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Development of the Prekindergarten Learning Receptiveness Assessment (LRA) Greenhouse: Process and Preliminary Findings

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Abstract

In this technical report we document the development and piloting of the Learning Receptiveness Assessment (LRA) Greenhouse for Prekindergarten. This technological tool was designed to prevent reading disabilities by supporting effective *assessment-guided instructional decision-making* by Preschool teachers. The LRA Greenhouse comprises a tablet-based formative assessment and app-enabled research-based intentional teaching activity plans, monitoring checklist, and reports; it also includes a support website containing printable curriculum materials, online training modules, and teacher resources. The LRA measures emergent pre-reading skill levels, classroom behavior regulation, and working memory processing capacity in the fall, winter, and spring to provide teachers with multi-dimensional information for addressing children's "high priority needs" in time for Kindergarten. Activity plans focus on building children's literacy and behavior regulation for managing social-emotional and task engagement experiences, which are crucial to adequately develop during the Prekindergarten-Kindergarten transition as children adjust to classroom-based learning. We share our development process, descriptions and screenshots of wrap-around supports and features, as well as findings from two pilot studies conducted across 12 classrooms. Our goal is to present lessons learned from developing a technological tool intended to feasibly and sustainably "bridge a gap" in reading disabilities prevention between early childhood and K-12 schools, and preliminary evidence of positive impact for both Prekindergarten children *and* their teachers.

Introduction

The LRA Greenhouse grew from work developing the Learning Receptiveness Assessment (LRA), a tablet-based assessment designed to quickly, reliably, and easily identify Prekindergarten children at risk for experiencing persistent reading disabilities (RD). We aimed to extend prior school-based research that has shown how reading difficulties can be appropriately identified and intervened with before they become disabling (e.g., Chard, et al., 2008; Compton, et al., 2012). However, similar approaches with younger children have yielded mixed results (e.g., Bailet, et al., 2009; Greenwood et al., 2013; Hindson, et al., 2005; VanDerHeyden, et al., 2007), suggesting there are unaddressed underlying issues. Through our LRA Greenhouse development work, we indeed discovered more deeply nuanced obstacles, which we discuss (along with the solutions we tried) in this technical report. Our hope to is to help advance the development of effective evidence-informed RD prevention tools for use in Prekindergarten by sharing our lessons learned and promising findings.

Learning Across the Kindergarten Transition

The broader Kindergarten transition (from Prekindergarten through the end of Kindergarten) entails an important and complex shift between home and formal schooling that shapes future learning success (Rimm-Kaufman & Pianta, 2000). This critical adjustment period involves more than a change in environment. Children must adapt to changes in interactions, contexts, routines, and connections; how successfully children can adapt influences how well they will respond to classroom instruction. “Learning” in a classroom is a fundamentally different enterprise than at home, with very different learning goals and ecologies (even when, for example, there is a shared focus on reading development). Together, Prekindergarten and

Kindergarten classroom experiences frame how children transform into student learners, but their philosophically different approaches to learning create a transformation gap that can impede smooth transitions.

For example, although Kindergarten signals a departure from early childhood and arrival into formal schooling, classroom learning is aligned with school expectations that have become increasingly skill-based and academic-focused (Bassok & Latham, 2017). The primary grades (Kindergarten through Second grade) are now a critical period for establishing timely reading development, thereby raising the importance of *early* reading difficulties identification to prevent the emergence of later, specific and disabling reading problems. In contrast, Prekindergarten classroom learning is aligned with home expectations because of their location in early childhood centers where children, as young as infants, are also served. This context directs their classroom focus and aims to educate the "whole child", instead of the more skills-oriented (school-aligned), "pre-reading child". Consequently, developing children's literacy in Prekindergarten is an important, but not central, priority. Prekindergarten teachers focus on providing well-rounded classroom learning experiences that promote social, emotional, physical and health, cognitive, and general learning competencies, much like families do at home (NAEYC, 2020). However, increased concerns about children's readiness to successfully learn in school highlights the pressing need for more coordinated strategies and enhanced alignment across the Prekindergarten-Kindergarten transition, to strengthen children's learning outcomes (Atkins-Burnett, 2007; Wesley & Buysse, 2003).

Strengthening Emergent Literacy Learning and RD Prevention

Despite important differences in the ways that children learn across the Kindergarten transition, we believe that Prekindergarten is a particularly fruitful time for preventing RD, before reading development problems become disabling, precisely because it bridges home and school "learning". Two years (Prekindergarten + Kindergarten) of coordinated support for developing robust reading skills may significantly reduce the incidence of reading difficulties experienced in school. More specifically, Prekindergarten is uniquely positioned to "level the playing field" as an approach to preventing RD prior to schooling—to help disentangle opportunity-to-learn disadvantages from "true" learning disabilities, a complexity that has long plagued the field (e.g., Algozzine, et al., 1982; Compton, et al., 2012; Fletcher, et al., 2007; Kavale & Forness, 2000; Lyon, 1994; Olson & Mealor, 1981; Swanson, 1991). Through the initiation of intentional, evidence-informed Prekindergarten strategies for addressing early learning difficulties as *all* children learn how to learn (Rimm-Kaufman & Pianta, 2000), those most vulnerable to experiencing RD can receive the additional and cohesive literacy learning support necessary for adequate prevention.

Structural Challenges. However, important differences in how early childhood is structured, compared to K-12 schools, create challenges to effectively creating balanced alignment and coordination between Prekindergarten and Kindergarten approaches to reading development. Although increased attention has been drawn to children's "readiness for Kindergarten", current Prekindergarten options comprise a mix of state-funded, for-profit, and non-profit programs that exacerbate existing inequities in children's early learning experiences. This hodge-podge of learning opportunities, in addition to at-home (non-classroom) care

options, hamper the early identification of learning difficulties in Kindergarten: There is too much disadvantage "noise" to capture a true "signal" of persistent learning difficulties.

Because children differentially transition to Kindergarten, more than just their skill levels are at play—varying abilities to receive instruction dramatically impact their academic performance. Thus, accurate and consistently measured early learning skills *and* their key contributors (e.g., learning-related behaviors, classroom engagement, executive functioning; McClelland & Morrison, 2003; Reilly & Downer, 2019; Williford et al., 2013), over time, are needed to clarify "high priority" learning differences across the diversity of Prekindergarten options (and effectively assist with disentangling "noisy" disadvantage). In doing so, a change to early childhood uses of assessment, beyond the typical diagnosis of developmental disabilities or meeting of program accountability requirements, is necessary. More specifically, adopting assessment use for guiding instructional practice, to precisely inform how children's learning needs are supported, would elevate current intentional approaches to Prekindergarten teaching to a more strategic level for preventing reading difficulties.

The LRA Greenhouse approach described in this Technical Report emphasizes the creation of an educational technological tool developed to enhance children's literacy development by helping Prekindergarten practices "reach up" to Kindergarten practices to build a more seamless pathway to reading success and prevent RD (in contrast to "push down" Kindergarten practices into Prekindergarten). That is, we began our work on this project knowledgeable about effective school-based practices while acknowledging chief assets within early childhood systems. Our team sought to utilize the strengths of both approaches to learning to erect a Prekindergarten-Kindergarten transition "bridge", by identifying and

adjusting evidence-informed strategies known to work in Kindergarten and working closely with Prekindergarten classrooms to build sufficient scaffolded supports for enabling a feasible fit within existing ecologies. Below, we describe key Prekindergarten and Kindergarten inequities that influenced the types of supports developed for the LRA Greenhouse, to help better "level" the Prekindergarten-Kindergarten playing fields.

Early Childhood Education Inequities. System-wide supports for ensuring high-quality learning between Kindergarten and Prekindergarten early childhood systems vary greatly. For example, Kindergarten teachers benefit from a long history of state-wide standards that outline expectations for high-quality instruction and learning success, and full administrative funding for curriculum and professional development. In contrast, within the United States, only 44 of 50 states have adopted early childhood learning standards, and 27 states have policies that require paid professional development (Friedman-Krauss, et al., 2019). In addition, unlike the requirement that Kindergarten teachers maintain a teaching license, only 50% of states require Preschool teachers to minimally hold a bachelor's degree and training certification (Friedman-Krauss, et al., 2019). Similarly, just half of states have "approved" or "recommended" curriculum to support widespread uses of effective instructional practices (Friedman-Krauss, et al., 2019). Thus, Preschool teachers face a distinct disadvantage in acquiring the knowledge, skills, and resources necessary to maintain high-quality instruction in the absence of concrete standards-based expectations, equal supports for professional development, basic requirements for certified training, and a state-wide consensus on recommended curricula and practices.

Without clear early learning standards and formalized curricula to align what children should know by the end of the Prekindergarten year, adequately preparing *all* children to start school is a formidable challenge given the diversity of children's experiences prior to Kindergarten. For example, among the nation's nearly 2.4 million children, about half receive Prekindergarten classroom experience outside of their homes (Snyder et al., 2019): 48.7% attend centers, 19.5% receive care in either a relative's home or another (non-relative) home, and 2.5% stay home. To promote successful transitions into and during Kindergarten, not only must curricula and instructional practices be flexible enough to serve diverse Prekindergarten experiences, but they must be linked to shared understandings and expectations for learning. Kindergarten classrooms benefit from district-centralized support for understanding the impact of standards on teaching and learning, whereas many Prekindergarten classrooms do not; consequently, idiosyncratic learning goals are often implemented across different classrooms (even within the same center). Thus, a fundamental aspect of RD prevention efforts during the Kindergarten transition must include building a shared pathway for developing reading readiness for Kindergarten despite diverse *pre*-kindergarten experiences.

The lack of coordinated and systemic support for Prekindergarten children's and teachers' learning impacts:

(a) teacher knowledge about what and how to prevent early learning difficulties,

(b) programming quality for ensuring children's adequate preparation for school, and

(c) retention of providers committed to contributing to children's incremental development beyond "day care" (e.g., high turn-over rates exist in Preschool classrooms; Whitebook & Sakai, 2003).

Therefore, Prekindergarten RD prevention efforts must be more than strategic producers of children who are "reading-ready", they must also enhance the quality of preschool programming more generally. In other words, to sustainably impact practice, RD prevention efforts must be feasible and flexible enough to enable effective implementation under varied and fluctuating conditions, and without great financial or time costs.

Intervention as Prevention Solutions. For more than two decades, researchers have documented the pivotal role that Prekindergarten literacy skill development plays on later reading achievement in school (Lonigan, et al., 2000; Lundberg, et al., 1988; Storch & Whitehurst, 2002). In particular, skill levels measured during Preschool remain stable into the primary grades (Cabell, et al., 2011; Storch & Whitehurst, 2002). Therefore, we believed that a two-pronged approach to "learning" during the Kindergarten transition was needed, consisting of supports for children's literacy development for directly preventing RD and equal focus on supporting Prekindergarten teachers' development as active caretakers capable of ensuring solid literacy foundations in time for school. We believed that the skills and strategies teachers would learn needed to be doable, sustainable, and practice-shifting (in ways that more closely align, but do not exactly match, with the reading instruction children receive in Kindergarten).

Children may exhibit weak literacy-related skills for a variety of reasons: disadvantages in the home, processing delays, behavioral difficulties that hinder learning, and/or inexperience (i.e., lack of opportunity to learn them). Studies of emergent reader skill profiles have revealed substantial heterogeneity in the performance patterns of children at risk for persistent RD (Cabell, et al., 2013; Ozernov-Palchik, et al., 2017). Because structured reading skill development occurs during the first year of school within the United States, Kindergarten

teachers are faced with an inconceivable challenge when wide disparities in receptiveness for learning exist. The failure to adequately and efficiently build key skills, particularly in Kindergarten, can have long-lasting, negatively cascading effects (Bast & Reitsma, 1998; de Jong & ven der Leij, 2003; Sáez, et al., 2016). Early intervention can help prevent problems from becoming RD (e.g., Al Otaiba, Connor, et al., 2008; Justice, et al., 2003; Torgesen, et al., 1999), but the consistency of instructional quality is an important mitigating factor that must be considered (Greenwood, et al., 2013; Justice, et al., 2008).

Importantly, it cannot be assumed that Prekindergarten teachers understand the pivotal role that high-quality pre-reading instruction can play in the prevention of early reading difficulties that place children at risk for RD. Given the weak alignment between school and early childhood systems, and inconsistencies in training requirements and supports for professional development, Prekindergarten teachers may not know how to strategically intervene in ways that help weak skills efficiently "get on track" in time for Kindergarten. To be clear, we do not support the view that Prekindergarten classrooms should become "the new Kindergarten". Rather, we recognize the underdeveloped importance of effective and efficient Prekindergarten intervention on critically underdeveloped literacy skills that, when left unaddressed, negatively impact children's later reading development. We believe in fully supporting Prekindergarten teachers to ensure that children can begin school with solid literacy foundations to reduce their RD risk.

***Assessment-Guided Instructional Decision-Making*.** Increasingly, schools engage in prevention frameworks that involve the use of assessment data for making instructional decisions, as part of an ongoing process to improve learning (Hamilton, et al., 2009). However,

providing access to reading achievement levels through assessment data is not enough—teachers must be clear about how to effectively interpret the results for setting meaningful goals and initiating beneficial supports (Stecker, et al., 2008). As an early example of a data-based decision-making model in the schools, Response to Intervention (RTI) frameworks pair universal screening practices with increasingly complex tiers of intervention for addressing children's different academic learning needs (e.g., Fuchs & Fuchs, 2006;). Adaptations within early childhood (e.g., Buysse & Pelsner-Feinberg, 2010; Greenwood et al., 2011) also employ a tiered model approach with collaborative problem-solving around assessment results and progressively intensive instruction to meet diverse learning needs. More recent prevention models have expanded the RTI academic focus to also build positive behaviors needed for learning, as well as outline principles for formalizing a school's cultural system, known as *Multi-Tiered Systems of Support* (MTSS; e.g., Sugai & Horner, 2009).

