A) SIGNIFICANCE / RATIONALE

A.1 Introduction. Among mandated reporters, early childhood professionals (ECPs, aka early childhood educators, daycare providers, pre-school teachers, childcare providers, etc.) are particularly well suited to protect the most vulnerable children from child abuse (used herein to denote physical, sexual, and emotional abuse, as well as neglect). Because ECPs often may be the only people outside of immediate family to spend extended periods of time with young children, they are strategically positioned to help prevent patterns of abuse from taking hold. Despite this (and the fact that >313,000 confirmed victims are ≤5 years-old), fewer than 1% of substantiated cases of child abuse are identified and reported by ECPs. Further, because ECPs are not adequately prepared to identify at-risk children, their reports of suspected abuse are less likely to be substantiated than most mandated reporters. Unfortunately, early childhood education is beset with many barriers to creating effective, scalable interventions to help ECPs better identify and report suspected child abuse. The parent iLookOut for Child Abuse (iLookOut) study was funded in part for its promise to create such an intervention – and one that can be readily adapted for any U.S. state. That said, an intervention is only as good as its lasting effect. This renewal proposal is to develop and systematically evaluate an interactive, gamified micro-learning intervention to promote retention and implementation of learning – which would be the first of its kind for either child protection or early childhood education.

Built into the study design of the parent iLookOut grant was a plan to deliver basic, follow-up messaging to maintain awareness and promote knowledge retention among ECPs who had completed iLookOut’s core learning program. But while “spaced repetition and retrieval” of content is known to enhance cognitive mapping of new information and increase learning retention (including with low education populations), relatively little is known about how to optimize this process, or to do so in a way that is sustainable.

Due to various opportune circumstances, the iLookOut research team has been able to develop a highly innovative mobile technology-based intervention, designed to promote knowledge retention and help ECPs apply this knowledge to better protect children from abuse. Specifically, the iLookOut team has created interactive educational games, applied learning exercises, instructional videos, and other forms of interactive messaging – collectively called micro-learning – along with a cognitive sequencing map to ensure that this micro-learning is fully integrated with the content and objectives of iLookOut’s core learning program. The framework for micro-learning not only potentiates the impact of the parent study, it also offers an opportunity to systematically examine a potentially powerful approach to enhancing and sustaining learning using an active learning methodology. Moreover, micro-learning is imminently scalable because it can be readily adapted to any state, and only requires that learners have a smartphone or computer, and spend 5-10 minutes a couple of times per week in return for free professional development credit.

This opportunity arises in part because the iLookOut core learning program currently being used in the parent study (in Maine) is soon to be deployed in Pennsylvania, where a beta-version of iLookOut (with no micro-learning) had been previously deployed. Given the beta-version’s strong acceptance (>12,000 users to date), and demonstrated efficacy improving knowledge and attitudes, we have reason to believe the new version will experience similar uptake – particularly since in Pennsylvania mandated reporter training must be recompleted every 4 years, and the ECP workforce experiences annual attrition of 20-25%. As such, we are positioned to enroll a largely intervention-naive cohort of ECPs (see section C.1) with whom we can evaluate knowledge decay prior to micro-learning, boosts due to micro-learning, and knowledge retention after micro-learning (see Fig. 1). Like the parent study, this study will use a stepped-wedge design (see C.1) whereby ECPs are randomly assigned to receive micro-learning immediately following the core iLookOut learning program, vs after a delay of 3, 6, or 12 months. This design will allow us to systematically measure decays in knowledge over time, as well as evaluate whether a multi-faceted implementation strategy involving micro-learning can improve knowledge retention. Because implementation strategy is crucial for sustained success, we will evaluate whether ECPs consider micro-learning to be feasible, as well as measure their satisfaction with the multi-faceted approach involving iLookOut’s core and micro-learning interventions. This renewal leverages the existing infrastructure and materials of the parent study to both further its success and move towards establishing an evidence-based, integrated micro-learning program that has strong scientific grounding (see B.4), that learners find engaging, and that is readily scalable.

A.2 Progress Update. The aims of the parent study are to evaluate whether the iLookOut learning program: 1) gives rise to reports from ECPs that are more likely to be...
“high yield” (ie, result in findings of child abuse, and/or social services being recommended for the child/family); and 2) results in a lower proportion of state costs being expended for “low yield” reports (ie, reports that did not identify child abuse, nor result in social services being recommended). In the 3.5 years since receiving the grant (9/27/16 – 3/4/20), we have been highly productive. Accomplishments include having: 1) substantially revised the interactive storyline of the iLookOut learning program (including filming, editing, post-production, creating interactive learning modules and handouts);11 2) formally validated instruments; 3) developed and deployed a randomization scheme and recruitment strategy; 4) partnered with Maine state government to have key study data collected by all Intake staff and entered into (specially programmed) Child Welfare Information System data fields; 5) secured 3 hours of professional development credit for ECPs in Maine who complete iLookOut; 6) updated iLookOut’s online platform for core training; 7) secured small-grant funding to pilot micro-learning activities to reinforce learning about child abuse and its reporting; 8) successfully applied for supplemental funding to build our own micro-learning platform; 9) designed, built, and deployed a customized micro-learning platform that gathers research-quality data; 10) developed/deployed a smart-phone App; 11) partnered with the National Workforce Registry Alliance to develop a digital badges strategy for micro-learning (see C.4); 12) created a Cognitive Sequencing Map (see B.3) to catalogue and relate learning objectives with all elements of the iLookOut core program and follow-up micro-learning; 13) registered with ClinicalTrials.gov; 14) enrolled 1,167 ECPs into the study; 15) written 7 manuscripts – 2 published, 3 under review, and 2 in progress; and 16) given platform presentations about the parent study at 3 national conferences (Pediatric Academic Societies, National Association for the Education of Young Children, and National Workforce Registry Alliance).

