A) SIGNIFICANCE / RATIONALE

A.1 Introduction. Among mandated reporters, early childhood professionals (**ECPs**, aka early childhood educators, daycare providers, pre-school teachers, child care 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 are often the only people outside 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 >313,000 confirmed victims being ≤ 5 years-old),[1] fewer than 1% of substantiated cases of child abuse are identified and reported by ECPs.[2] Further, because ECPs are not adequately prepared to identify at-risk children and often fail to make high quality reports,[3-5] their reports of suspected abuse are less likely to be substantiated than most mandated reporters.[4, 6] Unfortunately, early childhood education is beset with many barriers to developing effective, scalable interventions to help ECPs better identify and respond to children at risk for abuse. The *iLookOut for Child Abuse* (**iLookOut**) parent study was funded in part 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. This effort 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 an exploratory effort to deliver basic, ad hoc follow-up messaging to maintain awareness and promote knowledge retention after completing *iLookOut*'s Core training. That said, it was beyond the scope of the parent study to either build a fully integrated follow-up intervention, or to study its impact. However, now that there is strong evidence regarding the efficacy of *iLookOut*'s Core training, our team is positioned to examine the longitudinal impact of micro-learning on both knowledge and behavior. Moreover, though some of the core precepts of micro-learning (notably spaced repetition and retrieval) are known to enhance cognitive mapping and thereby retention (including with low education populations[7]), relatively little is known about how to optimize this process, or to do so in a way that is either sustainable or leads to behavior change[8-10] –particularly among ECPs, with whom such interventions are virtually unknown. Just as rigorous research is needed to determine the optimal timing to administer booster doses of vaccines to bolster children's immunity against infectious diseases, it is essential to understand patterns of knowledge decay and optimal timing for micro-learning to boost ECPs' waning knowledge/preparedness for protecting children from abuse.

    Because the *iLookOut* team constantly pushes to be better, we created opportunities through small grants and collaborative partnerships to develop a mobile-technology-based active learning intervention to help ECPs retain and put into action what they learned from *iLookOut* about protecting children from abuse.[11] Delivered to smart-phones and other mobile devices, these interactive educational games, applied learning exercises, videos, and other messaging –collectively called **Micro-Learning**– are fully integrated with the content and objectives of *iLookOut*'s Core training, and offer a promising approach for sustaining and enhancing learning, and examining impact on behavior.[12] Moreover, *iLookOut*'s Micro-Learning is scalable as it can be readily adapted to any state, offers free professional development credit, and only requires that learners have a smart-phone or computer, and spend 5-10 minutes a few times per week. But this Micro-Learning's efficacy with ECPs has yet to be established, hence the need for this study.

    This opportunity arises in part because the *iLookOut* Core training currently used in the parent study (in Maine) is soon to be deployed in Pennsylvania. Building on the parent study strengths, this proposed study also will use a *stepped-wedge design* (see C.1) whereby ECPs are randomly assigned to receive Micro-Learning immediately following the *iLookOut* Core training, vs after a delay of 3, 6, or 9 months. This design will allow us to systematically measure decays in knowledge and changes in behavior over time, as well as to evaluate latent effects of Core training on knowledge and behavior (see Fig. 1). Because

FIG 1. SIMPLIFIED STUDY DESIGN

Knowledge Test $(K)^1$
Behavior $(B)^1$

iLookOut Core Training

K^2B^2

(variable period of time)

K^3B^3

Micro-Learning

K^4B^4

(3 months)

K^5B^5

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 move towards establishing an innovative, 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* Core training: 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
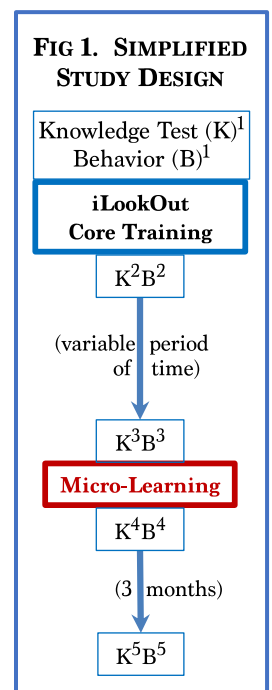
expended for "low yield" reports (ie, reports that did <u>not</u> identify child abuse or result in recommended social services). In the 4 years since receiving the grant (9/27/16–9/26/20), we have been highly productive. <u>Accomplishments</u> include having: 1) fully revised the interactive storyline of the *iLookOut* Core training (including filming, editing, post-production, interactive learning modules, and handouts);[11] 2) formally validated instruments; 3) deployed a randomized 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; 8) secured supplemental funding to build our own micro-learning platform; 9) designed/built/deployed a customized micro-learning platform that gathers research-quality data; 10) developed/deployed a smart-phone App for micro-learning; 11) partnered with the National Workforce Registry Alliance to develop a digital badging 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 training and follow-up micro-learning; 13) registered with *ClinicalTrials.gov*; 14) enrolled 1,500 ECPs into the study; 15) written 9 manuscripts –4 published, 3 under review, and 2 in progress; and 16) given platform presentations about the parent study at 4 national conferences (Pediatric Academic Societies, National Association for the Education of Young Children, National Workforce Registry Alliance, Work Learning Academy). Additionally, the success of the parent study has prompted the state of Maine to decide that (starting next year, after the parent study concludes) *iLookOut*'s Core training will be the official state training for <u>all</u> mandated reporters.

A.2.1 Preliminary Data. An initial randomized controlled trial <u>(**RCT**) in Pennsylvania</u> (n=741)[17] established that <u>*iLookOut*'s Core training</u> significantly increased knowledge and improved attitudes about child abuse and its reporting. A subsequent <u>real-world trial</u> (n=11,065)[13] yielded very similar results, and showed that ECPs were highly satisfied with the Core training (mean=8.81, SD=1.56, where <u>10=highest</u>). In the <u>ongoing parent RCT in Maine</u> (n=1,500), the revised *iLookOut* Core training significantly (p<.001) outperformed *Standard* training on mandated reporting both at improving **KNOWLEDGE** (**effect size=1.09** vs 0.67) and changing **ATTITUDES** (**effect size=0.66** vs 0.54); 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 <u>10=highest</u>). Preliminary data from the parent study also suggest that, compared to reports from ECPs who completed *Standard* training on mandated reporting, i) reports from ECPs who completed *iLookOut*'s Core training are more likely to be "screened-in" for investigation by child protection services (86% vs 70%, p<.001), and ii) these screened-in reports are more likely (56% vs 34%, p=.001) to be "high yield" (ie, child abuse is identified and/or social services are recommended).