A recent position paper released by the Division for Early Childhood (DEC) Council for Exceptional Children suggests emerging interest in applying a MTSS approach in Prekindergarten (DEC, 2019). Although a discussion of this particular MTSS model is beyond the scope of this report, the approach includes an emphasis on (a) *what* is taught; (b) *where* instruction takes place; (c) *when* instruction is delivered; and (d) *how* instruction unfolds (DEC, 2019). The DEC proposed model, similar to RTI and MTSS models in primary schooling, identifies five important process steps for making data-based decisions about strategically moving children across three tiers of increasingly intensive support: gather information, document, summarize, analyze, and interpret. In addition, it explicates four key practices:

universal screening, differentiated instructional goals or outcomes, tiered supports, and ongoing progress monitoring (DEC, 2019).

Similarly, but independently, we aimed to develop the LRA Greenhouse to help teachers simply and meaningfully use assessment results to identify, address, and support "High Priority Need" RD risk factors during the Prekindergarten year for positively impacting children's emergent reading development in Kindergarten. Our primary goal was to help Prekindergarten teachers use evidence-informed practices (the "what") that were developmentally appropriate in feasible ways (the "where", "when", and "how") to promote timely learning. To do this, we emphasized the development of fundamental pre-reading (rather than exhaustive literacy) skills *and* classroom self-regulation behaviors needed for learning. The co-learning of these two competencies is especially important because of their long-term connection in how children approach literacy development, and in the process, shape how teachers support their learning (McClelland & Cameron, 2012; Pianta & Stuhlman, 2004; Sáez, et al., 2012). Children who demonstrate greater cognitive and behavioral control (or self-regulation) positively impact their skill development directly, and also indirectly through beneficial classroom relationships with peers and teachers, which makes their coupled learning an important mechanism for supporting school readiness (Blair & Raver, 2015).

We additionally highlighted children's learning needs related to cognitive processing constraints that hamper literacy development and are associated with RD (e.g., see Johnson et al.'s meta-analysis of learning disability cognitive processing deficits; Johnson et al., 2010). The identification of potentially interfering cognitive processing weaknesses can enhance teachers' understanding of specific ways to promote efficient learning, which is especially important for

generating progress. Thus, our goal was not to increase children's cognitive abilities, but rather, address "hidden" factors associated with learning difficulties. We believed that this multi-dimensional view of RD risk (and how each dimension contributes to different learning needs) was especially warranted during the Kindergarten transition when Prekindergarten instruction focuses on growing well-rounded school readiness. In addition to promoting school readiness, this approach is aligned with the early childhood field's desire for strategies that increase professional accountability in teachers, and social and emotional development in children (Wesley & Buyssee, 2003).

Finally, we assumed that Prekindergarten teachers could be trained to effectively and sustainably implement intentional evidence-informed practices if provided adequate supports that fit *their* needs. Preschool teachers use a wide-range of curricula and instructional practices (Pretti-Frontczak, et al., 2002). Therefore, the LRA Greenhouse was designed to flexibly co-exist with teacher practice; as such we view it as a supportive and generative tool for simultaneously enhancing Prekindergarten literacy skills development for all children *and* preventing RD for the most vulnerable children with identifiable "high priority" needs. We worked closely with Prekindergarten teachers to streamline and scaffold their intentional instruction, providing not only pre-implementation online training, but also in-the-moment supports. Technology was leveraged to simplify assessment administration, assessment results access, interpretation and management, instructional delivery, and support for generating learning progress. Below, we describe the development, field-testing, and associated data collection of the LRA Greenhouse. We discuss the LRA followed by the wrap-around Greenhouse support components.

LRA Development

Initial Test & Item Development

Administration Modality Decision-making

Addressing the need for teachers to have immediate access to assessment information for guiding instruction was a primary LRA development goal. Consequently, test item delivery through tablets was an intentional administration strategy for four main reasons. First, the tablet medium allows teachers to streamline data collection, ensure its integrity, and provide real time data for use in facilitating instructional programming. Teachers have limited time for test administration and data-based decision making (Roehrig, Duggar, Moats, Glover, & Mincey , 2008). Because the LRA is a self-contained tablet-based tool (using audio guidance and image selection), it requires minimal training for test administration (Sáez & Pilger, 2016), making it a more flexible option for gathering information about children's abilities than classroom observation methods.

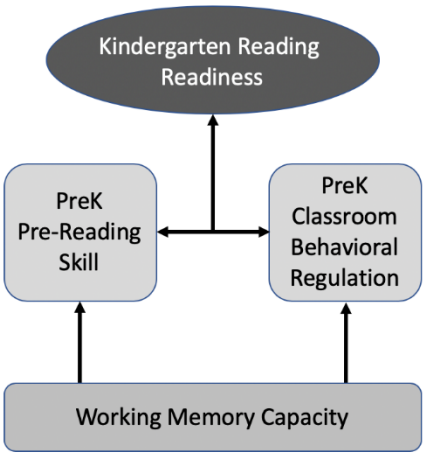
Second, we also anticipated greater efficiency through the use of computer technology, compared to paper-based performance assessments, because multiple children can be simultaneously assessed in small groups (with headphones) using the LRA. For example, Carson, Gillon, and Boustead (2011) found that a computerized assessment administered at school entry was more efficient (taking 20% less time) than a paper-based version administered with an examiner. Prior research documents the benefits of touch screen technology use with young children to predict early risk for learning and attention difficulties (Berger, et al., 2000; Gaggi, et al., 2012; Groot, et al., 2004).

Third, we anticipated greater feasibility for preschool classrooms with tablet administration because these devices are generally affordable ($50 - $100 each) and portable. Unlike schools, prohibitive material costs can prevent early childhood centers from using beneficial tools, particularly if they lack government funding. Tablets have a variety of uses, beyond test administration, that may provide added investment value for early childhood sites.

Fourth, image-based tablet administration is developmentally appropriate, and a pervasive technology in many Prekindergarten homes. Via technology, even complex concepts can be reliably assessed easily through simplified language, format repetition, automated guiding prompts, and basic response demands. For example, children can respond to all items using the touch of their finger (i.e., no mouse or keyboard is required), enabling them to fully focus on the mental aspects of each task.

Measurement Domains Identification

The development of the LRA was initiated in 2015, based on an increased need within the state of Oregon for a statewide Kindergarten assessment to evaluate school entry skills, as well as better tools for preventing Kindergarten (and beyond) learning difficulties. Three primary constructs served as the basis for LRA measurement: pre-reading skill, classroom behavior regulation levels, and working memory (WM) capacity. We focused on these constructs because of their unique, yet related, contributions to RD risk in young children. The figure (on the right) depicts these construct relations.



Pre-reading literacy skills and behavioral regulation are critical contributors to Kindergarten reading readiness, both of which are enabled by WM capacity to effectively develop skills and regulate behaviors while learning. Weaknesses in emergent reading skills and classroom behavioral regulation can both impair reading development by recurrently hampering learning, and their relation to each other is reciprocal (Goble et al., 2017). For example, first-grade children with RD exhibit greater behavior problems in third grade than their peers, and children exhibiting poor task engagement are more likely than their peers to experience reading difficulties in third grade (Morgan et al., 2008).

Coie and Krehbiel (1984) described four ways in which academic and behavior problems interact to disable learning: (1) behavior challenges limit instructional access, (2) limited attention hinders both behavioral and instructional efforts, (3) early academic challenges increase social rejection, and (4) inadequate progress of academic interventions leads to poor behavioral responding. The second interaction in the list above aptly characterizes how WM deficits undermine behavior and academic learning through its moderation of children's attention as they learn to read (Kofler, et al., 2018; Sáez, et al., 2012). For example, weak WM capacity can impair children's learning opportunities by repeatedly limiting the information they receive, attend to, and express (Morgan, et al., 2019). Furthermore, WM predicts reading achievement and behavior regulation (Nguyen & Duncan, 2019), highlighting its importance as another important early indicator of RD risk. Below, we operationalize the LRA constructs (pre-reading skill, behavior regulation, and WM) and describe how they are measured.

It is important to note that the LRA was designed to capture *early risk* for RD in a multi-dimensional, developmentally appropriate manner. We focused on critical precursors (pre-

reading skills) *and* learning supportive factors (behavior regulation and WM processing capacity) that, when underdeveloped, create hinder reading skill development. Beginning Kindergarten with significantly weak pre-reading skills, however, does not solely determine the emergence of RD. Rather, it is the combination of significantly weak skills and learning-related behaviors (both of which are influenced by WM processing capacity) that suppress efficient development and undergird increasingly complex learning difficulties that can become disabling (and hard to "catch up" with on-grade learning expectations; Torgesen, 1998). Thus, we assumed that providing Prekindergarten teachers with information and training in these three areas (emergent pre-reading skill, classroom behavior, and executive WM processing) would create separate, but related, directions for making impactful instructional decisions to address children's early learning needs in time for more successful starts to Kindergarten.

Pre-reading literacy measurement was composed of alphabet knowledge and phonological sensitivity tasks, based on the National Early Literacy Panel findings (NELP, 2009) and RD research base. Phonological sensitivity refers to the ability to detect and manipulate phonemes in spoken words (Anthony, et al., 2003; Treiman & Zukowski, 1996). This sensitivity ranges along a continuum, in which listeners become more refined in their processing of smaller word parts (e.g., blending or segmenting words > blending or segmenting onset/rime word parts > blending or segmenting phonemes; Anthony & Lonigan, 2004; Phillips, et al., 2008; Schatschneider, et al., 1999). Greater sensitivity benefits sound-to-print mapping through more refined sound detection and linguistic manipulation capabilities (i.e., playing with sounds), an ability used in emergent decoding (Lonigan, et al., 2000; Wagner, et al., 1997).

In addition, effective beginning readers rely on alphabetic knowledge to translate oral language to print. Delays in the development of phonological skills can have long-lasting impacts on reading development (Boscardin, et al., 2008; de Jong & van der Leij, 2003). Letter name knowledge develops first and facilitates the emergence of letter sound knowledge (Kim, et al., 2010; McBride-Chang, 1999), providing a necessary alphabetic label for phonetic sounds. Letter sound knowledge, however, more strongly predicts beginning word reading (Schatschneider, et al., 2004), and weaknesses in Kindergarten create early and lasting disruptions to reading development (Boscardin et al., 2008; Sáez et al., 2016). Thus, we considered letter name and letter sound knowledge separately as measurement targets.

Behavior regulation measurement was composed of *task* and *prosocial engagement* subdomains. Task engagement emphasizes factors that impact on-task behavior and task completion such as: sustained attention, memory for routines, demonstrations of confusion, and independent completion of multiple steps. Prosocial engagement emphasizes factors that impact active classroom participation, including: cooperation, sharing, emotional self-control, and help-seeking. These subdomains were drawn from research focused on WM processing difficulties associated with learning disabilities, Kindergarten readiness, and early childhood approaches to learning (e.g., Bierman, et al., 2008; Bronson, et al., 1995; Duncan, et al., 2007; Gathercole, et al., 2008; La Paro & Pianta, 2000; McClelland & Morrison, 2003; Rimm-Kaufman, Pianta, & Cox, 2000) because of the significant challenge that children face when transforming into successful classroom learners for school (Rimm-Kaufman & Pianta, 2000). These two aspects of classroom engagement interact, but also play separate roles in how children self-regulate and learn.

Emerging behavior regulation in the classroom (and in particular, the ability to regulate task completion and prosocial relations within the classroom) are vital to the quality of a child's classroom experience (Hamre & Pianta, 2001; Williford, et al., 2013). The effective execution of "learning-related" (McClelland, et al., 2006) and prosocial behaviors reflects the crucial ability to balance one's emotional and cognitive state required for self-regulation and internal well-being (Blair & Diamond, 2008). Effective engagement of goal-directed learning activities requires that children increasingly attend to and control their behaviors to adopt valued classroom routines, school-wide rules, learner "habits of mind", and social "rules of engagement". Such engagement involves integrated cognitive and emotional circuitry management for responding to these demands (Bierman, et al., 2008; Blair & Diamond, 2008). Thus, behavioral regulation of both task and prosocial engagement encompasses the control and maintenance of arousal states in support of goal attainment, and often they work in concert during active learning (when learning has an intentional goal orientation).

Better behavioral regulation reliably predicts better beginning reading outcomes (McClelland, et al., 2000). In addition, emotional regulation also predicts Kindergarten achievement (Howse, et al., 2003). Self-control substantially impacts the quality of a child's classroom experience through its shaping of effective interactions during cooperative group work, through listening to others and following directions, and by taking turns and sharing, which invite future social-learning opportunities. Because the ability to regulate one's behavior is relatively stable (McClelland & Morrison, 2003), it helps to cultivate motivation, peer acceptance, and teacher support. For example, higher "effortful control" predicts better Kindergarten reading and school enjoyment (Gaias, Abry, Swanson, & Fabes, 2016), along with

social competence and likability among peers (Denham, et al., 2003). Positive teacher-child relationships are also associated with better beginning reading achievement over time (Pianta, et al., 2008). Effective behavioral regulation is associated with better school adjustment through its positive effect on the emergence of internalizing (sadness, anxiety, and social withdrawal states that can lead to inattention) and externalizing (aggressiveness, impulsivity) problems (Eisenberg, et al., 2001).

