonal fluctuations between on-the-job training and e-learning. Quarterly progress reviews allow for sufficient progress between meetings without losing track of competencies acquired early in the review period. The mentor can use progress reviews as an opportunity to guide the mentee in e-learning content areas to ensure he or she is advancing toward the next career level.

The American Association of State Highway and Transportation Officials (AASHTO) publishes a detailed list of inspection competencies and levels on its **website**. Table 1 contains an excerpt of the contract administration competencies. The four skill levels AASHTO uses are defined by the level of supervision required (9). The following are simplified definitions:

- Level I: Entry level; performs work under direct supervision.
- Level II: Performs specific tasks under general supervision.
- Level III: Advanced; performs broad-based tasks with little to no daily supervision.
- Level IV: Manager or supervisor; oversees or manages day-to-day activities.

The mentee should prepare for the progress review with a self-assessment. He or she can then submit evidence for evaluation to gain credit for acquiring new competencies. The mentor should do the evaluation separately to this meeting. The mentor's current role is to identify competency gaps and guide the mentee in e-learning, job aids, and other opportunities for acquiring the competencies needed for current work assignments and ongoing career development.

Discipline	Skill Level I Competencies	Skill Level II Competencies	Skill Level III Competencies	Skill Level IV Competencies
Project Daily Documentation	Provides information regarding daily activities	Documents daily activities	Documents daily activities	Reviews documents for accuracy and non-bias and incorporates into permanent records
Office Procedures	Follows office filing procedures for project	Follows office filing procedures for project	Prepares project-relevant reports and correspondence	Prepares project-relevant reports and correspondence
Scheduling	Follows project schedule in the execution of assigned work activities	Interprets project schedule	Monitors project schedule and ensures compliance	Reviews contractor schedule modifications and makes recommendation for corrective action

Source: AASHTO

Table 1: *selection of contract administration competencies from the AASHTO Construction Skill Level Matrix (9).*

Competency Evaluations

Evaluation is a critical part of the learning process that provides validity to the program. Assessing the inspector's knowledge retention is less important with e-Construction, where the inspector has access to searchable job aids. Rather, it is important to assess the inspector's performance. Judgment and problem-solving skills are best assessed in a real-world scenario.

Mentors will need training in how to perform competency evaluations. They can use a range of assessment strategies to evaluate the inspectors' competency levels. Examples include the following:

- Reviewing a portfolio of completed work examples that the inspector submits.
- Remotely monitoring the inspector executing a task through phone or video chat.
- Reviewing videos of the inspector executing a task.
- Reviewing the inspector's performance in a constructed scenario or simulated walk-through.

A valid evaluation is repeatable and verifiable. The mentor should document how the competency was evaluated and when. Documentation should be timely, and it should focus on what the inspector did in a real-life scenario, rather than the mentor's overall impression of the inspector's knowledge. This ensures the evaluation is defensible and justifiable.

Learning Management System

A Learning Management System (LMS) is an online software tool that administers, delivers, and tracks electronic training. LMSs are usually commercial products. Many manage e-learning content that spans micro-learning, job aids, competency matrices, and Web-based training. The purpose is to streamline the e-learning process and competency tracking. With an elearning mobile app, inspectors could access an LMS from the field.

An LMS is an important component of an e-learning solution. It provides a way for inspectors and mentors to collaboratively manage learning and track progress. A mentor could use an LMS to monitor an inspector's progress and assign training. An inspector could use an LMS to access transcripts, locate training materials, and complete courses.

The LMS should track the e-learning that inspectors complete and provide completion certificates. Ideally, the LMS should also provide a way to track competencies that a mentor evaluated, rather than automatically assigning competencies after completion of content. The LMS is also a tool the agency can use to assess how the training program is performing through program-wide analytics.

On-Call Support

Agencies can no longer depend on having experienced staff on every jobsite. However, through technology, mentors can bring their advanced skills to the jobsite by remotely assisting inspectors when needed. Inspectors need training in how and when to access experts. Mobile devices and network-connected project offices enable agencies to utilize their experts more efficiently through activities such as video conferencing, monitoring remote inspection video camera streams, and reviewing video footage collected using small unmanned aerial systems (sUAS). The mentor can guide the inspector or merely listen in and intervene only if necessary, evaluating the inspector's performance and providing feedback after the task is complete.

Not all support needs to be delivered in real time. Table 2 is an example troubleshooting protocol that guides the inspector toward the correct strategy based on the urgency and potential impact of the issue.