Due to problems with a former vendor –including limitations regarding the granularity of data its learning platform could collect– we have no reliable data on **MICRO-LEARNING** prior to May 2019. However, since launching our own Micro-Learning platform mid-2019, <u>the majority of ECPs in Maine who complete *iLookOut*'s Core training have gone on to engage in Micro-Learning.</u> Because ECPs in Maine had the option to complete Micro-Learning in 2, 4, or 6-months, 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. Because its role in the parent study is merely exploratory, there are no data correlating Micro-Learning with behavior.

Data on **KNOWLEDGE DECAY** are limited. In the Pennsylvania RCT of *iLookOut*'s beta-version, knowledge gains decayed by ~50% 4 months post-intervention –but did remain significantly higher than baseline.[14] No re-test data are available for the real-world trial (due to its open enrollment format). In the ongoing RCT in Maine, repeat knowledge testing only occurred with ECPs (n=133) who completed the *iLookOut*'s Core training 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 133 ECPs, re-testing showed a mean decay in their initial knowledge gain of 52%.

A.3 Accounting for Forgetting. The *forgetting curve* (first quantified in 1885 by Ebbinghaus, and reconfirmed in recent studies[15]) 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,[16] and spaced retrieval is known to be vital for sustained advances in learning.[17] Thus finding ways to reinforce learning is crucial, especially for topics people may not be naturally drawn to revisit.[18] *iLookOut*'s Core training, itself, does this by combining an engaging video-based storyline with interactive learning exercises. ECPs learn about events that occur over 2

FIG. 2. REPLICATION OF EBBINGHAUS' FORGETTING CURVE
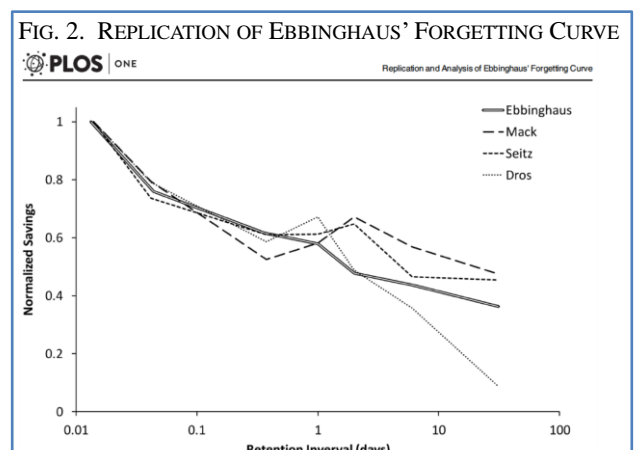
days in the work-life of an ECP named Megan as she recounts them to Elisha, a mentor whose guidance she is seeking. At different junctures, the learner is provided resources (eg, Facts about Abuse, Red Flags handout), posed didactic questions, and given opportunities to both apply new information and practice decision-making. Such immersion into real-life scenarios helps ECPs absorb and operationalize information, as well as begin developing skills to identify, support, and protect at-risk children. But that is not enough. <u>For learning not to fade, it must be reinforced, …and reinforced again</u>.

A.4 The Road to Micro-Learning. From its inception, the parent study planned to pilot <u>ad hoc</u> follow-up messages (eg, tips, best-practice guidelines, intermittent cases for reflection) to reinforce learning after *iLookOut* completion. Through a series of small grants and partnerships, the study team began to enhance the follow-up messaging with educational games, applied learning exercises, and other interactive activities. Collaborators included *Maine Roads to Quality* (which provides professional development to ECPs in Maine); Erin Knight, founder of the >1,000 organization *Badge Alliance* ecosystem;[19, 20] and the National Workforce Registry Alliance, which represents organizations that provide continuing education to ECPs, and hopes to create *nationwide* "badging" to track ECPs' professional development credit.[21] As attested in their letters of support, these entities see great value in developing micro-learning, particularly in light of our existing study team expertise in gamification (Kapp), decision-making (Hamm), early childhood education (Fiene), educational psychology (Panlilio), child abuse and child mental health (Humphreys), and online learning for ECPs (Mincemoyer).

   To this end, we developed an *iLookOut* App (iPhone & Android), and began creating follow-up activities with a leading firm in the field of micro-learning. However, their platform soon proved inadequate –lacking the granularity and analytics needed to answer research questions, the responsive design functionality needed for dynamic interactions on smart-phones, as well as the flexibility to easily tailor learning activities for *iLookOut*'s subject matter. Through supplemental funding (3R01-HD088448-04S1) we developed our own micro-learning platform with the Center for Applied Information Technologies (**CAIT**, which had programmed, and continues to host *iLookOut*'s Core training) along with 3-hours of basic Micro-Learning activities, 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 fully develop a tailored, gamified Micro-Learning course, and to systematically evaluate its impact on learning and behavior.

   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, and to impact ECPs' behavior. 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 acceptance[10, 22] as a way for professional credentialing to be readily transportable, and is strongly in sync with the goals of the National Workforce Registry Alliance (see LOS).

A.5 Summary. <u>In contrast with the parent study (which examines the impact of *iLookOut*'s Core training) this study will evaluate whether gamified Micro-Learning 1) promotes knowledge retention and 2) changes behavior with regard to protecting children from abuse, and 3) is feasible as part of a multi-faceted implementation strategy</u>. Though advanced technology is used in multiple settings to promote learning,[23, 24] it has not been used to help protect at-risk children from abuse. This project aims to create <u>an innovative, engaging, and highly generalizable strategy for helping mandated reporters become more knowledgeable and more inclined to take action when they suspect a child is in harm's way</u>.

B) INNOVATION:

B.1 Description of Micro-learning. For this project, Micro-Learning involves a series of 5-10 minute interactive, applied learning exercises that involve gamified activities delivered to smart-phones (or computers) to reinforce and augment learning, measure knowledge retention, and build skills for promoting children's well-being. What makes an intervention or practice innovative is its being perceived as new by the group adopting it.[25] As the many letters of support for this grant application attest (see LOS from Annie E Casey Fdn, PennAEYC, PA Key, BKC, CYS, OCDEL, Perkins, & NWRA), *iLookOut*'s Micro-Learning is <u>highly innovative</u> for both the ECP workforce and the subject of child abuse.