Working memory **(WM)** measurement comprised a typical span design (Conway, et al., 2005), in which information to be remembered is presented, followed by a distraction (to invoke retention + concurrent processing), and then recalled. Our view stems from General Capacity Models (e.g., Turner & Engle, 1989), in which the ability to concurrently "work with" different mental information is based on individual differences in WM capacity, independent of the specific kind of information (e.g., linguistic, emotional, semantic, or visual-spatial) being processed (Courtney, 2004). Our use of WM span in the LRA corresponds with Baddeley's conception of the central executive (Baddeley & Hitch, 1974), which is a domain-general capability.

As one of three critical "executive" functions (Miyake, et al., 2000), WM plays a particularly important role in learning because it significantly determines processing capacity for attention (Engle, 2010; Swanson, et al., 2006). Strong WM results in efficient mental processing of multiple pieces of information, effective resistance to interfering thoughts or stimuli (or focused attention), and the successful completion of goal-directed complex task performance (e.g., information integration, engaging in multi-step activities). Weak WM increases one's susceptibility to mental overload, often manifested as distractibility,

forgetfulness, confusion, and feeling “overwhelmed”. Low WM capacity is a stronger predictor of later achievement outcomes than IQ (Alloway & Alloway, 2010) and is associated with RD (deJong, 1998; Gathercole & Pickering, 2000; Siegel & Ryan, 1989; Swanson & Sáez, 2003). WM is not recruited for the direct retrieval of long-term stored information, but instead, enables the “working with” of information that underlies coordinated thinking, and is separate from short-term retention (Bayliss, et al., 2005). This unique “general” role, when weak, can disrupt learning in ways that “quietly” impair effective learning (e.g., by impeding mental processing needed for complex task activities and self-regulation).

By Prekindergarten, the three core executive functions (WM, inhibitory control, and mental shifting/flexibility; Miyake et al., 2000) emerge as key players in how children learn, including by regulating attention (Garon, Bryson, & Smith, 2008). WM plays a critical role in attention regulation by keeping necessary information current and “in mind” despite distractions or interference (Conway, et al., 2005). Through children’s emerging abilities to simultaneously process different information, they gain greater control over their internal experiences (i.e., feeling and thought attentional regulation) and behaviorally regulated responses, benefitting their learning within a school environment (Blair & Diamond, 2008).

WM mediates the relation between classroom inattention and poor reading (Rogers, Hwang, Toplak, Weiss, & Tannock, 2011). Inattention is a stable predictor of later poor reading achievement (Duncan, et al., 2007), and has been found to interfere with phonological processing skills needed for reading development through its role in Kindergarten children’s failure to adequately attend to the phonemic structure of language, resulting in protracted poor word recognition (Dally, 2006). However, low WM is also associated with teacher ratings

of behavior dysregulation, including student inattention, high distractibility, problems with monitoring work quality, and difficulties with problem-solving (Gathercole, et al., 2008). Relatedly, and crucial to LRA development, Preschool children who have difficulty managing their "learning-related" behaviors are often considered less "ready to learn" in Kindergarten by teachers (Lin, et al., 2003), and students with weak WM in Kindergarten continue to experience these difficulties into elementary school (Alloway, et al., 2009). The role of WM and attentional, then, on Kindergarten reading is both general (or "executive"), and skill specific (Welsh et al, 2010).

Individuals with weak WM capacity are also less able to suppress their emotions (Schmeichel, et al., 2008), which makes behavior regulation challenging, particularly when emotional arousal is high. There are, however, environmental factors, such as noise level, that can also subtly increase children's cognitive load and weaken their ability to effectively function in the classroom. Even among children as young as three, how well background noise is filtered out predicts later reading outcomes (White-Schwoch et al., 2015). In other words, loud classrooms contribute to cognitive "noise" that children must inhibit in order to focus on learning. For children with weak WM capacities, the effort of focusing attention to learn while also inhibiting competing distractions makes them more likely to become mentally "flooded" or overwhelmed because their "brains become too full" sooner. Therefore, in our view, WM processing plays a critical role in both new literacy skill development (through the concurrent processing needed to make conceptual and linguistic connections in learning) and behavioral regulation needed for effective classroom learning. We note that WM processing *span* is used, rather than other WM indices, because of its interpretation ease in relation to implementing

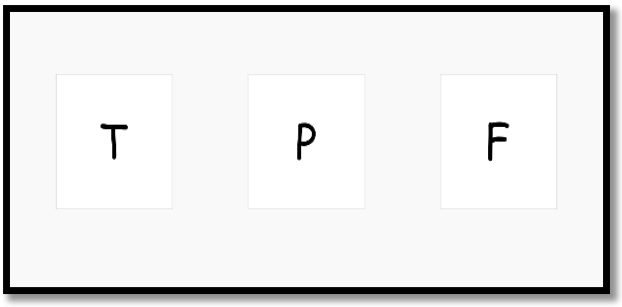
environmental “thinking support” strategies to aid Prekindergarten learning (Conway, et al., 2005).

Item Generation

All ***Pre-reading*** items were formatted for audio-visual multiple-choice delivery, using three picture-based response options shown with audio prompting. For the phonological sensitivity items, each image is announced when it is shown on the screen to ensure children’s correct recognition of all response options. A practice item with bifurcated response feedback is provided to clarify task demands (i.e., children receive oral and visual feedback on their response, to either validate a correct response or gently reinforce the correct answer for an incorrect response). All items are scored 0 (incorrect) or 1 (correct), and summed to compute a total score.

We based the range and depth of ***Pre-reading*** items on the Common Core State Standards in Kindergarten (later refined using the Oregon State Early Learning Guidelines; Oregon Department of Education, 2016), and published reports of item difficulty (e.g., Drouin, et al., 2012; Justice, et al., 2006; Phillips, et al., 2012). A Kindergarten teacher and elementary reading specialist were hired and trained to assist with item writing, as early reading content specialists. Ninety-six literacy items (48 alphabet knowledge and 48 phonological sensitivity) were initially developed in the item bank, which were reduced to 24 working items (16 alphabet knowledge and 8 phonological sensitivity). Working items were selected based on their capacity for imaging, perceived difficulty (based on easy, medium, and hard categorizations), and “fit” with the multiple-choice format (enabling one correct answer and

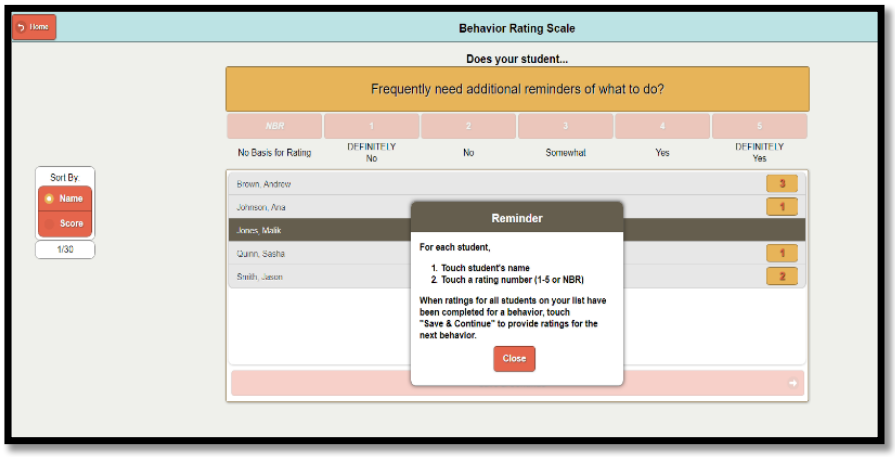
two plausible distractors). Each distractor was developed to be either phonologically or visually similar to the correct choice. See Pre-reading item examples below.



We drew the initial list of behaviors for the ***Behavior Rating Scale (BRS)*** from research literature (e.g., Bronson, et al., 1995; McClelland & Morrison, 2003), which was reviewed by a Kindergarten teacher for wording, developmental appropriateness, and clarity. The revised list was then evaluated in five preschool classrooms (*n* = 75) by two researchers to examine the extent to which listed behaviors could be easily observed in Preschool settings. Classrooms varied widely in educational philosophy, ranging from daycare (without clear instructional objectives) to pre-academic (with clear daily instructional goals), with play-based classroom structures falling in between. Two systematic observations, within one month, were conducted at each site to examine whether behaviors were observable across: (a) diverse sites, (b) genders, and (c) common routines (e.g., Circle, Snack, Project, Transition, Story). In addition, each behavior was evaluated on the extent to which a teacher might feasibly and reasonably notice variation among children given the frequency of occurrence, bustling environment, and differing task elements. Teacher delivery of directions for these activities was also examined across sites to clarify potential variation and constraints on children's opportunities to learn pre-academic skills and prosocial behaviors in the classroom (e.g., the extent to which multi-step directions are used, thereby shaping task engagement requirements, across settings).

A five-point scale (1 = *definitely not*; 5 = *definitely yes*) was used for the behavior ratings, including an option for "no basis for rating" (0), with the generic prompt, "Does the child…". Items were presented by a displayed target behavior (e.g., "…need additional reminders of what to do?"), in which teachers rated their entire class before moving to the next behavior prompt. This whole-class design was used to help minimize responder drift (by reducing the potential for "halo" or "horn" effects for specific children) and to increase rating completion

efficiency by keeping teachers' attention focused on the same behavior for the entire class at a time. The ***BRS*** contained 30 items (15 task engaged and 15 prosocial behaviors), with a total possible score of 150 points, 75 points per subdomain. See a BRS item example below.



The ***Working Memory (WM)*** task was developed using a span design for two main reasons: (1) span accounts for performance even when processing efficiency is controlled (Gavens & Barrouillet, 2004), and (2) the theorized, positive association between span and information quantity that can be held concurrently in mind directly applies to classroom functioning (making it more useful in practice for assessment-guided instructional decision-making). Thus, a larger obtained span confers a greater capacity for mental processing, even in children as young as four years old (Gathercole, Pickering, Ambridge, & Wearing, 2004). Conversely, a smaller obtained span reflects a more limited capacity for mental processing, and a corresponding need for teachers to provide "thinking supports" to facilitate strong learning.

Using a definition of "holding information in mind while processing something else", the WM task was designed with the following three steps for gradually increasing set sizes: (1) children are shown a *stimulus* ("Buddy", a juggling monkey who drops 2 to 5 objects, depending

on the span set size, up to 5 levels), (2) a *distractor* (Buddy doing something novel on the screen, like driving a car), and then (3) prompted to *recall* (the selection of Buddy's dropped items in the order that he dropped them). Examinees are provided with three practice items with bifurcated response feedback to clarify task demands before proceeding to the actual test. In this way, practice items teach children to attend to and remember (a) what Buddy is juggling and the object dropped, (b) multiple objects that may be dropped, and (c) the order in which objects were dropped. WM test items are scored 0/1 with total span scores ranging from 0 (unable to accurately process 2 items concurrently with distraction) to 5 (able to process 5 items concurrently with distraction). To minimize frustration, a stop rule was used to cease testing when 2 of 3 items are wrong within a level. See a WM practice item example, below.

Field Testing & Item Refinement

Internal beta-testing was undertaken for each phase of LRA test and item development. The initial prototype was developed in black and white, and compared with black and white paper and pencil administration with *n* = 50 Kindergarten students to examine:

(a) the extent to which tablet technology was feasible for use among younger children,

(b) the efficiency of paper-pencil compared to audio-guided tablet administration, and

(c) the motivational impact of black and white presentation given the age of examinees.

For an initial field-test, children were drawn from four classrooms located in Southern Oregon, children in two AM and two PM half-day classrooms were counterbalanced and assigned to either individual paper-pencil or tablet administration.

Children rated their interest in completing items before and after administration, using a 1 (*strongly dislike*) to 5 (*strongly like*) point scale. In general, children rated their experience similarly (4/5) pre- and post-administration. Item analyses (of time and performance) suggested specific areas for refinement, and observations of student performance indicated that children were able to complete the tablet version with minimal teacher support and that the bifurcated practice item feedback functioned as intended. Children interviews revealed an expressed desire for the assessment to more closely approximate personal experiences with tablets and smartphone games by using colored images, which explained the similar ratings found across administration type (i.e., personalized human administration was rated as positively as black and white tablet technology use).

A revised version of the LRA ***Pre-reading*** items was subsequently developed using colored images, and field-tested in two Kindergarten classrooms (one AM and one PM, with *n* = 42 students) in small groups of 4-6 children using headphones. Children, on average, completed the 60-item (including 6 practice items with feedback) test in 13.70 minutes. From this work, important implementation needs, such as the use of visual barriers, smaller headphone sets, and the role of prior experience for “touching” the correct answer were identified (e.g., tentative/hesitant, swiping, or touch users were observed to differentially respond to audio

commands). Additional item analyses (of time and performance) indicated areas for test item refinement. In addition, we solicited feedback from three Kindergarten teachers on test items and screen elements (considering functionality, design, and user-friendliness).

After item refinement, a third field-test was conducted with *n* = 15 Prekindergarten children (in small groups with "kid-sized" headphones and visual dividers) using a shortened test form that included representative "easy" items from the Kindergarten battery. Our goal was to examine: (a) whether tablet administration was similarly feasible for Prekindergarten children and (b) the extent to which anchor pre-academic and behaviors items could be shared between the two age groups. On average, Prekindergarten children responded to items within 4.6 seconds, one second slower than Kindergarten participants (when the same "easy" items were compared). In general, Prekindergarten children completed the assessment similarly to Kindergarten students in small groups; however, touch submission reinforcement, task focus redirection, and reassurance during uncertainty were more frequently observed, as expected for younger and less experienced Prekindergarten children (only about 25% reported previous tablet use). Administration observations indicated that children similarly understood and positively responded to practice feedback (Sáez & Pilger, 2016).