A.2.1 Preliminary Data. An initial randomized controlled trial (RCT) in Pennsylvania (n=741)17 established (with validated measures) that iLookOut’s core learning program significantly increased knowledge and improved attitudes; and a subsequent real-world trial (n=11,065)13 yielded virtually identical results. In the ongoing parent RCT in Maine (n=1,167), the updated iLookOut core program significantly (p<.001) outperformed Standard mandated reporter training both at improving KNOWLEDGE (effect size=1.42 vs 0.82) and changing ATTITUDES (effect size=0.85 vs 0.62); and ECPs rated iLookOut significantly higher (p<.001) on all 6 evaluation items – with a mean overall SATISFACTION score of 8.75 (SD=1.56, where 10=highest). Additionally, preliminary data from the parent study suggest that, compared to reports from ECPs who completed Standard mandated reporter training, i) reports from ECPs who completed iLookOut’s core learning program are more likely to be “screened-in” by child protection services (70.7% vs 50.0%, p<.01), and ii) these screened-in reports are more likely (42.3% vs 33.8%, p=.02) to be “high yield” – meaning that child abuse is identified and/or social services are recommended to the child/family who was reported.

Due to problems with a former vendor, we have no reliable data on MICRO-LEARNING prior to April 2019. However, since launching our own micro-learning platform, the majority of ECPs who complete iLookOut’s core program have gone on to engage in micro-learning. Because ECPs in Maine were given the option to complete micro-learning over a 2, 4, or 6 month time-frame, attrition rates are not yet known. But 40% (137/345) have completed the full 3 hours of micro-learning, and another 16% (56/345) have already completed at least 1 hour.

Preliminary data on KNOWLEDGE DECAY are limited. In the RCT of iLookOut’s beta-version, knowledge gains decayed by ~50% 4 months post-intervention – but did remain significantly higher than baseline.17 No re-test data are available for the real-world trial (due to its open enrollment format); and for the ongoing RCT in Maine, repeat knowledge testing only occurred with ECPs who completed the core iLookOut learning program but then had to wait ≥4 months (due to a hiatus as we built our own micro-learning platform) before starting micro-learning. For these ECPs (n=133), re-testing showed a mean decay in their initial knowledge gain of 52%.

A.3 Accounting for Forgetting. The forgetting curve quantified in 1885 by Ebbinghaus, and reconfirmed in recent studies,18 shows how new information is lost over time unless efforts are made to retain it (Fig. 2). Recently learned information is mostly lost within a few days to weeks,19 and spaced retrieval is known to be vital for sustained advances in learning.20 This means it is important to find ways to reinforce learning, especially for topics people may not be naturally drawn to revisit.21

The iLookOut learning program, itself, does this by combining an engaging video-based storyline with interactive learning exercises. ECPs learn about events that occur over 2 days in the work-life of an ECP named Megan as she
recounts them to Elisha, a mentor whose guidance she is seeking. At different junctures, the learner is provided resources (eg, Facts about Abuse, Red Flags handout, etc.), posed didactic questions, and given opportunities to both apply new information and practice decision-making. Such immersion into real-life scenarios helps ECPs absorb and operationalize information, as well as begin developing skills to protect children from harm. But that is not enough. For learning not to fade, it must be reinforced, ...and reinforced again.

### A.4 The Road to Micro-Learning

From its inception, the parent study planned to use mobile technology to send follow-up messages (tips, best-practice guidelines, and cases for reflection) to reinforce learning after iLookOut completion. However, opportunities emerged to enhance the follow-up messaging with educational games, applied learning exercises, and other interactive activities. We initially partnered with mLevel (a leader in the field of micro-learning), hoping to later develop advanced, gamified learning activities, along with sophisticated back-end analytics, detailed real-time assessment, and subgroup analysis on all user responses.

Through our partner, Maine Roads to Quality (which provides professional development education to ECPs in Maine), we also began collaborating with Erin Knight who founded The Badge Alliance (an open badging ecosystem with >1,000 organizations),22,23 and the National Workforce Registry Alliance, which represents organizations that provide continuing education to ECPs, and is interested in starting a nationwide “badging” initiative to track professional development credit for ECPs.24 As attested in their letters of support, these entities saw great value in developing micro-learning to promote knowledge retention. The integrated strengths of these collaborators, combined with existing study team expertise—in gamification (Kapp), decision-making (Hamm), early childhood education (Fiene), educational psychology (Panllio), child abuse and child mental health (Humphreys), and online learning for ECPs (Mincemoyer)—generated enormous potential to expand iLookOut to include micro-learning.

After obtaining a small grant, we developed an iLookOut App (iPhone & Android), and began creating micro-learning activities with mLevel. However, their platform soon proved inadequate—lacking the analytics needed to answer research questions, the responsive design functionality that enables micro-learning to work well on smart-phones, as well as the flexibility to easily tailor learning activities for iLookOut’s subject matter. We then obtained supplemental funding (3R01-HD088448-04S1) to develop our own micro-learning platform with the Center for Applied Information Technologies (CAIT), which had programmed (and continues to host) iLookOut’s core learning program. The supplemental funding allowed us to build the necessary learning platform infrastructure and 3-hours of basic micro-learning activities (which are being sent out to ECPs in the parent study—see A.2.1), but not enhanced gamification, tailoring of activities, nor an interactive dashboard (for professional development tracking and digital badging). As such, we are now poised to finish developing fully tailored, gamified micro-learning activities, and to systematically evaluate their impact on learning.

The present grant proposal capitalizes on the potential of mobile apps and smart-phone technology to promote knowledge retention through spaced learning engagement, higher-order thinking, and gamified learning that provides practice opportunities to develop and master skills. Building on Erin Knight’s micro-credentials work (ie, digital badges to motivate, assess, and promote communication), this proposal includes creating a badging system to recognize individuals’ achievements, guide them toward mastery, and enable ECPs to build a portfolio of their skills, which then can be shared with others. This notion of a digital “skills passport” is gaining acceptance10,25 as a way for professional credentialing to be readily transportable, and is part of what motivates the partnership between iLookOut and the National Workforce Registry Alliance (see LOS).

In contrast with the parent study (which examines reporting behavior) this study will evaluate whether 1) gamified micro-learning can promote knowledge retention about how to protect children from abuse, and 2) a multi-faceted implementation strategy is feasible for educating ECPs about child abuse and its reporting. Though advanced technology is used in multiple settings to promote learning,26,27 it has not been used to help individuals identify suspected child abuse. This project aims to create an innovative, engaging, and highly generalizable modality for optimizing learning with regard to child abuse and its reporting. This is because, in addition to providing a model for micro-learning, iLookOut’s micro-learning platform was designed so that state-specific “cohorts” can be created within the platform—such that learning content can be readily adapted (as needed) for other states; and data collection, analysis, and credentialing can be rendered distinct for multiple cohorts of learners.