   Following completion of the *iLookOut* Core training program, ECPs will receive 2 Micro-Learning activities per week over a 3-month period (content=3 hours total). These will include matching activities, drop-and-drag games, skill-building exercises, jeopardy-type games, as well as links to written materials, podcasts, videos, webinars, etc. Micro-Learning will also include scenario-based activities depicting varying levels of risk across a variety of circumstances and potential kinds of abuse (modeled after Stokes & Schmidt).[26] ECPs will 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. Expert feedback for each scenario will include evidence-based information about the risk factors represented, the estimated likelihood of abuse, and what the response from "Intake staff" would likely be if this scenario was reported to child protective services.

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 that reinforce *iLookOut*'s Core training, then progressing to more applied interactive exercises that provide advanced information– and 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 a computer). Learners can access activities when desired (completing them right away or in batches), but should receive the full 3 hours of content over a 3-month period –though we will monitor usage to track how long ECPs take to complete the course (see C.1 & C.6.3).

FIG. 3. BADGING

The basic educational content for 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 training's learning objectives. For this study, we will revise all content to comport with Pennsylvania law, and also enhance the Micro-Learning functionality to make it more engaging for learners, and better able to capture granular question-level data. Enhancement is important because to have long-term feasibility micro-learning activities must be sufficiently engaging/appropriately fun that they motivate continued participation. As such we will integrate more game elements/mechanics, including achievement badges (eg, Fig. 3), which have been shown in multiple settings to help sustain engagement.[10, 27]

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 Micro-Learning is tailored for Pennsylvania, we anticipate similar approval in Pennsylvania (see PA Key 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 gamified Micro-Learning activities per week will serve as a strong incentive for ECPs to continue with Micro-Learning (see PennAEYC LOS). Accordingly, for ECPs who begin micro-learning we anticipate being able to keep >75% engaged for the entire 3-hour course.

B.2 Multi-faceted Implementation Strategy. To integrate evidence-based interventions into standard practice, systematic implementation strategies are needed.[28] Such strategies may be discrete (ie, *iLookOut*'s Core training) or multi-faceted (eg, Core+Micro-Learning). Traditional teaching methods for mandated reporting are discrete, employing a single training event (in-person or online) and/or procedural intervention to deliver information without explicit knowledge-to-practice translation.[29] These efforts' effectiveness has been mixed at best,[30-33] particularly in terms of long-term efficacy.[34] Moreover, standard educational approaches regarding child abuse detection and reporting often focus solely on individual learner outcomes[35] (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, *iLookOut*'s Core training+Micro-Learning would constitute the first multi-faceted implementation strategy regarding child abuse to be tested with ECPs. Thus, 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.3 Programming Needs. Supplemental funding obtained during Year 3 of the parent study allowed us to work 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 exported 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 badging) that will also capture detailed question-level data.

B.4 Cognitive Sequencing Map. Micro-Learning's impact is maximized to the extent that it is integrated with *iLookOut*'s Core training. To do this, we map the relationships between *iLookOut*'s 1) <u>learning objectives</u>; 2) existing <u>content</u> (within the storyline script, interactive learning exercises, and resource files that make up learning modules); 3)

FIG. 4. EXAMPLE OF COGNITIVE MAP –showing relationships between micro-learning and other *iLookOut* elements								
Learning Objectives (LO) and Learning Modules (LM)			**Core Training Content**		**Knowledge Test (KT) Questions**	**Micro-Learning Reinforcement**			
			Learning Module	**Script**		**Content**	**Modality**	**Purpose**	**Timing**
LO-1: Understand and recognize possible abuse	**LO-1.4:** Know signs & symptoms of abuse	**LM-8:** Various signs of abuse --- Multiple choice questions on bruises	Bruises are a huge red flag in any child who isn't yet walking or cruising	"You may learn something important by asking. But nothing her mom says will change the fact that a five month-old infant had a bruise"	**KT-3.13** Any bruising on an infant who has not started pulling to stand (Y/N/Unsure)	If you suspected abuse, what type of abuse depicted in this scenario?	Case vignettes	Identify types of abuse	5 min
						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
						As a mandated reporter, it is important to know the red flags for abuse. When you aren't sure whether a given behavior, injury, or situation should cause you to have reasonable suspicion of abuse, document your observations. Specific, accurate documentation goes a long way to help Child Welfare in their decision-making process.	Audio Recording	Understand role in preventing and responding to child abuse	10 min
		LM-24: Which bruises are suspicious for abuse --- Yes/No Questions	It's normal for toddlers to bruise shins, forearms, foreheads –where they land when they tumble.	"If they don't cruise, they shouldn't bruise"	**KT-3.14** Any bruising on a toddler's forehead (Y/N/Unsure)	Which of the following should be reported to child protective services as suspected child abuse?	Multiple response items	Develop decision-making skills	3 min

pre/post <u>knowledge test</u>; and 4) follow-up Micro-Learning (including content and modality). For example, the 1st of 3 Core training major learning objectives (LO-1) is *Under-stand and recognize possible abuse*. Of the subsidiary learning objectives, the 4th (LO-1.4) is *Know the signs and symptoms of abuse*, one of which is 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 to ensure Micro-Learning is fully integrated with these elements. It also tracks the modalities for delivering information, because knowing how Micro-Learning and its modalities relate to other variables is a precondition for any effective analysis of their functionality. [36]

B.5 Scientific Rigor. Research indicates that even excellent training interventions are seldom fully effective with a single exposure (ie, discrete implementation).[37-40] Accordingly, we propose to examine the impact of follow-up Micro-Learning (which has been piloted in the parent study) on knowledge and behavior with regard to children at risk for abuse. Micro-Learning employs 2 of cognitive psychology's most empirically validated concepts for increasing learning,[41] spaced practice and retrieval practice.

Spaced practice (aka, distributed practice) optimizes learning by providing consistent, interval-based exposure to content rather than as a single event.[42] Leveraging the broad evidence-base on spaced practice,[43-47] we believe Micro-Learning will boost ECPs' knowledge retention regarding child abuse and its reporting. Further, by providing recall cues through engaging activities, we expect improvement in ECPs' knowledge (content recall) and subsequent application of knowledge (ie, far transfer) to actually identify at-risk children and take appropriate action. *Retrieval practice* is likewise well-grounded in research that shows individuals retain information better when are challenged to retrieve it at multiple future time-points.[41, 48-51] Combined, these 2 practices have demonstrated positive impact on retrieval and recall, and also behavior –including those with health-related outcomes.[52, 53] Accordingly, we anticipate that Micro-Learning's retrieval practice will promote both ECP engagement and active reflection through its interactive, goal-directed, recurring learning activities.[54]