In addition, three Prekindergarten teachers evaluated the ***BRS*** items. Teachers were asked to indicate which children were perceived to be "high, average, and low" achieving within their class, which was cross-checked against their initial behavior ratings. Teacher feedback was used to refine item wording to better fit early childhood classroom activities. As a result, five behaviors were revised, unclear language was refined, and modifying words were moved to the beginning of all prompts (e.g., "Gets distracted easily" was changed to "Easily gets distracted").

Initial field-testing of the ***WM*** task included cognitive labs conducted with *n* = 4 elementary school children, which indicated that the original test item design using same-colored abstract and conventional shapes would be too difficult for Prekindergarten children (e.g., cognitive lab interviews revealed a "common object renaming" strategy used for recall). Consequently, all non-practice test items were transformed into common objects (e.g., the triangle was changed to a strawberry) that were thematically related (e.g., fruit) to enhance the task's developmental appropriateness. The revised version was field-tested with *n* = 3 Kindergarten and *n* = 3 Prekindergarten children. Practice and test items functioned as intended and we found a typical range of span performance (0-3) for this age group.

Scale Development

Teachers may choose to administer either the ***Pre-reading*** or ***WM*** tasks first, and item delivery can be stopped and resumed at any point. To begin, teachers select a child's name from the pre-registered class list and then the task. All child-administered tablet tasks begin with a simple multiple-choice image matching item (with bifurcated feedback) to familiarize children with the assessment format. When children complete a task, an image and audio file let them know that they are "all done!" Intermittent "keep going" audio prompts are provided at 30-second intervals for items in which no response has been submitted. When one task is completed, teachers unlock the screen to complete the two-step process again for the subsequent task. Teachers complete the ***BRS*** within the same testing window. They may enter and exit at any point after a given behavior has been completed for the class (i.e., ratings for all class members must be saved prior to exiting the BRS). Upon return, teachers begin rating after

the last completed behavior. Teachers may complete this measure using a tablet or computer (through the support website, described below in the LRA Greenhouse section of this report).

Preliminary Risk Cut-Score Determination

The final version of the LRA battery was field-tested in a Prekindergarten class with *n* = 15 children to identify an initial RD risk cut-score. This class was again administered the battery at the end of the school year. On both occasions, children were assessed in small groups within a one-week period, and the BRS was completed by the teacher within that same time frame. Children engaged in initial drafts of Greenhouse activities (described in the LRA Greenhouse section below) between the two assessment time points. An in-depth teacher interview was conducted to ascertain the teacher's perception of score meaning. For example, the teacher was asked about her understanding of specific scores in relation to others, how she could use the information to support enhanced learning, and likely un-assessed factors contributing to score results. In addition, the teacher ability-grouped her class for each domain and provided extended descriptions for characterizing different performance levels within her class. Descriptive item analyses were conducted using combined data additionally drawn from *n* = 33 Prekindergarten children during prior field-testing, to inspect performance variation on final items within the literacy measure. $Time_1$ and $Time_2$ differences were compared, and teacher-derived group differences were examined to create an initial "risk" cut-score.

The initial ***Pre-reading*** cut-score was determined based on preliminary analyses of the score distribution for *n* = 30 children across fall, winter, and spring time points. A broad "risk range" was targeted for performance between the 20^{th} and 40^{th} percentiles, consistent with the RD risk literature (e.g., Simmons, et al., 2008). We used 10 as the cut-point score across all

three time points to gradually narrow risk identification to between the 20th and 30th percentiles by the end of the year, and provide teachers with a consistent and clear benchmark for interpreting performance (with the goal to subsequently conduct IRT analyses with larger samples). Appropriately, follow-up examinations indicated that the risk cut-point fell between the 40th and 50th percentiles in fall, at the 30th percentile in the winter, and between the 20th and 25th percentiles in the spring. Children scoring below the Pre-reading cut-point are identified as at-risk on the "High Priority Needs" Report by name in **black**. For at-risk children whose WM performance is also zero (indicating that at the first level, at least two items cannot be held in mind despite distraction), their name is shown in **red** (instead of black) to indicate *higher* priority literacy-learning support needs (i.e., pre-reading skill + WM processing).

Similarly, for the ***BRS***, we targeted the 25th percentile as a stable cut-point (total score of 93 in the fall) for low behavior regulation that increases children's risk for disrupted reading development. Total scores (rather than subscale scores) were used; however, the cut-point later proved unsatisfactory during piloting and is currently not used to identify RD risk. As a final check on the appropriateness of "RD risk" classification, we examined face validity (i.e., score meaningfulness based on teacher perception of classroom experience), and asked four teachers to rank-order children in their classes into ability groups for each of the measured LRA constructs and provide defining characteristics for each group. Teacher RD risk grouping, on average, agreed with the LRA risk identification 82.2% of the time (Hinkle, et al., 2018).

Internal Consistency

Cronbach's alpha was computed to examine internal consistency for the LRA ***Pre-reading*** and ***BRS*** measures. Because of the ***WM*** span design, all items were not administered to all children (i.e., testing is stopped with two errors within a level), and thus, alpha could not be computed. For the 26-item ***Pre-reading*** measure, alpha was .79 in fall, .73 in winter, and .76 in spring. For the 30-item ***BRS***, alpha was .97 in the fall, .94 in the winter, and .95 in the spring (see Appendix, Table 3).

Cross-Measure Relations

Within-measure Pearson correlation associations were examined across fall, winter, and spring administrations. We summarize these findings in the detailed correlation matrix shown in Table 4 of the Appendix. ***Pre-reading*** inter-correlations ranged from .73 - .80 across seasonal administrations. Within the ***BRS***, task engaged item correlations ranged from .74 - .81 and prosocial engaged item correlations ranged from .81 - .89. ***WM*** span score inter-correlations were weaker, ranging from .17 - .28, a challenge previously reported by other researchers (Cowan, 2010; Gathercole, et al., 2004).

Relations between measures were also examined. ***Pre-reading*** correlated r = .18 - .56 with ***WM*** span scores, r = .38 - .69 with task engaged behavior ratings, and r = .36 - .59 with prosocial engaged behavior ratings (r = .40 - .71 with the ***BRS*** total score). ***WM*** span scores correlated r = .05 - .53 with the ***BRS*** total score. Task engaged behavior ratings correlated r = .12 - .49 with ***WM*** span scores and r = .52 - .77 with prosocial engaged behavior ratings. Prosocial engaged behavior ratings correlated r = -.05 - .57 with ***WM*** span scores. Winter ***WM*** scores yielded unexpectedly low associations with the other measures.

Teacher Report

For all implementing classrooms, we conducted systematic interviews to gather information about Prekindergarten teachers' perceptions of the LRA. In general, teachers reported positive perceptions of their experience using the LRA regarding test completion (child tasks and teacher behavior ratings), content, and score use. See Tables 5 - 9 in the Appendix for survey responses concerning various aspects of the LRA Greenhouse user experience (including specifically about the assessment component). In general, teachers positively rated the LRA's efficiency, ease of navigation, and usefulness of results. They unanimously agreed that measured pre-reading skills, classroom behaviors, and WM span were developmentally appropriate. Below, we provide representative quotes that capture the consistent themes found.

"The assessment was quick and the information got back to you quickly. I liked being able to assess them on the tablet- so I wasn't assessing them. I didn't have to score it and [could just] review it."

"I used them [LRA scores] as a weekly reminder to see those ones that are struggling. If you're not focused on them, you can forget, so the scores helped me see who I needed to focus on, who needed extra support- it helped me be pro-active."

"It's good to know that they're getting it and the ones who didn't [over time], so you can keep working on it. Because it [assessment] was more often in the year, I could keep tabs on how they're doing."

"The curriculum had it ready to implement and I had a real [assessment] score for me to understand, and then there was 3 terms to work with, and I could see the progress."

"When you're a teacher, and in constant motion, it's hard to see the overall big picture of each child's development. [The reporting] gave me a starting place at the beginning, and middle of the year."

Greenhouse Development

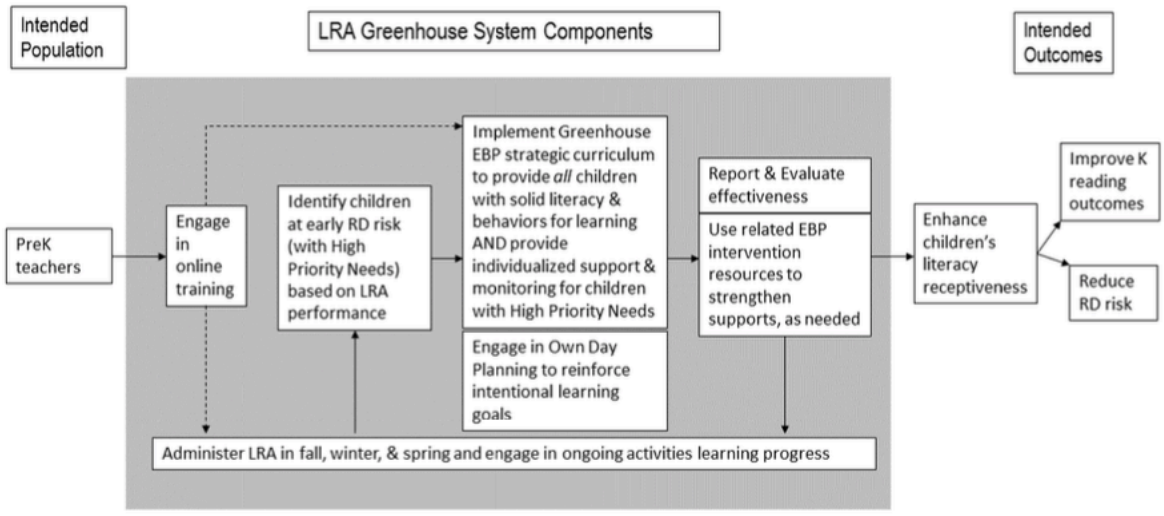
In 2016, we were awarded funding from the Office of Special Education Programs (OSEP) for a project entitled "Project ICEBERG" (#H327S150007). The purpose of Project ICEBERG was to identify implementation strategies for sustainably supporting evidence-informed practices across the Kindergarten transition using the LRA. Because the LRA was designed to facilitate Prekindergarten data-based decision-making, we aimed to build technology- and classroom-based strategies for empowering teachers to make effective "assessment-guided instructional decisions" for reducing children's risk for RD (Buysse & Pelsner-Feinberg, 2010; Greenwood et al., 2011), as well as generally strengthen children's literacy skills in time for Kindergarten. In addition, we strived to strengthen systems-level field supports for capable implementation of data-based decision-making practices within early childhood (Ratsavong, et al., 2017). Our primary goals included refining the LRA and developing reports to facilitate Preschool teacher reflection and action about children's "High Priority Need" risk factors, as well as identify and incorporate strategies and supports to sustainably and feasibly guide instructional decision making without unwieldly investments in training.

Therefore, our work was not focused on developing a "new" intervention; instead, the focus was on helping teachers to effectively implement practices known to work (Diamond, Justice, Siegler, & Snyder, 2013). This included developing and refining: an app for housing the assessment, reports, and instructional supports to enable efficient and effective teacher action; a support website to provide computer access for the tablet app, house online training modules, provide curriculum access, and store guidance products to scaffold feasible and

sustainable implementation; and all necessary content to enable effective assessment-guided instructional decision-making.

Theory of Change Model

Our theory of change model (see figure, below) reflects four critical teacher actions and three intended outcomes to help achieve the goal of successfully implementing the LRA in Prekindergarten classrooms. First, teachers participate in online training for educating them about their roles as decision-makers to prevent RD and key assessment-for- instruction decision-making concepts. Second, teachers administer the LRA at designated seasonal time points to identify early RD risk ("High Priority Needs") and provide intentional instruction as children engage in curriculum activities. Third, teachers implement Greenhouse activities with all children and individualize prompting, support, and monitoring for children identified with High Priority Needs. Fourth, teachers evaluate children's progress toward successful reading development outcomes and reduced RD risk and access additional resources to extend their understanding and use of targeted practices.



This theory of change model led to the development of a *5-step assessment-guided instructional decision-making model*: *Assess* (emergent pre-reading, behavior regulation, and working memory levels), *Interpret* (reported performance), *Instruct* (using intentional evidence-informed strategies for all), *Monitor & Evaluate* (the progress of children, particularly those identified with High Priority Needs), and *Individualize* (provide even greater support, as needed, based on the prior two steps to keep progress moving in the right direction). Assessment is ideally conducted in the late fall (after teachers have established their typical classroom routines), winter, and spring, during program-established two-week time frames, with curriculum activities implemented nine days per month between the fall and spring assessments (i.e., across six months). This model was originally based on data-based decision-making frameworks found in the research literature (e.g., Chard et al., 2008; Fuchs & Fuchs, 2006; Schatschneider, et al., 2004) and was later informed by survey, focus group, and interview work conducted across 10 early childhood sites during field-testing.

Strategic Supports Identification

Feedback from the Field. The types of supports most needed to scaffold effective assessment-guided instructional decision-making in Prekindergarten was examined through both field surveys and interviews (see Technical Report 1602 for "Innovation Needs Survey" findings; Irvin, et al., 2016). This was a crucial, initial step for exploring the feasibility and "fit" of the LRA Greenhouse for Prekindergarten use, to help move it from concept to widespread, real use (Smith et al, 2014). To summarize this report, *n* = 50 respondents (a convenience, "snowball" sample of Preschool and Kindergarten teachers and administrators from across the

state of Oregon) indicated that the following would be most needed to prevent RD using an innovative technological tool:

(1) Quick and easy access to information for teachers,

(2) Instructional strategies that were clearly linked to assessment results,

(3) Support for intentional practices that increase teacher knowledge flexibly and enhance planning, and

(4) Technological means to track ongoing progress for children at-risk.