The methodology that emerges from this project also has the potential to individualize learning to address what J. McVicker Hunt long ago dubbed the “problem of the match.”28,29 That is, micro-learning methodology could be used to develop an expansive database linking tailored feedback to question-items, such that learner responses trigger pre-programmed feedback to address gaps in learning revealed by individuals’ responses. The challenge is to ensure that micro-learning activities are sufficiently engaging/appropriately fun that the assessments become drivers for additional individualized learning (see B.1 & B.2).
A.5 Summary. In sum, this renewal will evaluate whether: 1) a multi-faceted implementation strategy is feasible for educating ECPs about child abuse and its reporting; 2) an integrated micro-learning program promotes knowledge retention about child abuse and its reporting; and 3) ECPs' knowledge (as well as attitudes, confidence, and sense of preparedness) is impacted by the feasibility of that implementation strategy.

B) INNOVATION:

B.1 Description of Micro-learning. For this project, micro-learning involves 5-10 minute interactive, applied learning exercises, gamified learning activities, or other messaging delivered to smart-phones (or computers) to reinforce and augment learning, measure knowledge retention, and build skills. Following completion of the iLookOut core learning program, ECPs will receive 2-3 micro-learning activities per week over a 2-month period. These will include matching activities, drop-and-drag games, case-based vignettes with skill-building exercises, jeopardy-type games, as well as links to written materials, podcasts, videos, webinars, etc. Micro-learning will be grouped based on topics (eg, Risk factors for child abuse) that correspond to a particular iLookOut learning objective (eg, Recognize possible child abuse). Assessments are built into each of these activities, allowing ECPs to earn professional development credit (see LOS from PA Key, NWRA, & MRTQ). Micro-learning must be completed sequentially, beginning with “basic” concepts covered in the core iLookOut learning program, then progressing to more applied interactive exercises that prompt ECPs to operationalize what they have learned. Notifications of a new micro-learning activity will appear in the iLookOut App (or inbox, if an ECP chooses to complete them on their computer). Learners will be able to access these activities when desired (completing them as soon as they arrive, or in batches), but will receive the full micro-learning course content over a 2-month period – though we will monitor usage to track how long ECPs actually take to complete the course (see C.1).

The educational content for these 3 hours of micro-learning has already been developed for the parent study (in Maine), and captured in a cognitive sequencing map (see B.3) that identifies each activity’s modality, purpose, sequence, duration, and relation to the core iLookOut program’s learning objectives. In addition to revising content to comport with laws and policies in Pennsylvania, we propose to enhance the micro-learning functionality to make it more engaging for learners, and better able to capture granular question-level data. Enhancement will involve integrating more game elements/mechanics, including opportunities to earn achievement badges (eg, Fig. 3), which have been shown in multiple settings to help sustain engagement.28

Upon completion of this micro-learning course, ECPs will receive 3 hours of (no cost) professional development credit. Approval for this credit has already been awarded in Maine for the parent study; and once the micro-learning has been tailored for Pennsylvania, we anticipate similar approval from the Pennsylvania Key (see LOS). Because professional development is required for licensure in Pennsylvania, and typically costs money, 3 hours of professional development credit at no cost for just 2-3 gamified micro-learning activities per week will likely serve as a strong incentive for ECPs to continue to receive and complete a micro-learning course that is integrated with iLookOut’s core learning program. Accordingly, we anticipate being able to keep >75% of ECPs engaged for the entire micro-learning course.

B.2 Multi-faceted Implementation Strategy. To integrate evidence-based interventions into standard practice, systematic implementation strategies are needed.30 Such strategies may be discrete (ie, a single process or action) or multi-faceted. Traditional teaching methods for mandated reporting are discrete, employing a single training event (in-person or online) and/or procedural intervention to deliver information.31 Perhaps not surprisingly, their effectiveness has been mixed at best,32-35 particularly in terms of long-term efficacy.36 Moreover, standard educational approaches regarding child abuse detection and reporting often focus solely on individual learner outcomes37 (eg, knowledge gain, confidence, satisfaction) without regard for implementation outcomes (eg, feasibility) that are key for ensuring that evidence-based interventions can become standard practice. To our knowledge, the iLookOut intervention (core plus micro-learning) would constitute the first multi-faceted implementation strategy regarding child abuse ever to be tested with ECPs. As such, findings from this study could help establish a standard for how to sustain long-term gains in knowledge about what child abuse involves and what to do to protect children from abuse.

B.2 Programming Needs. Supplemental funding obtained during Year 3 of the parent study allowed us to design and contract with the Center for Applied Information Technologies (CAIT) to develop a micro-learning platform specifically designed for the iLookOut project. This platform is distinct, but fully integrated with the learning management system for iLookOut’s core training (also hosted by CAIT). The current functionality for
this platform includes a SCORM/API engine that tracks all course content and learning activities; question-level data for registration demographics, pre-/post-tests, and evaluation results—all of which can be de-identified and provided in detailed reports. It also hosts state-specific registration that (along with course content) can be modified to accommodate new states and/or groups; can send scheduled notifications to learners via both the iLookOut mobile App and standard email; can assign/adjust groupings and send individualized content to specific cohorts of learners; and stores question-level data for question items that allow such granularity.

Despite these capacities, our current micro-learning activities are limited by the functionality of its eLearning design program, Rise 360. While Rise 360 allows for interactive branching exercises that include multimedia (audio, video, embedded links, etc.), only very simple lesson types (flashcards, quizzes, etc.) provide the kind of granular, question-level data needed for rigorous research. As such, funding is necessary to develop/program highly engaging micro-learning exercises (eg, interactive imagery, drag-and-drop functionality, dashboards for professional development tracking and digital badge, etc.) that will also capture detailed question-level data.

**B.3 Cognitive Sequencing Map.** The impact of micro-learning is maximized to the extent that it is integrated with the core iLookOut learning experience. To do this, we continue to map out the relationships between iLookOut’s 1) learning objectives; 2) existing content (within the storyline “script,” as well as the interactive learning exercises and resource files that make up the “learning modules”); 3) pre/post knowledge test; and 4) follow-up micro-learning (including their content and modality). For example, the 1st of the core learning program’s 3 major learning objectives (LO 1) is to Understand and recognize possible abuse. Of various subsidiary learning objectives, the 4th (LO 1.4) is to Know the signs and symptoms of abuse, one component of which involves bruising. The cognitive map (see Fig. 4 for simplified prototype) shows how this topic is addressed in the iLookOut script, learning modules, and post-test. It also helps ensure that micro-learning is fully integrated with these elements, and will catalogue the various modalities for delivering information and recording learner responses. Such mapping is particularly valuable for micro-learning because it is not known which types of interactive exercises best engage ECPs and optimize learning. Knowing how micro-learning activities and their modalities relate to other variables is a precondition for any effective analysis of their functionality.