That said, improved *quality* of behavior has not always been accompanied by higher quantity.[55] Work by Burns and Gurung[41] suggests we need to better understand how such strategies apply in real-world settings where long-term results are desired. We believe that preparing ECPs to protect children from abuse is exactly this kind of real-world challenge, one where empirically tested strategies are desperately needed.[5, 56, 57] Only 10 out of 50 state trainings on mandated reporting even include pre/post evaluations of knowledge,[58] and no training other than *iLookOut* has assessed their impact on either long-term knowledge or subsequent behavior. Spaced repetition and spaced retrieval use elaboration and rehearsal to promote such lasting impact by integrating and applying learning within the lived experiences of learners. To bring about long-term change in ECPs' understanding of child abuse indicators, and motivation to protect children, optimal strategies are needed.[59]

Creating and evaluating a fully developed and integrated Micro-Learning course was well beyond the scope of the parent study. However, due to the study team's initiative and subsequent pilot work, we are now positioned to operationalize and systematically test Micro-Learning as a strategy for optimizing learning and changing behavior. By serving as scaffolding to improve self-directed learning, rehearsal for applying new knowledge, and skill building, these applied learning exercises, interactive games, badging, and gamified components will engage ECPs in deeper learning over extended periods of time, and thereby promote both retention and meaningful implementation of what ECPs have learned.

An oft-cited frustration with training on mandated reporting is the lack of practical feedback.[60-62] This is particularly unfortunate in light of considerable research demonstrating that "more feedback" results in significantly better outcomes than "more instruction" for optimizing learning.[63-65] 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 (eg, cultural differences or communication barriers) can be crippling. Because uncertainty leads to decision avoidance, and practical feedback is often lacking,[66] many mandated reporters don't report their suspicions of child abuse.[67-70] Yet the challenge of accurately detecting child abuse is not unique with respect to uncertainty; 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.[71] 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 receive expert feedback to develop their judgment for those times when they will need to take action to protect a child from abuse.

The persuasive power of expertise is well known,[72-75] and can be explained in part by fundamental principles of social learning theory.[76] 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.[77] The proposed enhanced Micro-Learning will explore the impact of expert feedback on judgment and decisions 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 these features, and how child protective services would likely respond if a report were to be 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"[78] whose complexity and "ill-defined" nature leads to conflicting assumptions, evidence, opinions, and solutions.[79] Moreover, variability in mandated reporting statutory language,[80] concomitant risk factors (eg, poverty, intimate partner violence),[81, 82] different individual beliefs, attitudes, thresholds for reporting,[83] and preparedness to report,[32,84] along with variable organizational procedures[37] can make it challenging to develop interventions that guarantee improved detection and reporting of child abuse.

Despite strong arguments for using theory-driven, evidence-based educational strategies to effect changes in standard practice,[35, 40, 85, 86] to our knowledge there has been no assessment of different implementation strategies for training

FIG. 5. Conceptual Design.

Core Training → Micro-Learning

(Discrete strategy) → Implementation Outcomes

(Multi-faceted strategy) → Demographic & Site Characteristics

(Discrete strategy) → (Multi-faceted strategy) → Knowledge and Behavior Outcomes

This conceptual model allows us to compare the magnitude of effects from Core training and Micro-Learning, including how demographic and site characteristics may moderate the effects on knowledge, behavior, and implementation outcomes.

mandated reporters. The current study's AIM 3 will address this gap through a rigorous comparison of discrete (Core training) vs. multi-faceted (Core+Micro-Learning) implementation strategies.[35, 40] While the focus of this comparison will be on preventing and/or remediating knowledge decay (AIM 1) and changing behavior (AIM 2), we will also analyze the feasibility of discrete and multi-faceted implementation strategies (AIM 3), including the potential impact of moderating factors (eg, demographics and site characteristics) (see Fig. 5).
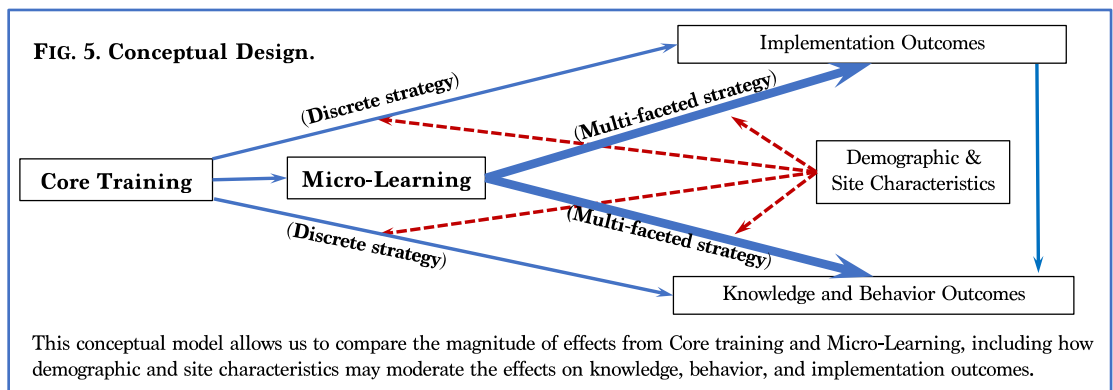
This approach meets all 6 criteria for a Hybrid Type 2 design[87] to dual test both an intervention and implementation strategy (I&IS): the I&IS both: 1) have strong face validity; 2) have a strong base of (at least) indirect evidence that they are applicable for the proposed setting; and 3) involve minimal risk; as well as 4) there is evidence (see A.2.1) that the intervention would be readily adopted if shown to be effective; 5) it is reasonable to suspect that the I&IS are both supportable in a real world setting; and 6) there is reason to gather more data on the effectiveness of the intervention. Hybrid I&IS study designs are increasingly recognized as not only efficient, but also important for establishing that interventions are both effective *and* sustainable.[87-92]

B.6 Generalizability. The methodology and content that emerge from this project also have significant potential beyond the present proposal (see Perkins, CYW, & NWRA LOS). This is because *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. Additionally, Micro-Learning can help individualize learning by tackling what J. McVicker Hunt long ago dubbed the "problem of the match."[93, 94] That is, micro-learning methodology can be developed to include an expansive database that provides tailored feedback to address gaps in understanding that are revealed by an individual's responses to question items.