Although 80% of survey respondents indicated that early screening for learning difficulties is important, they also noted existing screening practices, high-quality curriculum, parental action, and funding as obstacles to successful RD prevention. Fewer than 30% of respondents agreed that Preschool teachers are currently skilled in using assessment results to support children's learning needs. Given these findings, we revised our initial plans to present evidence-informed practices through one-page resources and guidance documents to instead create a more scaffolded system. For example, we adapted and systematically organized evidence-informed and promising practices within a *generative curriculum* (activities that simultaneously outlined for teachers what to do and inspired them to add to their typical practices on their "own days") rather than provide practice descriptions and overviews.

The resulting curriculum became the anchor for linking training, assessment use, instruction, monitoring, and "need to know" understanding components for effectively engaging in the 5-step assessment-guided instructional decision-making model. In this way, LRA Greenhouse implementation could "fit" with existing practices and better meet needs within the field (i.e., rather than seek to replace current literacy instruction, we aimed to "add on" to

existing approaches). This approach was driven by literature documenting the importance of addressing teacher beliefs and connecting, rather than opposing, new and used practices to enable professional mastery when initiating changes in practice and adopting new innovations (Al Otaiba, Hosp, et al., 2008; Ertmer & Ottenbreit-Leftwich, 2010).

Feedback from Preschool Teachers. We also administered a "Teacher Readiness survey" to *n* = 11 teacher participants prior to their use of the LRA Greenhouse to examine their perceptions concerning potential implementation strengths, needs, and barriers that might be encountered. Below, are the main themes drawn from the survey results.

- Current Implementation Assets: Existing teacher familiarity with the practice of developmental screening and the use of assessment results; well-qualified teachers that are already knowledgeable about literacy development; willingness to devote 20 minutes (per child) for group screening assessment three times a year; site access availability to reliable high-speed wireless internet; and interest in having "quick access to information" about children's learning needs to share with both colleagues and parents.
- Potential Implementation Needs: Resource availability (e.g., access, funding) to implement a high-quality curriculum; and ongoing coaching and technological support.
- Potential Implementation Barriers: Staffing changes; finding time/space for administering an assessment; knowing how to use assessment information to help support children in the classroom; varied teacher experience using tablet technology; uncertain administrator support; unclear standards and systems-level

support to guide how implementation efforts will back Kindergarten readiness efforts.

Consequently, we focused development on addressing three primary capacity-building needs.

(1) **Curriculum:** Create a highly scaffolded flexible curriculum (containing high-impact evidence-informed strategies) with support resources to facilitate feasible and sustainable implementation, with assessment use *for* instruction.

(2) **Knowledge & Strategy Access:** Enhance teacher knowledge about assessment, intentional instruction, and their link to reflective decision-making for driving intentional practices for preventing RD.

(3) **Technological Management:** Build quick and easy access to technology-enabled resources and supportive features to enable "on the job" deeper learning and successful 5-step model engagement.

Although we had previously established that Prekindergarten teachers could administer the LRA with minimal training, we learned that the role of guided instruction for teachers would be pivotal to effective tool use given the absence of unclear early learning standards and Kindergarten readiness expectations. The curriculum drove development to enable an important change to teacher practice: ongoing, feasible, and effective action for intentionally teaching foundational literacy skills to the entire class while responsively addressing identified weaknesses for children identified with "High Priority Needs".

In addition, technology was carefully incorporated to enable easy access and reduce cognitive demands associated with new learning and tool incorporation over time. Prekindergarten classrooms are bustling environments, and teachers have minimal time for

activity preparation and reflection, so highly-scaffolded supports were used to score and simply report assessment results (to facilitate meaningful interpretation), plan and deliver intentional instruction (to facilitate systematic and strategic practices consistently over time), evaluate learning while it happens (to facilitate cohesive thinking and action), and access information as needed (to bridge gaps in knowledge that may pose barriers to successful implementation).

Through the exploration process, we identified key practices and tool features that met the field's and teachers' expressed needs, matched evidence-informed practices to fill data-based decision-making gaps in Prekindergarten, identified (and instituted solutions to) barriers in policy that might hinder tool adoption, and organized Greenhouse development around building implementation capacity and sustainability (Blase, van Dyke, & Fixsen, 2013). We evaluated implementation readiness prior to development, as well as during development, using systematic interview, focus group, and survey protocols to inform *our* decision-making in building this new system. Below we discuss the development of the resulting instructional materials, 5-step model implementation resources, and wrap-around teacher supports, and findings from two pilot studies conducted for evaluating LRA Greenhouse use. We engaged in over 400 hours of classroom observations of curriculum activities implementation, followed by systematic teacher interviews to identify specific and strategic supports (described below).

Curriculum and Instructional Resources Development

The curriculum includes systematic classroom-ready activities and printable materials comprising *intentional learning opportunities* for three common classroom routines: circle time (EXPLAIN), learning centers (ENGAGE), and group storybook reading (EXPLORE). These activity types were chosen because of their generalizability across different programs and mix of group-

and individual- opportunities to learn. We assumed that ENGAGE center and EXPLORE story-reading could be flexibly implemented to reinforce EXPLAIN learning. Because of stark differences in how these common activities are named across the field (e.g., whether “Circle” is called “carpet time”, “daily gathering”, “morning meeting”, etc.), we created “new” names to foster a common language and help focus teachers’ attention to the function of each activity type. Developed activities include both child- and adult-led learning experiences, to provide a blended approach that values meaningful engagement of both children and teachers. Activity plans are presented within a tablet app, accessed via a monthly planning calendar (explained further below).

Each activity plan includes eight sequentially ordered app screens, although teachers can move through them in a different order using the icon-based navigation bar. Where appropriate, suggested phrasing and access to the Activity Checklist (for monitoring learning progress) is available through pop-up screens. Screen layout between units is identical, except in color, text (content), and icons. Although we recognized that teaching literacy skills and behavior regulation differs, we organized instructional strategies and content to similarly fit within EXPLAIN, ENGAGE, and EXPLORE classroom routines to facilitate efficient teacher learning, and endeavored to include both explicit and implicit strategies across both unit types to maintain a consistent framework.

In general, we applied well-known principles of learning science across activities (Deans for Impact, 2019), to provide regularly implemented intentional and choice routines; initiate opportunities for children to reflect on themselves and their changing worlds; nurture expression and promote warm interactions; incorporate playful challenge and increasing

complexity; allow for accurate, specific, and efficient teacher feedback while learning; infuse teacher modeling and diverse methods of practice for effective skill-building; and foster support for children's co-regulation of learning experiences. Essentially, we aimed to create a flexible (i.e., "drop-in") structure for fostering children's emergent goal orientations as "students" (Bergsmann, Lüftenegger, Jöstl, Schober, & Spiel, 2013), who effectively interact with teachers to learn and not just be "taken care of". Cultivating this critical relationship is associated with positive reading growth from Prekindergarten through elementary grades (Pianta, et al., 2008).

Initial activity drafts were designed for either a "prompted" or "instructional" implementation, with "prompted" activities emphasizing less structured teaching and more open-ended engagement (e.g., using child exploration to find the monthly letter using environmental print instead of teacher-led explicit instruction with picture cards). Both implementation approaches were first studied over the course of two months in a Prekindergarten classroom using the same alphabet letter to compare differences in observed learning, child engagement, and effective teacher implementation. The teacher was interviewed daily after observed implementation to gather feedback about activity instructional perceived assets, feasibility (including preparation), and challenges. Based on our findings, we selected the best activities from each approach to create a "balanced" activity plan (Connor, et al., 2006). We then field-tested the blended approach using a different alphabet letter, and once the format was established, began similarly developing behavior regulation activities.

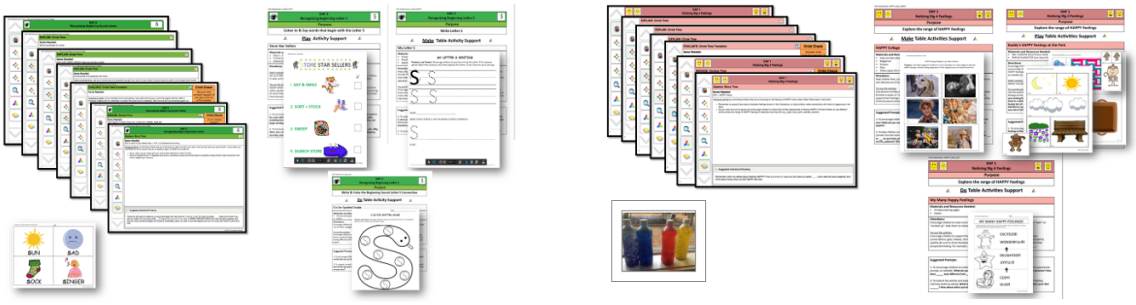
Instructional Activities

For each Activity Plan day, across both Literacy and Behavior curriculum units, teachers can access five activities: whole group Circle EXPLAIN (with Activity Checklist monitoring for

Literacy), whole group Story EXPLORE (with suggested, accompanying book titles aligned with the daily learning goal), and three small group Center ENGAGE activities (MAKE, DO, and PLAY). Teachers are walked through a 5-step Circle activity via the tablet app, with suggested phrasing provided in each step to help strengthen implementation fidelity and sustain intentional instruction. For example, teachers introduce the learning goal, engage in group sharing, conduct a check in understanding, and end with individual responding for evaluating learning and clarifying misconceptions, well-known features of explicit instruction (Archer & Hughes, 2011). EXPLAIN instruction was primarily designed using explicit, systematic principles because they are efficient and reduce cognitive demands for learning (Simmons, et al., 2007; Smith, Sáez, & Doabler, 2016). Within this basic organizing framework, teachers also demonstrate skills, provide examples and non-examples, and keep instruction focused and highly engaging (and when suggested phrasing is used, clear and concise; Archer & Hughes, 2011). Personalized feedback, monitoring, and scaffolded prompting is encouraged to promote high levels of learning success (Archer & Hughes, 2011).

MAKE and DO activities are table activities designed to provide flexible implementation options while still reinforcing daily learning goals. MAKE activities are complex and multi-step, involving high teacher facilitation, whereas DO activities are simple and entail significantly less teacher engagement (i.e., semi- or fully-led by children). PLAY activities involve either child-led dramatic play (for Literacy units) or imaginative, picture-card storytelling (for Behavior units), and teachers are trained to “drop in and out” of activities as appropriate. PLAY activities invite social, object, language, and pretend skills, which benefit social, emotional, behavioral, and cognitive development (Connolly & Doyle, 1984; Halberstadt, Denham, & Dunsmore, 2001;

Schwebel, Rosen, & Singer, 1999). Each ENGAGE activity includes a 1-page "table top" teacher support to guide preparation and implementation, and provide suggested prompts and questions to facilitate authentic intentional talk between teachers and children. Simultaneous activity within the classroom can create cognitive overload for teachers (Feldon, 2007); we created these 1-pagers to reduce the cognitive demands inherently part of implementing novel practices, particularly across differently skilled teachers working in the same room. Each *Table Topper* enables quick understanding about the activity's purpose, necessary materials, step-by-step instructions, and to provide supportive scaffolding questions, target words, or phrasing. Teachers are trained on the importance of each type of activity and can access guidance "Get Ready" resources on the LRA Greenhouse website to help organize when and how they will incorporate LRA Greenhouse activities into their daily routines. Below, see examples of curriculum Activity Plan, activity printables, and resources for Literacy (on left) and Behavior Regulation (on right) units.



Literacy Units. Literacy Activity Plans repeat each month for a different letter, with the instructional focus shifting across five days—teachers devote Days 1 and 2 to building phonological sensitivity, Days 3 and 4 to mapping those sounds to print for building letter sound knowledge, and Day 5 to making meaning (creating, comprehending, and using higher-level

literacy skills linked to the monthly letter). Activities are implemented across two weeks of alternating days, based on early field-testing that compared a consecutive, versus alternating, days model. Teacher feedback from the field-test suggested that consecutive days focused on literacy learning was less sustainable than alternating days, which is consistent with psychological research on the spacing effect (e.g., Dempster, 1988). Subsequent input from teachers revealed that they valued having their "own day" in between LRA Greenhouse Literacy unit days to "add in" their activities related to the beginning letter focus (e.g., incorporating "spring" activities in between LRA Greenhouse Days 1-5 "letter S" activities).

Each month, activities are repeated to promote teachers' on-the-job learning and help classrooms establish regular literacy learning routines. Specific activities were drawn from the *What Works Clearinghouse* and influential early childhood centers, such as Center for Early Literacy Learning (CELL); Center on the Social and Emotional Foundation for Early Learning (CSFEL); Promising Practices Network (PPN); and Center on Enhancing Early Learning Outcomes (CEELO). We also benefitted from numerous early childhood teacher websites for thematic activity and storybook inspiration, as well as for gauging developmental appropriateness.

We referenced the Embedded-Explicit Emergent Literacy Intervention (Justice & Kaderavek, 2004; Kaderavek & Justice, 2004) in constructing a balanced instructional approach. This model emphasizes unique contributions of embedded (naturalistic, whole-language) and explicit (systematic, skill-focused) activities. Based on the early reading and literacy literature, we focused on two skill-building emphases: transferring phonological awareness into beginning letter sound knowledge and developing critical thinking skills to support comprehension. These skill-building emphases entailed strategically building teachers' capacity to:

(a) Implement explicit activities for bolstering emergent literacy skill development,

(b) Engage in strategic prompting to sustain learning goals with fidelity over time, and

(c) Use assessment for guiding their instructional practice.