**FIG. 4. EXAMPLE OF COGNITIVE MAP –showing relationships between micro-learning and other iLookOut elements**

<table>
<thead>
<tr>
<th>Learning Objectives (LO) and Learning Modules (LM)</th>
<th>Core Training Content</th>
<th>Knowledge Test (KT) Questions</th>
<th>Micro-Learning Reinforcement</th>
<th>Timing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LO-1: Understand and recognize possible abuse</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>LO-1.4: Know signs &amp; symptoms of abuse</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LM-8: Various signs of abuse</td>
<td></td>
<td>KT-3.13 Any bruising on an infant who has not started pulling to stand (Y/N/Unsure)</td>
<td>If you suspected abuse, what type of abuse depicted in this scenario? Case vignettes Identify types of abuse 5 min</td>
<td></td>
</tr>
<tr>
<td>... Multiple choice questions on bruises</td>
<td></td>
<td></td>
<td>As a child care provider, you play a really important role in helping keep vulnerable children safe. How? Let’s look at some ways YOU can help prevent abusive head trauma Video Recognize indicators for serious injuries 7 min</td>
<td></td>
</tr>
<tr>
<td>LM-24: Which bruises are suspicious for abuse --- Yes/No Questions</td>
<td></td>
<td>KT-3.14 Any bruising on a toddler’s forehead (Y/N/Unsure)</td>
<td>Which of the following should be reported to child protective services as suspected child abuse? Multiple response items Develop decision-making skills 3 min</td>
<td></td>
</tr>
</tbody>
</table>

**B.4 Scientific Rigor.** Engaging ECPs as adult learners requires incorporating an andragogy perspective on self-regulated learning (SRL) and motivation. SRL employs dynamic processes to help learners monitor and regulate cognition and behavior toward acquisition of learning goals, particularly within a computer-mediated learning context. Andragogy, on the other hand, is the science of helping adults learn, and is based on 6 main assumptions that are compatible with SRL processes: self-concept (ie, learners are self-directed,
autonomous, and independent), role of experience (there is a pre-existing base on which to build), readiness to learn (to learn what they believe they need to know), orientation to learning (learning is problem-centered, task-oriented, and life-focused), internal motivation, and need to know (learners appreciate the value and reason for learning). From the perspective of SRL, even the best designed online training cannot be fully effective with a single exposure (ie, discrete implementation). Pre/post-test evaluations may demonstrate significant gains, but lasting impact on knowledge, understanding, and awareness requires spaced repetition, spaced retrieval, elaboration, and rehearsal that is integrated and applied within the lived experiences of learners. Thus, to effect long-term change in ECPs’ understanding of child abuse indicators, and motivation to protect children, optimal strategies are needed.

Based on what was initially feasible, the parent study included an ad hoc micro-learning strategy to reinforce learning. The current proposal significantly improves upon this by introducing a systematic, integrated micro-learning strategy to optimize learning. Micro-learning will now serve as self-regulated learning scaffolding activities for improving self-directed learning, rehearsal for applying new knowledge, and skill building. Per the principles of andragogy, applied learning exercises, interactive games, badging, and gamified micro-learning will reinforce self-regulatory strategies (eg, metacognition and critical thinking) that allow ECPs to engage in deeper learning over extended periods of time—which in turn will optimize the retention and meaningful implementation of what ECPs have learned.

An oft-cited frustration with mandated reporter training is the lack of practical feedback. This is particularly unfortunate in light of considerable research demonstrating that “more feedback” significantly outperforms “more instruction” for optimizing learning. That said, quality feedback about detection and reporting of child abuse is challenging because real-world decisions are often fraught with uncertainty. Even when strong signals (ie, red flags for abuse) are present, uncertainty introduced by contextual factors such as cultural differences or communication barriers can be crippling. Because uncertainty leads to decision avoidance, and practical feedback is often lacking, it is perhaps not surprising that many mandated reporters don’t report their suspicions of child abuse. Yet the challenge of accurately detecting child abuse is not unique with respect to uncertainty, as there are many fields where the “Truth” of a situation is hard (if not impossible) to discern. In these situations, expert judgment is still feasible, provided that the feedback is both discriminating and consistent. The use of enhanced gamification will allow iLookOut’s micro-learning to challenge ECPs to apply their knowledge to discern when children are at risk, and to receive expert feedback to help them develop their judgment for when they need to act to protect a child from abuse.

The persuasive power of expertise is well known, and can be explained in part by fundamental principles of social learning theory. Little is known about the effect expert feedback has on judgment and decision-making regarding child abuse, but its impact has been examined in other contexts. For example, an online interactive tool that provided expert feedback about treatment decisions for patients with lung cancer influenced 73% of oncologists’ clinical treatment decisions. The proposed enhanced micro-learning will explore the impact of expert feedback on judgment and decisions—here, with regard to ECPs and possible child abuse. We have developed several exercises involving paired scenarios in which key features are varied to represent the various types of abuse across a wide range of conditions, and variable degrees of likelihood. Expert feedback will include evidence-based information about the risk of abuse, as well as information about contextual features the learner should understand—including how to interpret features of the scenarios, and what would be the likely response from child protective services if a report were made.

Relatedly, situations constituting child abuse often are not readily apparent or clearly defined. As a major public health concern, child abuse has been called a “wicked problem” whose complexity and “ill-defined” nature leads to conflicting assumptions, evidence, opinions, and solutions. Moreover, variability in mandated reporting statutory language, concomitant risk factors (eg, poverty, intimate partner violence), different individual beliefs, attitudes, thresholds for reporting, and preparedness to report along with variable organizational procedures can make it quite challenging to develop interventions that guarantee improved detection and reporting of child abuse.