Urgency	Critical Impact	Major Impact	Minor Impact
Immediate	Escalate	Escalate	Real-Time Support
Next Hour	Escalate	Real-Time Support	Real-Time Support
Same Day	Real-Time Support	Support Ticket	Support Ticket
Next Day	Support Ticket	Support Ticket	Support Ticket
This Week	N/A	Support Ticket	Job Aids
This Month	N/A	Job Aids	Job Aids
This Year	N/A	N/A	Job Aids
Project Close	N/A	N/A	Job Aids

Table 2: *Example troubleshooting protocol based on the urgency and impact of the issue.*

Curate Accessible Documentation

New and inexperienced inspectors deploy to the field with large knowledge gaps. Inspectors can fill many gaps using just-in-time, workflow-based self-study if they are able to access job aids that provide clear guidance in a user-friendly, task-oriented format. Agencies could invest in making information readily available—loaded in searchable files on mobile devices—and train the inspection workforce on when and how to access the information from the jobsite safely. In addition to manuals and specifications, inexperienced inspectors need job aids such as checklists and step-by-step guides.

Many States use a combination of in-house and vendor-developed learning and e-learning resources (1). The AASHTO Transportation Curriculum Coordination Council (TC3) is a technical service program that makes resources available for the development of training products for highway construction and maintenance professionals. TC3 is a resource that States use to avoid redundancy and increase the accessibility of training materials. Forty-three States supported TC3 in 2018 (10).

The Florida DOT has created a far more detailed collection of inspection procedures and quality assurance-critical requirements that follow the specification organization. As part of its risk-based inspection strategy, these master lists are reduced to project-specific checklists (8).

Agencies might find it helpful to hyperlink documents to the specification and to job aids or micro-learning resources, such as images or short videos illustrating what the inspector should look for. Creating seamless connections saves time and helps the agency control which resources the inspector uses as guidance.

Chapter 1. INTRODUCTION

Scope and Objective

Construction sites can be a source of sediment and other pollutants to waterways. Best management practices (BMPs) are devices and activities that reduce or eliminate pollution sources and can include silt fences, settling basins, and even training.

This guide is a quick reference for inspectors and resident engineers in construction on topics related to installation, maintenance, and inspection of common BMPs. Using this guide helps departments of transportation (DOTs) stay in compliance with federal, state, and local regulations for improving stormwater quality and provides guidance where local publications may currently be lacking.

Source: AASHTO

Fig. 1-1. Proper management of construction sites through the use of BMPs can dramatically reduce stormwater impacts. Source: *RBF Consulting*

Preface to Readers

This publication includes discussion of BMPs, organized by their use. Categorization of BMPs may vary from state to state; however the basic recommendations for field implementation remain consistent. The information

Figure 4. *AASHTO's Construction Stormwater Field Guide is a job aid available on the AASHTO TC3 website.*

Figure 5: *Simulators provide real-life scenarios to assess judgment and job performance.*

Supply Technology

The minimal technology required to implement blended learning is the basic e-Construction toolset: a mobile device and an Internet connection. However, there are other supportive technologies. Remote camera feeds that allow the mentor to observe the inspector, such as a high mast, sUAS, dashboard, or body-worn camera, allow the mentor to provide better support or competency evaluation. These remote cameras can also record walk-throughs that can be used to provide feedback to the inspector or to create micro-learning resources such as walk-through simulations.

Simulators are used effectively in training for a variety of professions. Figure 5 shows a simulator used for bus driver training. When the trainee completes a simulated drive, he or she reviews the recording with the mentor. Rather than testing an inspector's retained knowledge, walk-throughs and simulators train and assess his or her judgment and actions in a real-life scenario. This meets the relevance and task-orientation criteria of effective adult learning.

A late-2018 review of technology that large contractors expect to deploy in the next 3 years identified wearable technology (17 percent), sUAS (60 percent), and augmented and/or virtual reality (40 percent). The top benefits noted that led to exploring these advanced technologies were increased labor productivity, better budget and schedule management, and jobsite safety (5). Agencies could explore how to partner with contractors to use data from these technologies or to evaluate how they can aid inspection. In the past, workers had to retain domain knowledge in their heads. Tomorrow's technologies could connect workers to information and experts through mobile and wearable technology such as smart helmets. These augmented reality devices are especially promising for providing on-the-job training (11).

Deploy Online, On-Demand Training

High-quality training materials form the backbone of an effective blended learning program. Agencies can rebalance their training delivery to blended learning by making investments in on-demand training and just-in-time access to micro-learning tutorials. These channels can serve a wide audience that accesses content using a mobile device. Teaching inspectors how to access information safely and when to call on expert support are important prerequisites for using just-in-time e-learning.