C) APPROACH –STUDY DESIGN

C.1 Participants & Arm Assignment. All ECPs in Pennsylvania will be eligible to complete (at no cost) *iLookOut*'s Core training to meet their state requirement for training on mandated reporting. In preparation for this (and in partnership with Pennsylvania's Department of Human Services), a newly adapted version of *iLookOut*'s Core training now fully accords with Pennsylvania law vis-à-vis definitions, requirements, resources, contact information, and legal penalties. A similar process will be followed to ensure that Micro-Learning is appropriately tailored for Pennsylvania ECPs. Completing the Core training involves downloading the *iLookOut* App, which then positions ECPs to receive notifications linked to subsequent Micro-Learning. Upon completion of the Core training, participants will be randomized to 1 of 4 study arms (see Fig. 6) to receive Micro-Learning notifications either immediately, or after a delay of 3, 6, or 9 months. Stratification will be based on child care program type (Family-based, Head Start, Center, Pre-school/Nursery school), as well as size, QRIS rating (quality rating and improvement system), and rurality (using both Federal census and RUCA designation).


FIG. 6. iLOOKOUT MICRO-LEARNING STUDY DESIGN

SUMMARY: Early childhood professionals (ECPs) in PA complete measures on **K**nowledge, **B**ehavior, **C**onfidence, **A**ttitudes, and **P**reparedness before ($KBCAP^1$) and after ($KBCAP^2$) *iLookOut*'s Core training. After being randomized to receive Micro-Learning –either immediately, or after a delay (3, 6, or 12 months, respectively)– ECPs then complete the measures before ($KBCAP^3$) and immediately after ($KBCAP^4$) the Micro-Learning course, and again 3 months after ($KBCAP^5$) completing the Micro-Learning course.

INTERVENTION = iLookOut's **Core** training (3 hr) + follow-up gamified **Micro-Learning** (3 hours total, delivered over a 3-month period in 5-10 minute units to ECPs' mobile devices)
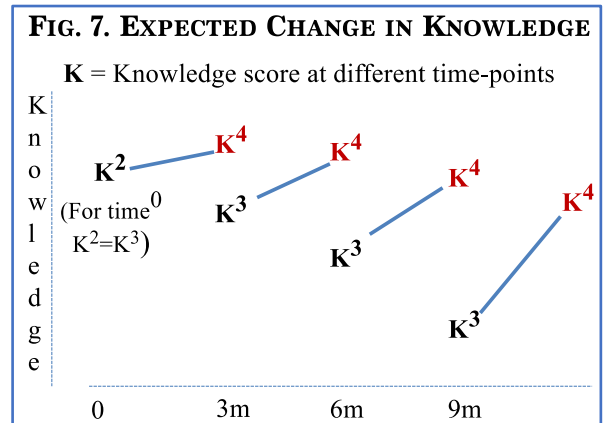
MEASURES
– Knowledge re. child abuse & reporting (**K**)
– Behavior re. at-risk children (**B**)
– Confidence, Attitudes, Preparedness (**CAP**)
– Implementation Measures (**IM**)(*Acceptability, Appropriateness, Net Promoter*)

OUTCOMES
Primary: Knowledge
Secondary: Behavior
Tertiary: Implementation
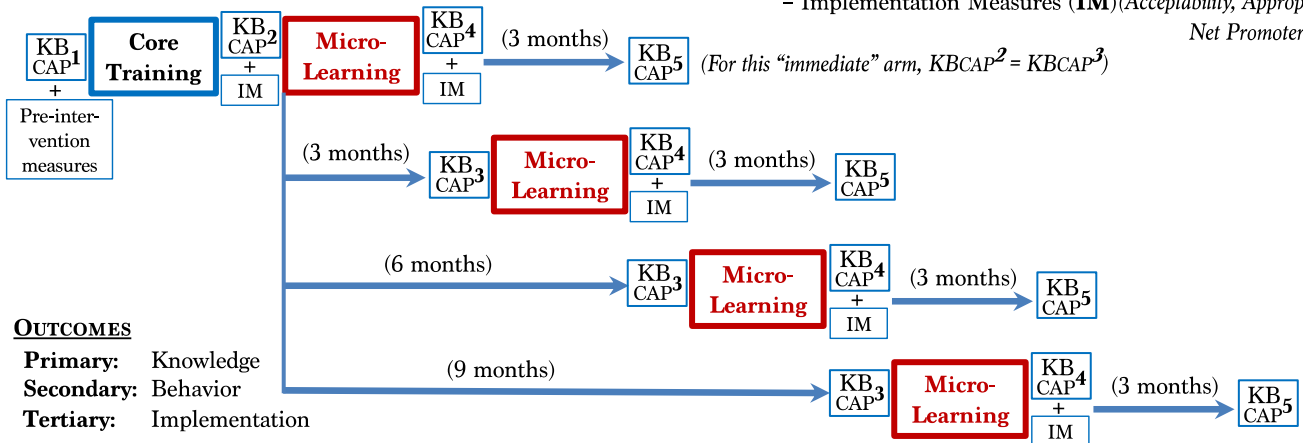
ECPs in the ***immediate arm*** will begin receiving Micro-Learning activities the day after they complete *iLookOut*'s Core training. Because they will have just completed measures for knowledge, behavior, confidence, attitudes, and preparedness (**KBCAP**), they will *not* repeat those measures before engaging in Micro-Learning. After finishing the Micro-Learning program, these ECPs will again complete KBCAP measures. Then, 3 months later, learners will complete the KBCAP measures one final time. Implementation measures (ie, acceptability,

appropriateness, Net Promoter –see C.4) will be completed after Core training, and then again 3 months after Micro-Learning. ECPs in the **other study arms** will follow the same study procedures, however, they will i) experience a time delay (of 3, 6, or 9 months) between completing the Core training and receiving Micro-Learning activities, and ii) complete the KBCAP measures prior to their first Micro-Learning activity (which will be used to measure knowledge decay and change in behavior over time).

While there is strong reason to believe that spaced retrieval/practice will help boost ECPs' learning,[43-47] the optimal timing for this reinforcement is not known. Accordingly, we will evaluate knowledge decay and the subsequent boost by randomizing ECPs (after they complete Core training) to 1 of 4 study arms to receive Micro-Learning at increasingly longer intervals (aka, *expanding schedules*).[43, 95] Based on prior research,[7, 47, 96] we anticipate (see Fig. 7) that 1) knowledge will decline more and more over time; 2) Micro-Learning will boost knowledge (from K^3 to K^4); 3) the greater the decline (from K^2 to K^3), the greater the boost will be; but 4) the longer the time period before Micro-Learning, the lower the end-knowledge (K^4). (*Please note that for ease of representation, the (K^5) final measure of knowledge that occurs 3 months after ECPs complete Micro-Learning is not depicted in Fig. 7.*)

FIG. 7. EXPECTED CHANGE IN KNOWLEDGE

K = Knowledge score at different time-points

Knowledge (For time $K^2 = K^3$)

K^2, K^4, K^4, K^4, K^4, K^3, K^3, K^3

0   3m   6m   9m

C.2 Recruitment

The exact number of ECPs in Pennsylvania is not known. However, based on past experience (>12,000 people completing the beta-version of *iLookOut* over 3.5 years in an open enrollment trial with no recruitment efforts, whatsoever), the need for all ECPs to re-take training on mandated reporting every 4 years, and the fact that this workforce has an annual attrition of 20-25%,[97-99] we estimate being able to recruit 1,500 participants per study arm (see also C.6.2). This number is entirely in keeping with recruitment in our parent study: 1,500 ECPs enrolled in 2.5 years in a state (Maine) whose population is roughly 10 times smaller than Pennsylvania.