From an andragogy perspective, ill-defined problems require 3 specific problem-solving skills from learners: inferential rules and strategies, metacognitive skills to select and monitor strategy use, and a process for monitoring the epistemic nature of problems. Epistemic monitoring of knowledge is particularly important for evaluating ECPs’ assumptions during problem-solving—that is, if we want to increase ECPs’ awareness and skills for reaching multiple solutions to help identify and protect children at risk for abuse. Particularly with complex/wicked/ill-defined problems like child abuse, conceptually richer learning strategies are needed. One such strategy, self-regulated learning (SRL) scaffolding, relies on promoting SRL abilities to help foster long-term knowledge retention and problem-solving skills. SRL scaffolds include the use of tools, strategies, or guides...
to enable learners to develop an understanding of content that extends beyond the immediate learning event. The spaced retrieval, spaced practice, and gamification of micro-learning in the present proposal is such an SRL scaffolding (here, for promoting more effective learning about child abuse and its reporting) whose multifaceted implementation strategies are known to improve outcomes.

Despite evidence that tailored educational strategies are more likely to yield changes in standard practice, most implementation strategies for mandated reporter training fail to account for individual variability in learning. It has been recommended that theory-driven, evidence-based approaches be used to identify specific strategies for overcoming such barriers; but rigorous methods for identifying such strategies remain unknown. There are certainly few (if any) high-quality, implementation-science-informed studies that involve mandated reporter training—particularly regarding strategies for promoting long-term knowledge retention. The current study aims will address this gap through a rigorous comparison of discrete (core training) vs. multifaceted (core + micro-learning) implementation strategies. While the focus of this comparison will be on knowledge decay (Aim 2), we will also analyze the study findings to better understand the relationship between implementation and individual outcomes (Aim 3), including potential mediating effects.

**C) APPROACH – STUDY DESIGN**

**C.1 Participants & Arm Assignment.** All ECPs in Pennsylvania will be recruited to complete (at no cost) the core iLookOut learning program to meet their state requirement for mandated reporter training. Because completing the program involves downloading the iLookOut App, all ECPs will be positioned to continue receiving notifications that allow them to engage in the subsequent micro-learning course. Upon completion of the core iLookOut learning program, participants will be randomized to 1 of 4 study arms (see Fig. 6) to receive
micro-learning notifications either immediately after completing the core iLookOut learning program, or after a delay of 3, 6, or 12 months. Randomization will be based on child care program type (Family-based, Head Start, Center, Pre-school/Nursery school), as well as size, QRIS quality rating, and rurality (using both Federal census and RUCA designation). The exact number of individuals who work or volunteer at child care programs in Pennsylvania is not known. However, based on past experience (>12,000 people completing the beta-version of iLookOut between 2015-2019), and the need for all ECPs to re-take mandated reporter training every 4 years, we conservatively estimate being able to recruit 1,500 participants per study arm to complete the core iLookOut learning program (see also C.5.2). We anticipate that very few ECPs who enroll in this study will have previously completed the beta-version of iLookOut’s core learning program (given the number of other approved mandated reporter trainings available to ECPs in Pennsylvania). But we will gather this history during registration, and control for it in our data analysis. Based on experience with the beta-version of micro-learning currently being used in Maine (under the aegis of the parent grant –see A.2.1), we anticipate that the majority of those who complete the core learning program will engage in micro-learning.

ECPs in the immediate arm will begin receiving micro-learning activities the day after they complete the core iLookOut learning program. Because they will have just completed measures for knowledge, confidence, attitudes, and preparedness (KCAP), they will not repeat those measures before engaging in micro-learning. After completing the micro-learning program, these ECPs will again complete KCAP measures. At this point, they will also evaluate the acceptability, appropriateness, and feasibility of micro-learning, and complete an instrument measuring their satisfaction with the micro-learning program. Then, 3 months later, learners will complete the KCAP measures one final time. ECPs in the other study arms will follow the same study procedures, however, they will i) experience a time delay (of 3, 6, or 12 months) between completing the core iLookOut learning program and receiving micro-learning activities, and ii) complete the KCAP measures prior to their first micro-learning activity (which will be used to measure knowledge decay over time).

While there is strong reason to believe that spaced retrieval/practice will help boost the ECPs’ learning,76-80 the optimal timing for this reinforcement is not known. Accordingly, we plan to evaluate this expected boost (and subsequent knowledge decay) by randomizing ECPs to receive micro-learning at increasingly longer intervals (aka, expanding schedules)79,81 after they complete the core iLookOut learning program. Based on prior research,77,82 we anticipate (see Fig. 7) that 1) ECPs’ knowledge (X) will decline more and more over time; 2) micro-learning will boost that knowledge score (from X to Y); 3) the greater the decline (from K to X), the greater the boost will be; but 4) the longer the time period before micro-learning is introduced, the lower the subsequent knowledge score (Y). (Please note that for ease of representation, the final measure of knowledge that will occur 3 months after ECPs complete micro-learning is not depicted in Fig. 7.)

C.2 Aims & Hypotheses. All study aims are intended to evaluate the usefulness of the iLookOut intervention, and in particular the use of micro-learning exercises following completion of the core iLookOut learning program. As noted above (see A.2.1), there is considerable evidence that iLookOut’s core training improves knowledge and attitudes regarding child abuse and its reporting.13-17 What is not yet clear is whether follow-up micro-learning exercises can promote i) knowledge retention, and ii) ECPs’ continued engagement in activities that help them think about how to protect children from abuse. The micro-learning exercises we have created build upon each other; expand information and topics previously introduced; help learners develop their judgment, decision-making, and communication skills; and provide opportunities to practice applying newly acquired knowledge. The first aim of the proposed project focuses on implementation targets for micro-learning exercises (following completion of iLookOut’s core training). The second aim focuses on measuring ECPs’ knowledge loss over time, and whether micro-learning exercises can remediate such knowledge decays. The third aim examines whether individual differences in perceived implementation success (as assessed by ECPs) explain the degree to which micro-learning promotes subsequent gains in knowledge and sense of preparedness.