The Embedded-Explicit model pre-supposes a multi-tiered instructional paradigm, in which children exhibiting struggle during whole-class activities are provided a more intensive small-group intervention. In general, the LRA Greenhouse corresponds with this approach, with one minor modification: Small-group Center activities (for providing additional learning experiences) are available to *all* children and teachers individualize enhanced supports based on observed child needs. For example, for some children, teachers might provide high levels of intentional language use during PLAY, whereas for others, they might personalize and reinforce learning during MAKE. Early teacher input indicated that this modification was necessary, particularly in classrooms with uncertain staff ratio support, where “pull-out” is not feasible.

Therefore, the LRA Greenhouse was designed to primarily serve as a Tier 1+ literacy and behavior regulation focused program, in which universal screening and high-quality instruction underlie decision-making around differentiated and individualized child supports within the regular education classroom. In the absence of widespread adoption of a tiered prevention-based system, time constraints and inconsistent (or absent) staff support, limits in specialized knowledge to properly lead group “intervention” (what could be done by whom), and concerns about early stigmatization, teachers required clear steps for intensifying their supports (who monitors the success of these efforts through ongoing evaluation of learning progress). In this way, the LRA Greenhouse supports ongoing quality improvement processes focused on addressing early literacy learning needs.

Finally, LRA Greenhouse literacy instruction also makes use of repeated "cycled targets" (Kaderavek & Justice, 2004). This type of horizontal approach involves simultaneous, multiple goals instead of vertical mastery of skills. The repeated cycling of multiple learning goals across months served to ease teacher "uptake" of the instructional plan. It also created regular literacy routines for children with different options for reinforcing learning, to provide variety for distributed practice (Archer & Hughes, 2011). How main literacy skills were incorporated into daily literacy activities each month is displayed in the table below.

Literacy Activities by Day and Skill (Repeated Each Unit)					
	PA-Beg Sound Awareness	**Letter Sound Knowledge**	**Print Concepts**	**Critical Thinking**	**Language**
Day 1	Circle, Story *Make* *Play* *Do*			Story *Make* *Play*	Story *Play* *Do*
Day 2	Circle, Story *Make* *Play* *Do*		 *Do*	Circle, Story *Play*	Story *Make* *Play*
Day 3		Circle, Story *Make* *Play* *Do*	Circle, Story *Make* *Play*	Story *Play*	Story *Play*
Day 4		Circle *Make* *Play* *Do*	Circle, Story *Play*	Circle, Story *Make* *Play* *Do*	Story *Make* *Play* *Do*
Day 5		 *Make* *Play*	 *Make* *Play*	Circle, Story *Make* *Play* *Do*	Circle, Story *Make* *Play* *Do*

Note. *Italicized* (Make, Play, Do) activities are small-group ENGAGE center activities. Circle = EXPLAIN. Story = EXPLORE.

Each unit repeats the same activities each month for a different targeted beginning letter-sound. However, PLAY themes vary in two main ways within and across literacy units. Within each unit, the design of PLAY emphasizes beginning sound recognition through the use of non-print materials on Days 1 and 2 (e.g., a "recipe" might use images only). On Days 3 and 4, print is introduced (e.g., the "recipe" might display simple words, with the beginning target letter highlighted, along with images). To maintain children's PLAY interest, two novel themes are employed within each unit (e.g., "pizza parlor" and "pet" store for "/p/ + Letter P").

Behavior Regulation Units. The focus of Behavior Regulation units shifts across four consecutive days (with the teacher "putting it all together" in their own way on Day 5) and each unit is organized around a monthly theme. Instructional targets "unfold" daily within a theme and are later repeated, where appropriate, in later units. Across six units, key concepts are introduced to help children learn mindful emotional awareness and coping strategies, different roles and routines within their community and what they can do (to build task and behavior regulation awareness), and social-emotional and task engagement regulation for problem-solving and self-control; concepts build on each other and culminate in their application toward becoming Kindergarten ready in the final unit.

Similar to Literacy units, both "prompted" and "instructional" intentional practices are used for instructional balance. Activities were drawn from the *What Works Clearinghouse* and influential early childhood centers, such as Center on the Social and Emotional Foundation for Early Learning (CSFEL); Promising Practices Network (PPN); and Center on Enhancing Early Learning Outcomes (CEELO); and Collaborative for Academic, Social, and Emotional Learning (CASEL). In addition, activities were drawn from prior mindfulness research conducted with

children (e.g., Flook, Goldberg, Pinger, & Davidson, 2015; Schonert-Reichl, et al., 2015; Zelazo & Lyons, 2012). We also gained inspiration from internet and library searches, as well as early childhood teacher websites, for related themes and storybook selections.

Although Behavior Regulation unit activities follow the EXPLAIN, ENGAGE, and EXPLORE structure, one important difference was incorporated for PLAY activities, based on field-testing. To achieve targeted behavior-regulation learning goals, instead of dress-up, a partially scripted picture card storytelling activity was developed to engage children in imaginative play. We chose storytelling for PLAY because, like socio-dramatic play, it is a child-led activity that can support literacy development as well as vicarious self-expression and problem solving. In addition, storytelling enabled us to focus on different, specific behavior regulation experiences each day (akin to the focus on particular alphabet letters for PLAY within literacy units). For example, all stories were carefully written about "Buddy", the monkey children encounter on the LRA WM span task, who is a Preschooler transitioning to Kindergarten. Buddy experiences highly relatable problems to help children explore behavior regulation challenges linked to each daily topic and related instructional goals.

In the initial version of this activity, the story was introduced during PLAY. However, based on field-testing classroom observations, we added teacher modeling of storytelling during Circle to strengthen the quality of children's later storytelling (with or without adult support). That is, teachers model daily storytelling using the open-ended story script (approximately 100 words) and assigned picture cards. Later, during PLAY, children tell their own version of the same story using the picture cards (and teacher assistance, as available). This design change led to improved story richness and organization during PLAY, and better

supported assisting staff who facilitate the activity. Because teachers make up their own story ending, we found that it also provided teachers with the opportunity to emphasize points they wanted to share.

Across the six units, final behavior regulation concepts and skills were selected and organized to help children:

(1) Develop awareness about how their *Big 4 Feelings* (*happy*, *mad*, *sad*, and *afraid*) look and feel, expand their vocabularies for describing different feeling intensities, and regularly practice evaluating feelings,

(2) Learn and practice three general *Helpful Choice* strategies for calming down (*breathing*, *talking*, and *relaxing*, which teachers explore using their own specific methods with curriculum guidance),

(3) Develop awareness about "jobs" (tasks) and routines that are done as part of "Community Caring",

(4) Explore and practice team problem solving (and the emotional and behavior attributes involved for handling challenges),

(5) Extend Helpful Choice use to task-related challenges for supporting self-control, and

(6) Revisit key concepts with specific reference to the Kindergarten transition.

We focused on melding children's developing knowledge around emotions (and emphasized four specific feelings) to simplify learning, build mindful awareness about feelings and behaviors, and practice using helpful strategies for managing intra-personal, social, and task challenges. Theme selection was based on the perspective that Preschool children benefit from learning life skills for self-managing their behaviors (i.e., self-regulation; Raver, et al.,

2011; Skibbe, Montroy, Bowles, & Morrison, 2019), particularly in contrast to having behaviors solely managed by teachers (Bilmes, 2004). Importantly, the Helpful Choices strategies encourage teachers to use (or find) specific methods that work because they are embedded within their classroom ecology and can be implemented outside of Greenhouse activities. Although general suggested techniques are provided for teacher inspiration, instructional details are not provided in the curriculum.

Another unique feature of the Behavior units is that children engage in a daily routine of emotional self-evaluation using the Big 4 Feelings concepts learned in the first unit. For example, teachers create a classroom pocket poster to give children a structured opportunity for evaluating their feelings in particular any moment. To provide structure, prior to Circle, on each Behavior unit day, children are asked to "notice" how they are feeling and place a Big 4 Feeling emoji card in their pocket to show it. Teachers are trained to use this opportunity throughout the day, but at least once a day, to give children practice noticing and expressing (if they desire) how they feel. In addition, two concepts ("glitter mind jars" and a "beginning, middle, end" feelings process) are used across Behavior units to convey the transient nature of emotions and how we can control their intensities.

Below we show the five main areas emphasized for each unit. We note that "Community Caring" and "Team Problem Solving" units also emphasize teaching of routines, task engagement, and teamwork, which involved learning about community helpers, as well as exploring how children can help their community, topics that were outside of the main areas of our focus but strongly grounded in early childhood and kindergarten readiness practices.

Behavior Regulation Instructional Targets by Thematic Unit and Activity					
Behavior Unit	**Emotions Awareness**	**Mindfulness & Self Knowledge**	**Behavior Concepts**	**Critical Thinking**	**Language**
Unit 1 "Big 4 Feelings"	EXPLAIN**** *Make**** *Play**** *Do**** EXPLORE****	EXPLAIN **** *Make**** *Play**** *Do**** EXPLORE ****	EXPLAIN **** *Make**** *Play**** *Do**** EXPLORE ****	EXPLAIN **** *Make**** *Play**** *Do**** EXPLORE ****	EXPLAIN **** *Make**** *Play**** *Do**** EXPLORE ****
Unit 2 "Worked Up Feeling Choices"	EXPLAIN *** *Make**** *Play**** *Do*** EXPLORE ****	EXPLAIN ** *Make*** *Play*** *Do*** EXPLORE ****	EXPLAIN **** *Make*** *Play**** *Do**** EXPLORE ****	EXPLAIN **** *Make*** *Play**** *Do**** EXPLORE ****	EXPLAIN **** *Make** *Play**** *Do*** EXPLORE ****
Unit 3 "Community Caring"	EXPLAIN ** *Play*** EXPLORE ****	EXPLAIN *** *Make*** *Play**** *Do**** EXPLORE ****	EXPLAIN **** *Play**** EXPLORE ****	EXPLAIN **** *Make**** *Play**** *Do**** EXPLORE ****	EXPLAIN **** *Make** *Play**** *Do**** EXPLORE ****
Unit 4 "Team Problem Solving"	EXPLAIN *** *Make*** *Play**** EXPLORE ****	EXPLAIN * *Make*** *Play** *Do****	EXPLAIN **** *Play**** *Do*** EXPLORE ****	EXPLAIN **** *Make**** *Play**** *Do**** EXPLORE ****	EXPLAIN **** *Make** *Play**** *Do*** EXPLORE ****
Unit 5 "Self-Control"	EXPLAIN **** *Make***** *Play**** *Do**** EXPLORE ****	EXPLAIN **** *Make**** *Play**** *Do*** EXPLORE ****	EXPLAIN **** *Make**** *Play**** *Do**** EXPLORE ****	EXPLAIN **** *Make**** *Play**** *Do**** EXPLORE ****	EXPLAIN **** *Make*** *Play**** *Do**** EXPLORE ****
Unit 6 "Kindergarten Ready"	EXPLAIN **** *Make**** *Play**** *Do**** EXPLORE ***	EXPLAIN ** *Make*** *Play*** *Do**** EXPLORE ****	EXPLAIN **** *Make*** *Play**** *Do*** EXPLORE ****	EXPLAIN **** *Make**** *Play**** *Do**** EXPLORE ****	EXPLAIN **** *Make*** *Play**** *Do**** EXPLORE ****

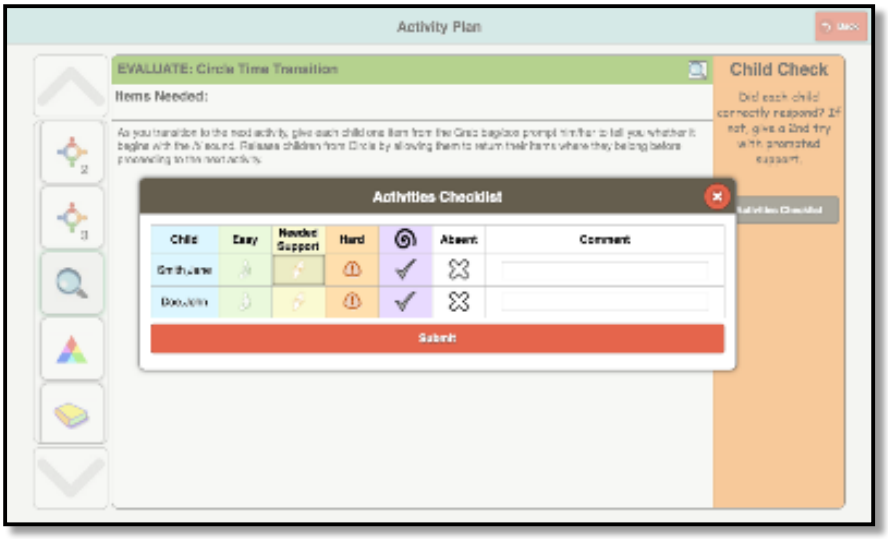
Note. * = # of days of emphasis per unit (out of 4 possible). *Italicized* (Make, Play, Do) activities = ENGAGE center activities.

Progress Monitoring

An activity checklist feature was developed as a "pop-up" screen at key locations within activity plans. Prior research has documented the challenges that teachers experience when monitoring progress in the classroom (Roehrig, et al., 2008). Furthermore, perceived usefulness greatly shapes users' acceptance of technology (Davis, 1993). Consequently, the checklist app feature provides teachers with a simple, organized system for documenting how difficult learning new concepts and behaviors are for children in their class, particularly those identified as having "High Priority Needs". Through evaluating and reporting whether the activity was *easy*, *needed support*, or *hard (with support)* across instructional days, teachers develop a clearer understanding of individual children's learning strengths and needs, and how they change (or not) over time. In addition, a text box space is provided for teachers to reflect and report specific observations about whether behavior interfered with learning for a particular activity. Information can be inputted across multiple activities within a Literacy unit day, and across units, to help teachers pinpoint potential patterns (when examining the output in the Activity Checklist report) that impact a child's learning so that they can better hone their individualized supports for children over time.