We anticipate that few ECPs who enroll will have previously completed the beta-version of *iLookOut*'s Core training (given the many other trainings in Pennsylvania), but will record this during registration, and control for it in data analysis. Based on experience with the beta-version of Micro-Learning currently deployed in Maine (see A.2.1), we anticipate >50% of Pennsylvania ECPs who complete Core training will engage in Micro-Learning.

Because *iLookOut* is online (via website or the *iLookOut App*) it is largely immune to many of the barriers that hamper in-person training. The *iLookOut* trainings will be available at no cost, and the Core training is already approved for meeting state requirements for training on mandated reporting. The following recruitment strategies will ensure visibility of *iLookOut* and promote engagement by ECPs. Tier I: 1) work with Pennsylvania child care organizations (see LOS from PA Key, OCDEL, PennAEYC, & BKC) to promote the *iLookOut* trainings via email list-serves, Facebook pages, newsletters, etc; 2) host webinars and informational video-conferences; and 3) deploy social media campaigns (including sample activities, interactive videos, etc). Tier II: 4) contact child care programs by phone, as well as distribute recruitment materials to child care programs 5) by mail and 6) in-person. All these strategies have been successfully employed by the parent study.

Following initial recruitment, ongoing retention will be promoted by the quality of *iLookOut*'s content and delivery, as well as by Elisha (the electronic mentor who guides ECPs through *iLookOut*'s trainings) –including (after the Core training) weekly email and/or App reminders of new learning topics. In the parent study, >90% of ECPs who start the Core training completed it, and >50% of those have gone on to engage in the beta-version of Micro-Learning. For the current study, gamification and learning design experts will enhance the design of Elisha's weekly communications to further increase engagement in Micro-Learning. Additionally, we will regularly send out various kinds of reminders to learners who lag behind their assigned learning schedule.

C.3 Aims & Hypotheses.

The parent study has shown (see A.2.1) that *iLookOut*'s Core training improves knowledge and attitudes regarding child abuse and its reporting,[100] and preliminary data suggest that over the short-term it also improves reporting of suspected child abuse (see A.2.1). What remains unknown is whether follow-up Micro-Learning can promote 1) knowledge retention or 2) changes in behavior, or 3) whether it is a feasible intervention for keeping ECPs engaged in activities related to protecting 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 study aim is to measure ECPs' knowledge loss over time, and how much Micro-Learning remediates such knowledge decays. The second study aim is to measure behavior

changes after ECPs complete Micro-Learning, using the stepped-wedge study design to control for latent effects from the Core training. The <u>third study aim</u> focuses on implementation to judge the feasibility of Micro-Learning.

AIM 1 involves assessing <u>knowledge decay</u> (following Core training) regarding child abuse and its reporting, and the impact of Micro-Learning on <u>knowledge remediation</u>. Analyses will be based on a 4-arm design, in which (*immediately after completing Core training)* ECPs are randomized to start Micro-Learning right away, or after a delay of 3, 6, or 9 months, respectively (see C.1). Knowledge assessments (see C4.1) will occur at 5 time points (**K^1-K^5, see Fig. 6**, where *knowledge* is notated as the "**K**" in the Knowledge-Behavior-Confidence-Attitudes-Preparedness [**KBCAP**] 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 work by Ebbinghaus[101] and more recent research on learning and forgetting,[15, 102-104] we expect that (relative to mean knowledge scores immediately following the Core training, ie, K^2) knowledge loss will be greater the longer the interval between completing Core training and beginning Micro-Learning.

For **Hypothesis 2**, we expect that completing Micro-Learning exercises will result in improved knowledge scores (K^4>K^3). This hypothesis is based on broad evidence on the efficacy of post-intervention "booster" sessions.[105-107] 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.[108] This design enables examination of behavioral drift, that is, how long knowledge (and skill, for AIM 2) regarding child abuse and its reporting will be sustained after reinforcement is removed.

AIM 2 focuses on <u>behavior change</u> consequent to Micro-Learning, in terms of 1) ECPs' reporting of suspected abuse, and 2) behaviors ECPs take to support at-risk children and their families. We will measure **reporting practices** in two ways. <u>First</u>, as part of the KBCAP, we will <u>survey ECPs about the number of children they have reported over the preceding 3 months</u>. ECPs' responses after completing Micro-Learning (ie, B^4 and B^5) will be compared to reporting practices both before (B^1) and after (B^2) the Core training, as well as prior to starting Micro-Learning (B^3). <u>Second</u>, in collaboration with Pennsylvania's child protection services (see LOS from CYS), we will assess <u>whether reports of suspected abuse were more likely to be substantiated if the person who made the report had completed *iLookOut*'s Micro-Learning</u>. To accomplish this, a child protection service administrator will cross-check the names of ECPs who completed Micro-Learning (which we will share) with the names of ECPs who reported suspected child abuse, and then will compare substantiation rates for those reports vs reports from ECPs who did *not* engage in Micro-Learning.

The <u>second</u> type of behavior change we will evaluate is **actions ECPs take to protect and/or support at-risk children and their families**. These data will be collected as part of the KBCAP measures at the time points indicated above for reporting practices. The actions we will measure include: *identifying resources to help children/families in need* (eg, making referrals to social services, creating handouts with contact information for resources); *promoting protective factors for children and their families* (eg, participation in activities that build parental resilience, social connections, social/emotional competence); and *formal documentation of concerns related to a child being at-risk* (eg, inadequate resources, family stress, intimate partner violence, substance use disorders). In addition, given the likely link between an individual's knowledge and their subsequent behavior, we will explore whether increased knowledge mediates changes in reporting behavior.