Aim 1 involves establishing the feasibility of a multi-faceted strategy (core + micro-learning), as defined by all the following criteria being met: 1) ≥ 50% of ECPs who complete iLookOut’s core learning program also complete the 3-hour micro-learning course; 2) >75% of ECPs endorse the iLookOut intervention (core and micro-learning), as defined by a positive (>0) Net Promoter Score (NPS) –a widely used index whose -100 to +100 scale measures users’ willingness to recommend a product to others (a positive NPS is any score greater than zero,
which is generally deemed “good,” a NPS of +50 is deemed “exceptional”);\(^{83-85}\) 3) >75% of ECPs rate the iLookOut intervention as acceptable, defined as a mean score >30 on the (8-48) Abbreviated Acceptability Rating Profile;\(^{86}\) and 4) >75% of ECPs rate the iLookOut intervention as appropriate using the Assessment Follow-Up scale adapted from Bartholomew\(^{87}\) (where appropriateness is understood as the “perceived fit, relevance, or compatibility of the innovation or evidence based practice for a given provider...or perceived fit of the innovation to address a particular issue or problem”\(^{88}\)).

**Aim 2** involves assessing knowledge decay (following the core training) regarding child abuse and its reporting, and the impact of micro-learning on knowledge remediation. Analyses will be based on a 4-arm design, in which ECPs are randomized to either micro-learning immediately following the core training, or after a delay of 3, 6, or 12 months, respectively (see C.1). Knowledge assessments will occur at 5 time points (K\(_1\)-K\(_5\), see Fig. 6, and note that knowledge is notated as the “K” in the Knowledge-Confidence-Attitudes-Preparedness [KCAP] measurement). To test **Hypothesis 1**, the change in score from K\(_2\) to K\(_3\) will be used to calculate mean knowledge decay for each of the arms in which there is a delay between the core and micro-learning programs. Based on seminal work by Ebbinghaus\(^{89}\) and more recent research on learning and forgetting,\(^{90-92}\) we expect that knowledge loss will be greatest for ECPs randomized to the 12-month delay arm, followed by those in the 6-month delay arm, followed by those in the 3-month delay arm—all relative to the mean knowledge scores immediately following the core training (K\(_3\)). For **Hypothesis 2**, we expect that completing micro-learning exercises will result in improved knowledge scores (K\(_4\)-K\(_5\)). The rationale for this hypothesis is based on broad evidence on the efficacy of post-intervention “booster” sessions,\(^{93-95}\) We also plan to investigate whether micro-learning related improvement in knowledge scores (K\(_4\) vs K\(_3\)) and their sustainability (K\(_5\) vs K\(_4\)) vary based on the timing of micro-learning. Here, our hypothesis is that longer delays between the core training and micro-learning will be associated with greater recovery (ie, greater increases from K\(_3\) to K\(_4\), given the greater initial knowledge loss from K\(_2\) to K\(_3\)), but that the longer the delay, the lower the subsequent knowledge (K\(_4\)). We then expect to see roughly equal rates of knowledge loss in the 3 months after completion of micro-learning (K\(_5\) vs K\(_4\)). This hypothesis is based on observations that specialized knowledge requires more immediate practice following initial information acquisition.\(^{96}\) This design enables examination of behavioral drift—ie, how long knowledge regarding child abuse and its reporting will be sustained after reinforcement is removed.

**Aim 3** explores whether individual learner outcomes are explained in part by their assessments of the feasibility of the iLookOut intervention (core and micro-learning). These analyses will use a mediation approach to examine whether individual learning outcomes (ie, changes in knowledge, attitudes, confidence, preparedness, and satisfaction) are explained by evaluations of iLookOut’s feasibility—in terms of ECPs’ ratings of the intervention on the Net Promoter Score scale, the Abbreviated Acceptability Rating Profile, and the Appropriateness scale. Based on the model specified by Proctor (see Fig. 5),\(^{88}\) we hypothesize that the long-term effectiveness of micro-learning strategies on individual provider outcomes (eg, knowledge, preparedness) will be mediated by specific implementation outcome domains. For example, if ECPs perceive that these specific program components are relevant for their role as mandated reporters (ie, appropriateness), then knowledge retention may be higher compared to those who do not think that the intervention is relevant to their role. This path analytic approach is in line with the recommendation by Proctor and colleagues who called for the need to engage in theory-building research that would allow for modeling interrelationships of factors across the implementation process.\(^{88}\)

**C.3 Measures.**

**C.3.1 Motivated Strategies for Learning Questionnaire (MSLQ).**\(^{97}\) Developed to examine college students’ motivation and learning strategies, the MSLQ also has been used with less educated groups.\(^{98}\) Based on a social-cognitive theoretical framework, the MSLQ uses 7-point Likert-type question-items (1=not true at all to 7=very true of me) comprising 15 scales, of which we will use 4 scales each from the motivation section (22 items) and learning strategies section (29 items). Motivation scales include intrinsic goal orientation (α=0.74), extrinsic goal orientation (α=0.62), task value (α=0.90), and self-efficacy for learning and performance (α=0.93). Learning strategies scales include critical thinking (α=0.80), meta-cognitive self-regulation (α=0.79), time and study environment management (α=0.76), and effort regulation (α=0.69). This will be administered pre-intervention (ie, prior to starting the core iLookOut learning program), and to minimize participant burden will be gamified.

**C.3.2 Online Self-regulated Learning Questionnaire (OSLQ).** The OSLQ was developed to capture learners’ self-regulated learning (SRL) processes in online learning environments.\(^{99,100}\) Given that this renewal proposes to use both discrete and multi-faceted implementation strategies aimed at increasing learners’ SRL in an online environment, the OSLQ can provide additional information on the effectiveness of both strategies. The OSLQ is a 24-item scale with a 5-point Likert-type response that range from 1=strongly disagree to 5=strongly agree. Subscales from the OSLQ include environment structuring, goal setting, time management, help seeking,
task strategies, and self-evaluation. Internal consistency shows good overall reliability ($\alpha = 0.90$), with subscale alphas ranging from 0.67 to 0.90. This will be administered pre-intervention, and to minimize participant burden will be gamified.

C.3.3 Epistemically-Related Emotions Scales (EES). The EES is a 24-item self-report questionnaire that measures 7 epistemic emotions related to learning activities: curiosity, enjoyment, surprise, confusion, anxiety, frustration, and boredom. The measure has been demonstrated to have good internal consistency (ranging from $\alpha=0.76$ to 0.86) and shown to have external validity with a broad range of populations by predicting use of learning strategies and learning outcomes. This will be administered pre-intervention, and to minimize participant burden will be gamified.