We worked closely with teachers to design the interface, location, and amount of informational input for monitoring children's learning progress. The adoption of educational innovations and new practices in support of reading development is hampered when perceived by teachers as time-intensive (Al Otaiba, Hosp, et al., 2008; Roehrig et al., 2008). Although progress monitoring may bring instructional focus, it may also create challenges with technology use (input and output of information), information use, and time management

(Roehrig et al., 2008). Therefore, we were careful to design the checklist app feature to enable teachers to efficiently document “in the moment” how learning proceeded for children across three basic levels (*easy*, *needed support*, or *hard with support*) and whether they perceived either internalizing or externalizing behaviors as impediments to learning within a specific activity. We include behavior with literacy skill monitoring because of their reciprocal effect on learning (Coie & Krehbiel, 1984; Goble et al., 2017; Morgan, et al., 2008). We included the text box feature out of teachers’ expressed desire for recording more extensive observations about skill, behavior, or implementation factors (e.g., activity adaptations made). A report was also created (described below) to help teachers evaluate progress over time by pinpointing specific patterns of strength and weakness across literacy learning classroom activities. See screenshot below.



Implementation Resources

To foster sustainable use of the LRA Greenhouse, a variety of implementation resources (35+) were developed to quickly and easily scaffold teacher use. During the first two years of

development, we conducted in-depth teacher interviews to learn about teachers' perceptions concerning what worked well and less well in their classrooms, as well as implementation strengths, needs, and barriers. We asked structured, regular questions to examine changes over time, as well as made specific inquiries based on observed implementation. We also used teacher feedback, comments, and questions as sources for developing intentional resources.

Based on our findings, we created resources to meet three kinds of needs: teacher knowledge building, instructional preparation, and activities implementation. Tool use requires content, pedagogy, and technological knowledge (Mishra & Kehler, 2006) for effective assessment-guided instructional decision-making activities. Teachers' feedback clearly emphasized their lack of time for reading a manual, and their desire for more manageable, "bite-size" chunks of information. Therefore, we created a number of technological, assessment, and instructional resources that could be used "on the fly" to provide teachers with content, pedagogical, and technological knowledge efficiently. We also created paper and video resources to aid in preparing to implement the LRA Greenhouse to help them develop confidence and early success (Ertmer & Ottenbreit-Leftwich, 2010).

For example, based on a composite created from Prekindergarten teacher experiences of learning how to use the LRA Greenhouse, we created brief "think aloud" videos for enabling teachers to witness another teacher's early installation steps. We created "Table Topper" supports for keeping ENGAGE center activities connected, organized, and scaffolded for multi-teacher facilitation. In addition, we created word lists to help teachers engage in authentic yet strategic dialogues with children about the monthly letter-sound. Working memory load (i.e., how much teachers are mentally processing) is positively associated with language production

(Belke, 2008); therefore, we aimed to support authentic, yet strategic, conversation by listing common words for teachers to reduce mental demands. Teachers reported that this resource not only helped them "think of words to say" for intentional talk, but also more quickly gather materials in preparation for implementation.

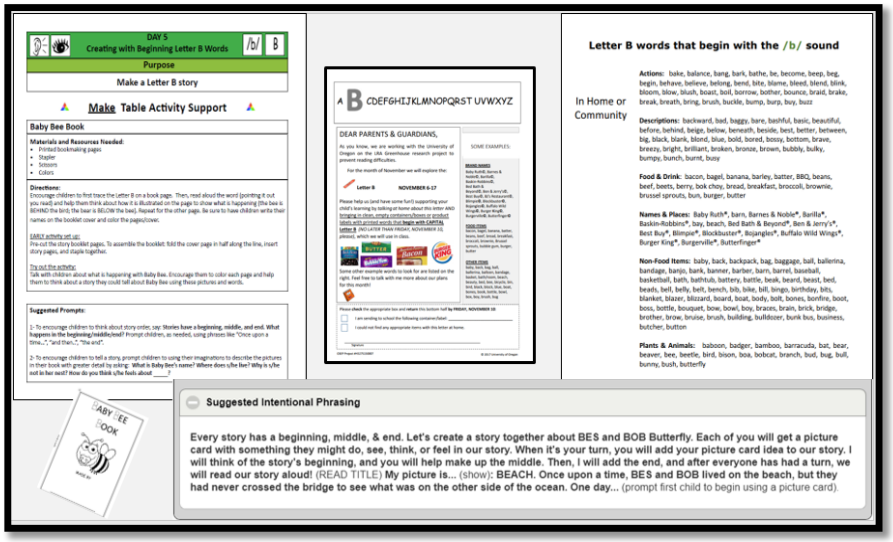
We also created two types of letters to be sent home in order to enhance communication about the LRA Greenhouse for families. One letter introduces the program and explains some instructional differences that may be observed on LRA Greenhouse days, and the other is a series of letters (one is sent home each month) to encourage families to bring in items that "begin with the monthly letter") to encourage family participation on Day 3 literacy learning activities. The letter provides brand examples and a return slip response option to let teachers know what might be brought in to support the letter recognition "pass around" activity. Family involvement in early childhood learning is an important component of quality programming because it: enhances communication, builds teacher-family connections, creates volunteer opportunities, and strengthens collaborative decision-making (Morrison, et al., 2015). We aimed for our Day 3 environmental print activity to encourage parent volunteering to promote classroom literacy learning connections, as well as pride among children for their family's contribution to the lesson. In the tables, below, we list these implementation resources available and their intended purposes.

Knowledge Building	
Implementation Resource	**Purpose**
Key Terms Glossary	Defines essential words used in the LRA Greenhouse system
16 "How-To" support 1-pagers • Navigate the Tablet App • Navigate the Training • Navigate the Support Website • Create the Class List • Administer the LRA (2 Checklists) • Complete the Behavior Rating Scale • Use the Activity Plan • Use the Activities Checklist • Read Reports & Interpret LRA Scores • Prepare the "How Do I Feel? Poster • Prepare Behavior Unit Story Picture Cards • Make Glitter Mind Jars • Make the "Same Sound Game" • Use Environmental Print • Choose a Story	Provides quick "on the go, need to know" support for technology use, key activity materials preparation, and making informed decisions that are aligned with the LRA Greenhouse approach

Preparation	
Implementation Resource	**Purpose**
Dramatic Play Theme Overview	Provides a preview of the dramatic play themes to help with early prep and gathering of materials
Extended Suggested Story List	Offers other, suggested stories (for extended for substitution use) for LRA curriculum units
LRA video walk-through	Demonstrates a quick overview of different assessment parts
5 brief "Think Aloud" videos & 1 "Getting Started Literacy unit organizer	Provides a teacher model for organizing, preparing, and coordinating LRA Greenhouse system use, based on insights gleaned from teachers who helped with the tool's development
Family Introduction to the LRA Greenhouse Letter	Introduces families to the classroom use of the LRA Greenhouse and explains some potential differences in typical activities

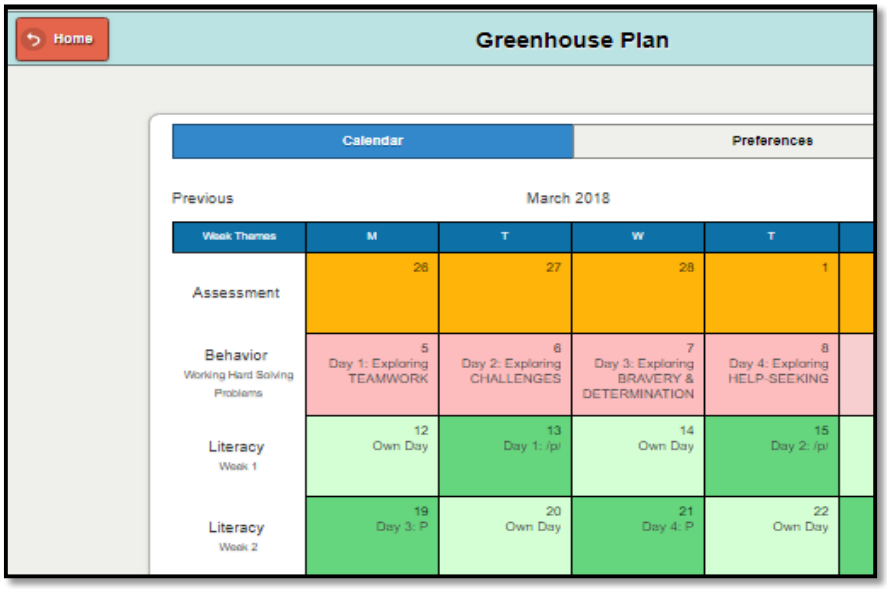
Activities Implementation	
Implementation Resource	**Purpose**
Curriculum Printables • Word Lists • 54 1-page activity "Table Toppers" for MAKE, DO, and PLAY • 6 Family Letters Home	• Supports teachers' use of authentic + intentional teaching language • Provides the activity goal, directions, and suggested prompting • Informs and encourages family participation on Day 3 during the Literacy Circle activity by bringing labeled items in
Ensuring Children's Success	Describes what "successful learning" looks like when using the LRA Greenhouse to guide instructional support decisions
Implementation Fidelity Checklist	A 5-day instructional observation checklist for helping administrators evaluate the quality of key literacy unit strategies implementation.

Below, is screenshot of example resources (from top left: Table Topper, Literacy Unit Family Letter Home, Word List, and Activity Plan suggested phrasing).



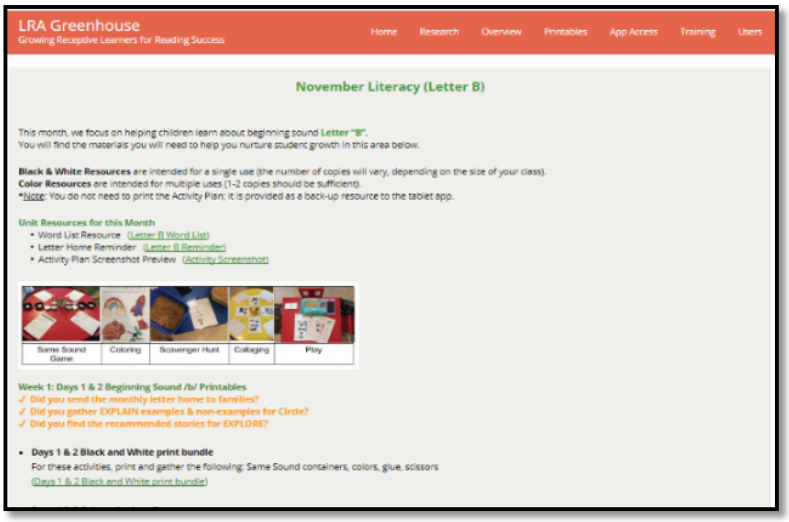
Wrap-Around Teacher Supports

Planning Calendar. We created monthly planning calendar to help teachers organize implementation. Because sites differ in their daily routines (e.g., due to fieldtrips or regular community outings), and to facilitate timely assessment and activities completion with regular follow-through, the calendar was designed as a gateway to Activity Plans. This feature displays days colored by unit (or assessment window), and allows teachers to type on LRA Greenhouse days and uncolored "own days" (in which teachers implement their own activities). The monthly view is printable, allowing teachers to share instructional goals. In addition, on "own days," teachers can select from aligned literacy themes (e.g., "space" during the /s/+ Letter S unit) or type in their own ideas. To facilitate tracking implementation teachers can also mark daily activities as complete on the calendar. Gold coloring represents assessment days, pink coloring represents Behavior Regulation unit instructional days (lighter pink for "own day"), green coloring represents Literacy unit instructional days (lighter green for "own days"), and white coloring represents non-Greenhouse "own days". See calendar screenshot below.



Calendars can provide not only “external memory aid” for teachers (McDonald, et al., 2011), but also support for organizing information. For example, we aimed for a clearly organized calendar to visually facilitate “coordination” between LRA Greenhouse instructional days and teachers’ “own days”. Because teachers can toggle the monthly view, they can prepare and plan for the coming month or review previous the month simply and quickly.

Support Website. We developed a companion website to create an internet-based structural “container” for various program elements that provides teachers with scaffolded information (e.g., photos of activity set-up, reminders), access to the tablet app, training, and printable materials and resources. We anticipated the website would facilitate tool use by keeping information easily accessible, connected, and simply organized. Conceptualized as a “greenhouse” where teachers can access tools to promote literacy growth, the site included both public and private (registered users-only) materials. Of the drop-down menu options, three (Printables, App Access, and Training) are private. The Printables drop-down tab includes a “Get Ready” page that contains images, *need to know* resources (guidance documents, family introduction letter, and HOW-TOs), and brief teacher “think aloud” videos for getting organized. Access to the app allows teachers to navigate the tablet app on a computer so they can flexibly alter their class list, complete the behavior rating scale, and view/print LRA reports. As noted by McLoughlin and Marshall (2000), “scaffolding is intended to motivate the learner, reduce task complexity, provide structure and reduce learner frustration”. Through iterative work with teachers, we developed a website that functioned to scaffold LRA Greenhouse users, so that it benefitted teachers motivationally, educationally (in terms of facilitating their learning), and logistically. See screenshot below.