Some agencies, including the Texas and Florida DOTs, use external training vendors and make the content available to their consultant partners (1). Agencies can deliver content from different sources through an LMS and an app. Agencies should consider how consulting firms can access the training resources, so that consultant inspectors are trained using the same content as agency employees. The digital native generation engages well with a broad range of online digital content. By providing streamlined access to e-learning resources, agencies can help channel their employees and consultants to the preferred content.

Manage Performance

Program effectiveness should be measurable using the AASHTO performance management framework (12), which includes the following steps:

1. Select performance measures.
2. Track and report results.
3. Identify key performance factors.
4. Allocate resources.
5. Monitor and report progress.

Performance measures should be aligned to agency goals, especially those for managing institutional knowledge assets. Where possible, the LMS should automate tracking performance indicators, such as learning hours and competency level growth.

When selecting performance indicators for the training program, it is important to ensure they are balanced and reinforce the right outcomes. For example, tracking e-learning hours does not measure how well the e-learning leads to increased competency on the jobsite, but it is a good measure of the solution's utilization. Competency should be evaluated independent of the e-learning platform to determine how well the training is translating to performance on the jobsite. Example performance indicators include the following:

- Total learning hours completed and cost per completed learning hour.
- Total mentor contact hours and mentor contact hours per mentee.
- Aggregate competency growth and cost per competency acquired.
- Number of inspectors advancing to the next career level.

Effective training programs and training programs linked to career advancement are attractive employee benefits. It would be helpful to include feedback on the training program in routine staff surveys and to compare staff recruitment and retention rates before and after any significant changes in the inspector training program.

Scalability

The proposed formally mentored, blended-learning training program has aspects that are scalable. Standardizing inspection protocols through well-designed digital content and highly accessible elearning makes it easier for inspectors to move between jobsites. Agencies can be more dynamic in their resource allocation, moving inspectors from job to job as workload demands. Just as contractors move a saw-cutting team from project to project, agencies can move their highly skilled inspectors to meet needs for scarce skillsets.

Extending the Workforce

As agencies are challenged by how to best utilize their declining pool of experts, the use of remote support enables them to take the higher-skill aspects of tasks (such as decision-making) off-site. This gives agencies the flexibility to take highly skilled staff off the jobsite and utilize them as a centralized resource, supporting multiple geographically dispersed sites without losing travel time. It also enables agencies to retain staff on the cusp of retiring, or to attract retirees back to the agency part time, through satisfying work performed in a more comfortable, safe, and flexible work environment.

In the past, inspectors monitored the contractor's equipment on-site on a daily basis, keeping paper records. Today, on-site inspectors typically keep digital records using a mobile device, increasingly in a construction management information system (CMIS). In the future, an office-based inspector may monitor 10 sites via remote camera feeds, entering the records digitally into the same CMIS. On-site inspectors could also collect information during construction and defer the analysis and data extraction of low-risk or low-priority information to the off season or low season. Reducing the burden on on-site inspectors enables them to spend their time on higher-risk or higher-priority activities, while taking tasks from the site into the office reduces the need for some types of safety training.

Conclusions

Inspectors should adapt to a constantly changing landscape arising from the digital transformation of construction work. At the same time, the construction workforce continues to suffer attrition through retirement and lacks an adequate pipeline of skilled workers to fill anticipated vacancies. While these two forces are different, the result is that agencies have fewer resources and a growing training burden. Mentor-guided blended learning is a feasible solution.

A mentor-guided, blended-learning inspector training program has four areas of investment:

1. Centralized staff resources assigned to a formalized mentor program.
2. Documentation such as job aids and manuals that inspectors access electronically.
3. Mobile technology to enable access to online resources and to communicate with a mentor.
4. Online micro-learning and e-learning resources, preferably in an LMS.

Many States are already pursuing individual elements of this framework. Agencies can increase the value of these investments by implementing mentor-guided blended learning. Formalizing the mentor role to guide inspectors through blended learning has the following benefits:

- Recent high school and college graduates are familiar with blended learning.
- Formal mentoring fosters institutional knowledge transfer.
- Agencies may extend the careers of imminent or recent retirees through mentoring.
- Mentors can assess inspectors' skills and judgment and recommend training to fill gaps.
- Mentoring is extendable to providing remote expertise to the jobsite.

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- e-Construction
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- Construction Technology
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- Workforce Development

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