C.3.4 Achievement Goal Questionnaire–Revised (AGQ - R). The AGQ-R was designed to assess learners’ achievement goals based on a 2x2 achievement goal framework (ie, mastery-approach, mastery-avoidance, performance-approach, and performance-avoidance). The AGQ-R is a 12-item instrument where respondents indicate responses on a 7-point Likert-type scale (1=not at all true of me, 7=very true of me), and has high levels of internal consistency across all subscales (ranging from $\alpha=0.84$ to 0.94). This will be administered pre-intervention, and to minimize participant burden will be gamified.

C.3.5 Implementation Outcomes. Implementation outcomes will be measured via post-intervention survey questionnaires. A total of 16 items will be divided into the 3 main domains that include acceptability, appropriateness, and Net Promoter Score. The acceptability domain includes 8 questions that ask about ease of learning, as well as specific helpful program components. The appropriateness domain includes 4 questions that ask about the ECPs’ use of training materials, usefulness of the information for their role, if training information was recommended or discussed with others, and expectation that they will use the materials. These items were shown to have high internal consistency ($\alpha = 0.90$). Finally, the Net Promoter Score is a widely used index whose -100 to +100 scale measures users’ willingness to recommend a product to others (a positive NPS is any score greater than zero, which is generally defined as “good,” a NPS of +50 is deemed “excellent,” and anything over +70 is “exceptional”). We will also include 3 questions that ask about length of program completion time, ease of use, and whether the program kept interest and attention for the learner. This will be administered at the same time as KCAP4 (ie, post-micro-learning).

C.3.6 Provider Outcomes. Knowledge (K) gain will be assessed via pre-/post-test measures using a project-developed instrument containing 26 items divided across 5 subscales: actions by adults that might constitute child abuse (actions); bruises that might indicate child abuse (bruises); legal requirements regarding child abuse (legal requirements); signs or behavior that are concerning for child abuse (concerning signs); and legal penalties for failing to report child abuse (legal penalties). The current version of the iLookOut knowledge test was revised to improve reliability and validity, and its internal consistency has good reliability ($\alpha = 0.73$).

ECPs’ confidence, attitudes, preparedness (CAP), and satisfaction will be measured post-intervention using the following. Confidence: a Likert-type scale (1=not at all confident; 10=extremely confident) for the question “How confident are you that you can identify signs of child abuse?” Attitudes: 13-item scale adapted from a validated scale used previously with iLookOut examining ECPs’ attitudes regarding their duty to report child abuse. Preparedness: a Likert-type scale (1=entirely unprepared; 7=very well prepared) for the question “How prepared do you feel to report child abuse should the need arise?” Overall satisfaction: a Likert-type scale (1=not at all satisfied; 10=extremely satisfied) for the question “How satisfied were you with this program?”

C.3.7 Scenario-based Activities used in various micro-learning activities will comprise 1-2 paragraph scenarios involving varying levels of risk across a variety of circumstances and potential kinds of abuse (modeled after Stokes & Schmidt). ECPs will then be asked to identify risk factors for abuse, gauge the likelihood of abuse, and indicate which actions, if any (including reporting suspected abuse), they would take in this scenario. Expert feedback provided to ECPs for each scenario will include evidence-based information about the risk factors represented in the scenario, the estimated likelihood of abuse, and what the response from “Intake staff” would likely be if this scenario was reported to child protective services.

C.4 Badging & Activity-based Micro-learning. Use of badging for activity-based micro-learning is grounded in 3 concepts for reinforcing retention and recall. The first, retrieval practice, promotes long-term retention and meaningful learning by prompting learners to recall and apply information (eg, through a micro-learning activity) rather than simply re-read/re-listen to the content. It is not common for learners to practice retrieval without prompting, and when they do, learners often have difficulty objectively evaluating their own responses. Gamified micro-learning address both these issues. Second, weekly micro-learning promotes spaced retrieval, which has been found highly effective for retention of content, and when combined with retrieval practice can improve recall by as much as 41%. The third concept, game-based badging, recognizes
achievement and boosts motivation by helping learners reflect on their performance in relation to goals they set for themselves, which increases their sense of competence and motivation. The proposed game-based badging is designed to maximize the learner’s sense of agency, mastery, and relatedness—which can (per Self-Determination Theory) increase motivation.

Though digital badges are relatively new for benchmarking knowledge and skill achievement, they build on a rich history of research and understanding about motivation, reputation, and recognition. Cloth badges have motivated generations to engage in activities and master a wide variety of skills. Digital badges are now emerging as an innovation for credentialing, continuing education credit, and professional passports to document skill-based competencies. Systematically designed digital badging can render learning pathways and goals more transparent, and readily communicate learner competencies and progress in the form of a digital learning passport. As a credentialing mechanism, digital badges also provide visible recognition of educational achievements that can link directly to meta-data for public display.

C.5 Statistical Considerations & Data Analysis.

C.5.1 Randomization plan. A block-randomization procedure will be built into the iLookOut App with assignments occurring at the time ECPs complete the core training. ECPs will be randomized to 1 of 4 study arms, based on (as with the parent study) child care program type (Family-based, Head Start, Center, Preschool/Nursery school), as well as size, QRIS quality rating, and rurality (using both Federal census and RUCA designation). ECPs in the 4 arms will receive micro-learning notifications either immediately after completing the core iLookOut learning program, or after a delay of 3, 6, or 12 months, respectively (see Fig. 6). The overall recruitment is 3 years (Y2-Y4). To optimize data collection for the last arm (ie, those experiencing a 12-month delay prior to micro-learning), we will randomize in 2 consecutive phases: 1) initially assigning a sampling weight of (7, 7, 7, 9) to the respective arms, so that accrual of the last arm (ie, 12-month delay) can be complete within the first 2.5 years (assuming a constant accrual rate); and 2) assigning a randomization ratio of (1,1,1) for the first 3 arms after the 12-month-delay-arm has reached its targeted sample size.

C.5.2 Sample Size Justification. The exact number of ECPs in Pennsylvania changes over time. However, based on the requirement that ECPs re-take mandated reporter training every 4 years, the 20-25% annual turnover in this workforce, past experience (>12,000 people completing the beta-version of iLookOut between 2015-2018, which equals ~22% of Pennsylvania ECPs who completed mandated training), and the support expected from key stake-holders (see PA Key & OCDEL LOS), we believe at least 4,000 ECPs will complete iLookOut’s core learning program each year (total of 12,000 over 3 years). Moreover, based on experience with the beta-version of micro-learning in Maine (under the aegis of the parent grant), we anticipate that the majority (>50%) of those who complete the core program will engage in micro-learning. Therefore, we conservatively estimate that over 3 years 6,000 ECPs will complete the core iLookOut learning program and engage in micro-learning, allowing us to assign 1,500 participants to each study arm.