AIM 3 is to establish the <u>feasibility</u> of a <u>multi-faceted strategy</u> (Core+Micro-learning), as defined by <u>all</u> the following criteria being met: **1)** ≥ 50% of ECPs who complete Core training also complete the 3-hour Micro-Learning course; **2)** >75% of ECPs who complete Micro-Learning endorse the multi-faceted strategy, as defined by a positive (>0) Net Promoter Score (see C.4.2) **3)** >75% of ECPs rate the multi-faceted strategy as acceptable, defined as a mean score >30 on the (8-48) Abbreviated Acceptability Rating Profile;[109] and **4)** >75% of ECPs rate the multi-faceted strategy as *appropriate* using the *Assessment Follow-Up* scale adapted from Bartholomew[110] (where appropriateness is the perceived fit, relevance, or compatibility for addressing a particular issue or problem[111]). Additionally, we will compare the magnitude of parameter estimates between Core→implementation vs Core+Micro-Learning→implementation (see Fig. 5).

C.4 Measures.

C.4.1 Provider Outcomes. <u>Knowledge</u> (**K**) gain will be assessed via pre-/post-test measures using a validated 26-item instrument[104] with good reliability (α=0.73) comprising 5 subscales: *actions* by adults that might

constitute child abuse; *bruises* that might indicate child abuse; *legal requirements* regarding child abuse; *concerning signs* or behavior indicating child abuse; and *legal penalties* for failing to report child abuse. Change in <u>behavior</u> (**B**) will be assessed using the measures described above (see C.3 AIM 2) for ECPs' *reporting practices*, as well as *actions taken to protect and/or support at-risk children and their families*. These measures of behavior will be created and validated with the assistance of *Research Matters*, who helped with validation of *iLookOut*'s knowledge test,[104] using scales that allow for comparison across different time-points.

ECPs' confidence, attitudes, preparedness (**CAP**), and satisfaction will be measured using the following questions from a validated scales. *Confidence*: 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?"[112] *Attitudes*: 13-item scale (used previously with *iLookOut*[13, 14]) examining ECPs' attitudes regarding their duty to report child abuse.[113] *Preparedness*: 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?"[114] B *Overall satisfaction*: Likert-type scale (1=not at all satisfied; 10=extremely satisfied) for the question "How satisfied were you with this program?"[115] C

C.4.2 Implementation Outcomes. Implementation outcomes will be measured post-intervention (ie, concurrent with KBCAP**2** and KBCAP**4**, see Fig. 6) across 3 domains. *Acceptability* includes 8 validated questions focused on ease of learning, and helpfulness of program components.[109] *Appropriateness* domain includes 4 validated questions with high internal consistency ($\alpha=0.90$)[110] focused on the use and utility of training materials. *The Net Promoter Score* (**NPS**) is a widely used index whose -100 to +100 scale measures users' willingness to recommend a product to others, where a positive NPS score (>0) is generally deemed "good," a NPS of +50 is deemed "excellent," and anything over +70 is "exceptional").[116-118] We will also include 3 questions asking about program completion time, ease of use, and whether it kept their interest/attention. Based on Proctor et al's framework,[35] variability in these implementation outcomes can be examined in relation to Core (ie, discrete) or Core+Micro-Learning (ie, multi-faceted) by comparing the magnitude of direct effects between these implementation strategies, with further analysis examining possible moderators (eg, demographic factors, site characteristics).

C.5 Activity-based Micro-learning & Badging are grounded in 3 concepts for reinforcing retention and recall. The <u>first</u>, **retrieval practice**, promotes long-term retention and meaningful learning[119] by prompting learners to recall and apply information (via micro-learning) rather than to simply re-read/re-listen to content. Most learners do not practice retrieval without prompting, and when they do often have difficulty objectively evaluating their own responses.[119] Gamified micro-learning address both these issues. <u>Second</u>, micro-learning promotes **spaced retrieval**,[120] which has been found highly effective for retention of content;[53, 120, 121] and when combined with retrieval practice can improve recall by as much as 41%.[122] The <u>third</u> concept, **game-based badging**, recognizes achievement and boosts motivation by helping learners reflect on their performance in relation to goals they set for themselves,[123] which can increase their sense of competence and motivation.[124] Game-based badging is designed to maximize the learner's sense of agency, mastery, and relatedness –which can (per Self-Determination Theory)[125] 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.[19, 20, 126] Digital badges are now emerging as an innovation for credentialing, continuing education credit, and professional passports to document skill-based competencies.[22, 127, 128] 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.[9, 10, 27, 129] As a credentialing mechanism, digital badges also provide visible recognition of educational achievements that can link directly to meta-data for public display.[10]

C.6 Statistical Considerations.

C.6.1 Randomization plan. A stratified permuted block randomization procedure will be built into the *iLookOut* App with assignments occurring <u>at the time ECPs complete the Core training</u>. ECPs will be first subdivided into strata, based (as with the parent study) on child care program <u>type</u> (Family-based, Head Start, Center, Pre-school/Nursery school), as well as <u>size</u>, <u>QRIS quality rating</u>, and <u>rurality</u> (using both Federal census and RUCA designation), which helps achieve comparability between study arms. Within each stratum, a permuted block randomization will be applied to randomize ECPs to 1 of 4 study arms. This guarantees that at no time during randomization will the imbalance be large, and protects against temporal trends during enrollment, which can affect larger trials with long enrollment phases.

ECPs in the 4 arms will receive Micro-Learning notifications either immediately after completing the Core training, or after a delay of 3, 6, or 9 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 9-month delay prior to Micro-Learning), we will randomize in 2 consecutive phases: 1) initially assigning a sampling weight of (2,2,2,3) to the respective arms, so that accrual of the last arm (ie, 9-month delay) can be completed 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 9-month-delay-arm has reached its targeted sample size.

C.6.2 Sample Size Justification. >12,000 Pennsylvania ECPs completed the beta-version of *iLookOut*'s Core training between 2/15–5/18 <u>with no recruitment whatsoever</u>; and >50% of ECPs in Maine engaged in our pilot deployment of Micro-Learning. Hence, we anticipate being able to recruit ~12,000 ECPs to complete the new Core training during Y2-4, and conservatively estimate that over those 3 years 6,000 ECPs will both <u>complete the Core training</u> *and* <u>engage in Micro-Learning</u>, allowing us to assign <u>1,500 participants to each study arm</u>.