We estimate that the completion rate for the 3-hour micro-learning will be 70% for the ECPs in the intermediate arm, and that for ECPs in the 3-, 6-, and 12-month delay arms the completion rates will be 65%, 60.6% and 52.5%, respectively. These estimates are based on experience with the beta-version of micro-learning deployed in Maine, promised support from key stakeholders in Pennsylvania (see PA Key and OCDEL LOS), and the assumption that the 1-year ECP workforce attrition rate will be 25% with exponential decay. This will give us an estimated overall completion rate of 62%, or 3,720 ECPs, for Aim 1, with 88% power to detect a 2% deviation in completion rate at this significance level of 5%, or 97% power to detect a 3% deviation in the other iLookOut feasibility measures (among those who complete the micro-learning program) at an adjusted significance level of 5% after adjusting for multiple comparison, using two-sided binomial test. For Aim 2, we will have >95% power to detect an effect size of 0.209 in difference of knowledge scores between any time points (assuming the same exponential attrition of ECPs), using two-sample t-test at an adjusted significance level of 0.05. For Aim 3, the expected 3,720 ECPs will give us 99% power to identify a significant Pearson’s correlation coefficient of 0.1 at a 0.001 significance level. Power calculation was based on nQuery 4.0.

C.5.3 Data Analysis. The binomial test will be applied for outcomes in Aim 1. Logistic regression will assess the heterogeneity in child care programs and the effect of the delay in micro-learning from the core iLookOut program. In Aim 2, the knowledge decay will be estimated based on the data collected at KCAP and KCAP using mixed-effects linear regression model after controlling for participants baseline characteristics. The effect of micro-learning to remediate those decays will be assessed through the improvement from KCAP to KCAP using descriptive statistics within each arm and compared between arms using mixed-effects linear regression. Knowledge retention will be evaluated using data at KCAP and compared with the estimated knowledge decay curve. For Aim 3, path analyses will examine the potential indirect effects of implementation outcomes between
discrete and multi-faceted implementation strategies and subsequent individual provider outcomes of interest (see Fig. 5). Fit indices to examine data-model fit will follow recommendations by Hu & Bentler. Bias-corrected bootstrap confidence intervals will be included to examine direct and indirect effects across the models.

**C.5.4 Plan for the Handling of Missing Data.** We will handle missing data by taking advantage of all observed information while not exaggerating precision of findings based on incomplete data. Full information maximum likelihood will be employed as a data estimation method to account for missing variables in the data, and can produce unbiased parameter estimates and standard errors under the assumption data are missing completely at random (MCAR) or missing at random (MAR). The MCAR assumption will be tested using the single global test proposed by Little & Rubin. If an MCAR or MAR assumption seems tenuous, we will explore the use of modern missing data methods (eg, maximum likelihood or Bayesian multiple imputation) that address uncertainty when participants are lost-to-follow-up. To minimize risk of selective enrollment and differential attrition, we will use logistic regression to compare participants with national data on ECPs, and conduct post-hoc analyses to correct for any differences.

**C.6 Timeline.** During Year 1, micro-learning content and design will be revised, and study protocols and approvals will be completed. Participant Recruitment will occur in Year 2 through Year 4. During Year 5, study data will be analyzed and submitted for publication. (see Fig. 8)

**C.7 Potential Problems.** Perhaps the greatest potential problem for the proposed Revision is inadequate enrollment due to lack of uptake and/or attrition. To account for inadequate internet access as a cause of poor enrollment, both the core iLookOut learning program and the subsequent micro-learning were designed to minimize bandwidth requirements (through caching optimization). To account for lack of interest being a barrier to enrollment, the study team has partnered with influential stakeholders in Pennsylvania (see LOS from PA Key & OCDEL), will obtain approval for 3 hours of professional development credit (at no charge to ECPs), and will hold focus groups with (non-study) ECPs to gather feedback to optimize the appeal of the micro-learning activities. If ECPs don’t initially respond to micro-learning notifications, we can contact them via text or email (recorded during registration) and remind them that micro-learning provides 3 hours of professional development credit at no charge. That said, iLookOut’s track record suggests uptake will be strong. Over a 4-year period, >12,000 Pennsylvania ECPs completed the beta-version of iLookOut’s core training, without any active recruitment (ie, access information for iLookOut was/is simply included in an Excel spreadsheet of approved trainings posted on the Pennsylvania Department of Human Services website). Additionally, we do not expect this prior success to interfere with recruitment because: 1) the annual ECP workforce turnover is 20-25%, and 2) ECPs in Pennsylvania are required to re-take training on reporting child abuse every 4 years. Though micro-learning has not been introduced to Pennsylvania, it has had strong uptake in Maine (see A.2.1).

To account for selective enrollment and selection bias, we will track participants, compare them with the overall early childhood workforce (using logistic regression for age, educational level, ethnicity, rurality, etc), and re-contact ECPs from under-represented groups. We will account for differential attrition by comparing attrition across study arms, types of child care, and participant demographics. If differences are identified for either enrollment or attrition, we will conduct post-hoc analyses that correct for these differences. Also, we will 1) maintain updated records of participants so ECPs can be re-contacted; 2) limit the length of primary data collection to 18 months year (thereby minimizing participant burden); and 3) employ imputation and related estimation techniques to statistically manage attrition-related missing data (see C.5.4).

**C.8 Benchmarks for success.** If the aims of this study are met, we: 1) will have established that iLookOut’s multi-faceted implementation strategy is a feasible and effective means for improving knowledge and attitudes about child abuse and its reporting; and will better understand 2) patterns of knowledge decay on this important topic, as well as 3) how best to sustain learning through micro-learning reinforcement strategies. Because iLookOut is a readily scalable intervention (particularly with regard to micro-learning), study findings should 4) advance real-world strategies for preparing mandated reporters to identify and report suspected abuse. Future studies that could stem from this work include a) examining the scalability of iLookOut with other states and/or other populations of mandated reporters; b) evaluating micro-learning’s impact on behavior; and c) designing gamified micro-learning strategies for other important topics, including those that affect child well-being (eg, post-partum depression, substance use disorders, trauma-informed care).