We estimate that the completion rate for the 3-hour Micro-Learning will be >70% for the ECPs in the *immediate* arm, and that for ECPs in the 3-, 6-, and 9-month delay arms the completion rates will be 65%, 60% and 55%, 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 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% (ie, 3,720 ECPs) for Aim 3, with 88% power to detect a 2% deviation in completion rate at a significance level of 5%, or 95% 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 adjustment for multiple comparison, using two-sided binomial test. As noted, multiple strategies will be used to recruit the target number of participants. But even if external events (eg, COVID-related disruptions) impede recruitment we are adequately powered (80% power for the complete rate estimation and 90% power for other feasibility measures) if we only reach 80% of target enrollment. For <u>Aim 1</u>, we will have ≥95% power (and ≥90% power if recruitment problems arise) to detect an effect size of 0.21 between any arms (assuming the same exponential attrition of ECPs) in mean knowledge decay (K^3 vs K^2), Micro-Learning impact on knowledge remediation (K^4 vs K^3) or sustainability (K^5 vs K^4), using 2-sided two-sample *t*-test at an adjusted significance level of 0.05. For <u>Aim 2</u>, the expected 3,720 ECPs will give us 95% power (and 90% power if only 80% of target enrollment is reached) to identify a significant effect size of 0.06 in behavior change of 3-month child abuse reporting using 2-sided paired t-test. Power calculation was based on *nQuery 4.0*.[130]

C.6.3 Data Analysis. Separate mixed-effects linear regression model[131] will be applied to assess (1) the *knowledge decay* effect based on the data collected at KBCAP[2] and KBCAP[3], (2) the *knowledge remediation* effect of Micro-Learning based on change from KBCAP[3] to KBCAP[4], (3) the knowledge retention effect using data at KBCAP[4] and KBCAP[5], and (4) the behavior change between any time points and how it is correlated to the knowledge score for Aims 1 & 2, after controlling for participants' baseline characteristics and work setting. In addition, the regression model will adjust effects for allocation blocks and the factors for stratification in the analysis to reduce group variability.

Given the nested structure of the data (e.g., multiple reports from ECPs nested within a child care program, and multiple child care programs within each program type), the random-effects in the model are designed to be multilevel to account for shared variance explained by child care program. It is a useful approach in such contexts (ie, non-independent data structure) that models both within-program and between-program changes in knowledge and behavior (measured via KBCAP[t]) over time. Demographic and site characteristics will also be included in subsequent models to examine potential conditional effects (ie, **moderation**) on intervention. The multilevel model will be fit in R using the *nlme* package[132] with restricted maximum likelihood. If singular fit error occurs, Bayesian multilevel modeling will be applied instead using *JAGS*.[133]

Figure 8 illustrates a typical multilevel model example that we will apply for data analysis. For these equations, Y_{ijk} is an outcome variable representing the change of knowledge or behaviors (ie, ΔKBCAP[t]) for individual k in intervention arm i and randomization block j; A_i is the effect for being in arm i; and B_j is the random effect for being in block j, respectively. $f(P_{ijk}, \mathbf{X}_{ijk})$ is the moderator effect from factors P and $\mathbf{X}$,

FIG. 8. MULTI-LEVEL MODEL EQUATION

$$Y_{ijk} = \mu + A_i + B_j + f(P_{ijk}, \mathbf{X}_{ijk}) + \varepsilon_{ijk}$$

$$f(P_{ijk}, \mathbf{X}_{ijk}) = \sum_p \theta_p * I(P_{ijk} = p) + \mathbf{X}_{ijk}\boldsymbol{\beta}$$

$$\theta_p = \sum_t \eta_c * I(T_p = c) + \mathbf{Z}_p\boldsymbol{\gamma} + u_p$$

where P denotes the child care program, and $\mathbf{X}$ is a multivariate vector of baseline characteristics such as age and gender that are all program-unrelated. θ_p is the effect for program p, which consists of η_c, the effect of the program type $T_p=c$, and the effect of other program-related factors $\mathbf{Z}$ such as size, QRIS rating, and rurality level. ε_{ijk} and u_p are the random effects of ECP intercept and program intercept, respectively.

The binomial test will be applied for outcomes in <u>Aim 3</u>. Mixed-effects logistic regression will assess the heterogeneity in child care programs and the effect of the time-delay on Micro-Learning following the Core training after controlling demographic and site characteristics. P-values and 95% confidence intervals (CIs) for

comparison between arms. For behaviors listed as the second type in **C.3,** p-values and 95% CIs will be adjusted for multiple comparison using Bonferroni correction. Because we will track when ECPs receive their first Micro-Learning activity, and when they complete Micro-Learning, we will also explore the impact of any lag time prior to engaging in Micro-Learning, and how long it actually takes ECPs to complete the full course of Micro-Learning.

C.6.4 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.[134] 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)[135] that address uncertainty when participants are lost-to-follow-up.[136-139] 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[140] to correct for any differences.

C.7 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. 9)

FIG. 9. STUDY ACTIVITIES TIMELINE	Y1	Y2	Y3	Y4	Y5
Revise micro-learning content	√				
Design and program gamified micro-learning	√				
Develop randomization and recruitment protocols, obtain approvals (IRB, Prof Devel. Credit, etc.)	√				
Participant recruitment and data collection		√	√	√	√
Analyze data and submit manuscripts					√

C.8 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 training and Micro-Learning were designed to minimize bandwidth requirements (via caching optimization). To account for lack of interest as a barrier to enrollment, we have partnered with influential stakeholders in Pennsylvania (see LOS from PA Key, OCDEL, PennAEYC, & BKC), 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 Micro-Learning. If ECPs don't initially respond, we will contact them via text or email (recorded during registration) and remind them Micro-Learning provides 3 hours of professional development credit at no charge. That said, *iLookOut*'s track record in both Maine and Pennsylvania suggests uptake will be strong. To account for and minimize potential contamination, study participants will: 1) be randomized to 1 of 4 study arms *after* they have completed Core training; 2) receive a unique user ID, and 3) be asked to not share access with other ECPs. Moreover, we do not expect prior uptake of the beta-version of *iLookOut*'s Core training to interfere with recruitment given the 20-25% annual ECP workforce attrition,[97-99] Pennsylvania requires child abuse training be repeated every 4 years, and Micro-Learning has never been introduced in Pennsylvania. We will, however query about prior training on mandated reporting, and control for that in our analysis.

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[132] 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 for any given ECP to 15 months (thereby minimizing participant burden); and 3) employ imputation and related estimation techniques to statistically manage attrition-related missing data (see C.5.4).

C.9 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 behavior regarding 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), we expect our study findings will 4) advance real-world strategies for preparing mandated reporters to identify and report suspected abuse. **Future studies** stemming from this work include examining the scalability of *iLookOut* with other states and/or other populations of mandated reporters, and designing gamified micro-learning strategies for other important topics that affect child well-being (eg, post-partum depression, substance use disorders, trauma-informed care).

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