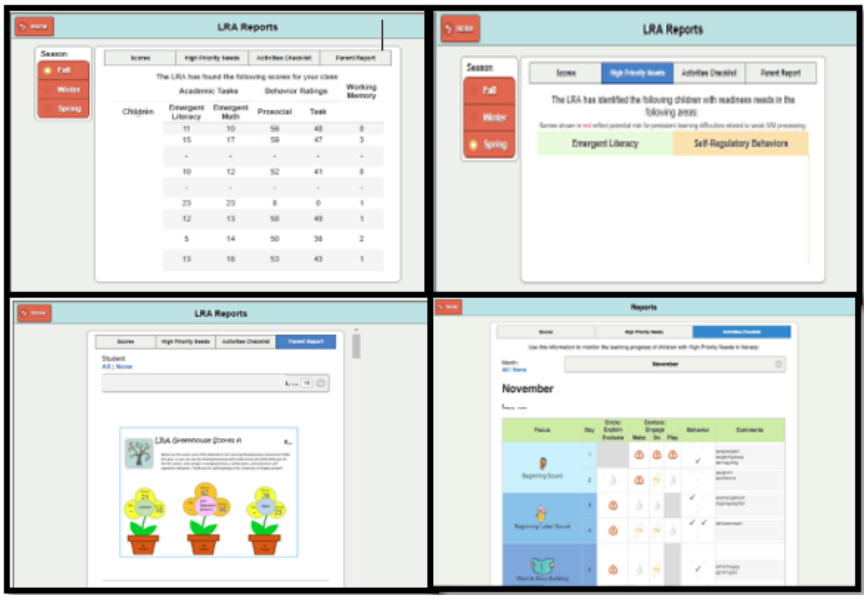
LRA Score Reports. We worked closely with teachers to enhance the assessment results information available for making intentional teaching and support decisions to prevent RD. An important aspect of our work focused on balancing the amount and kind of information to keep results accessible, meaningful, and actionable to prevent "information overload". The LRA Greenhouse tool provides teachers with four assessment score reports (see screenshot examples below, presented clockwise beginning with the top left):

(1) **Class Scores Report** for seeing how all children in a class are doing,

(2) **High Priority Needs (HPN) Report** for seeing which children have special learning needs to address,

(3) **Activity Checklist Report** for monitoring the progress of children on literacy activities (especially those with HPN), and

(4) **Individual Score Report** for seeing how each child is doing across the year.



Each report provides different information to help Prekindergarten teachers make "assessment-guided" decisions for providing supports to children who need it. Although some teachers may be able to early "identify" children at risk for learning problems (Taylor et al., 2000), using LRA results in conjunction with the curriculum activities can help all teachers pinpoint where individualized needs can be best met, which research shows is an effective practice for addressing learning difficulties by promoting growth (Chard, et al., 2008; Connor, et al., 2006; Fuchs & Fuchs, 2006; Hamilton, et al., 2009; vanDerHeyden et al., 2008).

Teachers are trained to first review the Class Scores Report to gain an understanding of overall class functioning, and then the HPN Report, which identifies specific children whose performance on the LRA suggests immediate support needs. After activity completion (and teacher input), the Activity Checklist Report can be examined to understand in-classroom learning patterns to help teachers tailor their supports and make stronger assessment-guided decisions to reduce children's risk for RD. Finally, the Individual Score Report is a printable report for sharing individual growth over time with parents and other practitioners. In addition

to an online training module dedicated to understanding the LRA and score meaning, teachers can also access resources to help them effectively reflect on how to meaningfully evaluate and act upon LRA results. Beyond making instructional changes based on teachers' interpretation of assessment results, teachers also engage in a feedback loop about their teaching that can positively impact their practice (Van den Hurk, Houtveen, & Van de Grift, 2016).

Online Training. Through iterative development cycles involving teacher feedback and a "think aloud" protocol, we created six online training modules that covered the breadth and depth of LRA Greenhouse content and implementation. We aimed for the online training to be high-quality, useful, and relevant for teachers. An important aspect of this training was to enhance teachers' understanding about their instructional role in organizing children's knowledge (Archer & Hughes, 2011). Our secondary aim was for the training modules to be teacher-friendly and time-sensitive, so that successful completion was feasible.

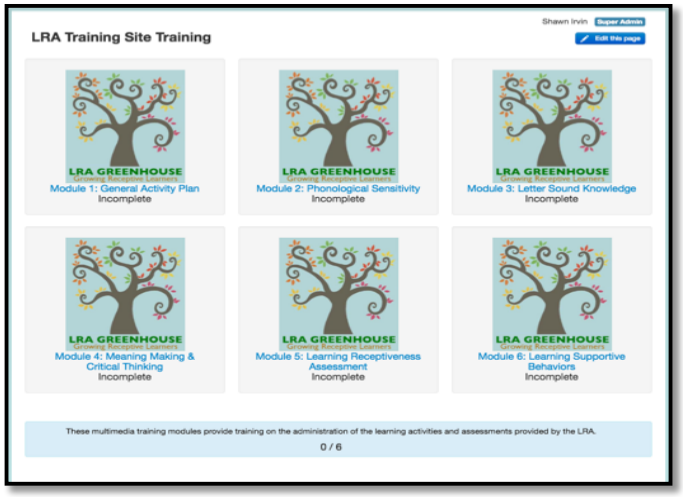
The training was designed to cover tool and curriculum fundamentals: Literacy (phonological sensitivity, sound to letter mapping, and meaning-making) and Behavior Regulation facts, procedures, and concepts (emotion awareness and labeling, mindful calming strategy selection, self-control, task and prosocial engaged behaviors) for effective curriculum activities implementation, and assessment administration, tool use, and assessment-guided instructional decision-making. Although the content differs by module, we implemented consistent design features taken from best practices in online professional development to facilitate teacher engagement and consistent learning strategies (e.g., Clark & Mayer, 2003). For example, we embedded and interspersed 10 multiple-choice quiz questions throughout the modules, with either validating (for correct selections) or guiding (for incorrect selections)

feedback, to provide checkpoints for learning. We aimed to equip teachers with sufficient, rather than exhaustive, grounding to effectively deploy the 5-step model and strategies. Our goal was to establish a firm foundation to allow additional "on the job" professional enrichment through continuous formative data use learning (Mandinach & Jimerson, 2016).

Each module was designed to take 30- to 60-minutes. Teachers who successfully complete the training earn six Continuing Education (CE) credits through the Oregon Registry (a printable completion certificate is available once an overall passing score is achieved). Low scoring modules can be retaken after a 6-hour delay. Six teachers were surveyed about their ease of completing the training using a 1 (hard) to 5 (easy) scale. On average, teachers rated their experience favorably, *M* = 4.17, and they agreed that completing the training helped them to more effectively implement activities (*M* = 3.83; 1 = strongly disagree to 5 = strongly agree).

Through online training, we focused on enhancing five main assessment-guided steps through teachers' use of the LRA Greenhouse: (1) implementing high-quality assessment practices; (2) using assessment information to strategically advance literacy growth for children with High Priority Needs (RD Risk); (3) implementing high-quality intentional teaching using evidence-informed practices, (4) systematically monitor learning to promote literacy skills development; and (5) engage in ongoing reflection and evaluation of literacy growth and RD risk needs. Teachers need to be able to effectively screen for RD and understand the purpose for LRA use before they can meaningfully use assessment results to support diverse literacy learning needs, particularly when the assessment method is unfamiliar to the field. In addition, teachers need to use strategic and high-quality instructional practices (including systematic monitoring of literacy learning progress) to help children develop critical pre-reading skills.

Finally, they need to engage in ongoing reflection about the children at-risk for RD and how their difficulties manifest in their classroom, so that they can evaluate their support and make timely and differentiated adjustments, as needed (e.g., Hoover, 2011). Below we show a screenshot of the training modules portal.



LRA Greenhouse Pilot Study Findings

We engaged in two pilot studies to examine LRA Greenhouse functioning. In the first pilot study, we compared LRA performance between six-month implementing and non-implementing classrooms. In the second pilot study, we examined the impact of partial LRA Greenhouse implementation (across three-months). We report quantitative findings from both studies, followed by teacher survey and interview findings that describe the tool's impact.

Pilot Study 1

Sample

Prekindergarten Participants*.* The initial pilot study of the full LRA battery with Greenhouse curriculum use was conducted in two waves across four Prekindergarten classrooms (*n* = 37 children). All classrooms were taught by Caucasian female teachers, ranging in age from 35 - 55 years, with 10 to 35 years of experience located within one mid-size Oregon city (median regional household income = $50,592). Sites included two center- and two home-based settings (reflecting a mix of four- and five-star ratings, out of five possible, within Oregon's Quality Rating for Improvement System [QRIS], now *Spark* in Oregon; https://oregonearlylearning.com/spark). On average, children were 53.5 months old in the fall, were primarily Caucasian (88.6% Caucasian, 8.6% Latino, and 5.4% Asian) and 21.6% had identified special needs pertaining to concomitant English Learning and developmental disabilities (cognitive, motor, visual, language). Forty-six percent of the children were female.

Class size ranged from 10 to 18 children, with a minimum of 6 Prekindergarten children per class (children younger than four were excluded from analyses). Teachers used published curricula in their daily practice (e.g., *Creative Curriculum* or *High Scope*) or a "classroom

created" curriculum (using materials either gathered from the internet or self-made) consistent with their unique educational philosophy.

Comparison Group. We examined fall and spring growth between four LRA Greenhouse implementing classrooms and four (non-implementing) comparison classrooms that were located at the same large center. The non-implementing center had a QRIS four-star rating, and shared similar demographics with LRA Greenhouse pilot participants, although located in a different county. The "business as usual" classrooms comprised *n* = 37 children; LRA tool use included the completion of assessment items delivered in the fall and spring only. Classroom teachers were Caucasian females, ranging in age from 24 to 51 years old, with 5 to 30 years of preschool teaching. On average, children in these classrooms were 54.1 months old in the fall, and represented 81.1% Caucasian, 13.5% Latino, 2.7% African American, and 2.7% Asian backgrounds. Two children had identified exceptional needs (5.4% of the sample), with one child identified as an English Learner and another identified with a motor developmental disability.

Staff support in varied from one to two adults per classrooms with three- and four-year old children, composed of 18 to 20 children per class; however, only four-year old Prekindergarten children took the LRA. Classroom instruction was observed for one hour on two separate occasions. Teachers used a "classroom created" developmental curriculum (using materials either gathered from the internet or self-made) that were considered "generally" grounded in *High Scope* principles. Instructional approaches varied between classrooms based on each teacher's educational philosophy.

Procedures: LRA Administration

Assessment in LRA Greenhouse implementing classrooms was observed for one hour 1 - 2 times per seasonal occasion (most of the child-administered testing was observed within this time frame). Assessment for comparison classrooms was conducted by trained research staff and involved the same materials and procedures. Children completed ***Pre-reading*** and ***WM*** tasks in approximately 13 to 16 minutes each administration. Depending on site resources, children took the LRA using headphones and visual dividers, either individually (at the back of the classroom during assigned quiet times) or in small groups of four children in a separate location outside of the classroom. All children were given brief instructions and screen-touch feedback prior to beginning. When needed, administrators provided direct hand feedback to help children understand whether their touch pressure was "too hard, too soft, or just right." Teachers completed the ***BRS*** separately on the tablet within the same assessment time frame, on average, in approximately 23 to 26 minutes.

Structured observations of LRA administration fidelity conducted by research staff indicated that, on average, trained teachers provided children with a quiet (63% of the time), non-distracting (71% of the time), and comfortable (96 - 98% of the time) assessment environment. Resource constraints (e.g., additional staff support or space limitations) were found to underlie the relatively lower fidelity for the noise and distraction factors. For example, intermittent noise and staff/parent interruptions were noted as affecting fidelity ratings, despite initially sufficient-quality conditions. Effective touch-screen submission was the most frequently observed challenge among children, particularly for those without prior cellular phone or tablet experience.

Teachers were rated as competent administrators across time points: 95% appeared comfortable leading testing sessions, 97% adequately assisted children during testing (e.g., with submitting responses when needed), 94% adequately managed off-task behaviors (e.g., children talking to each other), and 95% efficiently began and ended sessions. Total fidelity scores were based on a 0/1 (not observed/observed) scoring using a 11-item observation checklist that focused on testing environment and teacher behaviors throughout the testing administrations.

Procedures: Instructional Implementation

Participants used LRA Greenhouse activities (i.e., assessment, instruction, strategic monitoring and support of children with *High Priority Needs,* and reflective ongoing evaluation of progress) nine days per month over six months from fall to spring. Prior to implementation, teachers completed the six online training modules at their convenience over 4 - 6 hours. Instructional implementation was observed for approximately one hour, 2 - 3 occasions per month. We gave limited feedback to teachers, providing clarifications when needed and positive appreciation for study participation. Following observations, we interviewed teachers using a standard question protocol to gather information about their experience.

Teachers' implementation of literacy activities fidelity, as measured across monthly occasions per teacher, depended on the activity. For example, teachers properly implemented center MAKE and DO center activities 92.5% and 87.5% of the time, respectively, whereas PLAY and circle EXPLAIN activities were implemented with fidelity 76.2% and 74.3% of the time, respectively. Research staff used a structured checklist with a rating scale of 0 (not observed) to 3 (ideal implementation based on design) for evaluating multiple factors within each activity.

For example, levels of implementation were delineated for each of the steps within EXPLAIN activities as well as teacher instructional, quality of materials, and child engagement expectations during the other activities (based on unique daily learning goals). Total fidelity scores were obtained by summing activity implementation scores plus credit for using the tablet app (instead of printed screenshot copies, which were also available).

Results

Between-group mean fall ***Pre-reading*** scores were non-significant (F = .61, p = .44), suggesting similar skills at the beginning of the school year. Implementing and non-implementing comparison groups obtained mean scores of about 11 and 10 (M = 10.79 and 10.08, SD = 4.01 and 4.25, respectively). Seventeen children in implementing classrooms (45.9%) and 21 children (56.8%) in comparison classrooms were identified with RD risk based on performance below the fall cut-point.

By spring, mean ***Pre-reading*** scores were significantly stronger among children in the LRA Greenhouse implementing classrooms than children in comparison classrooms (F = 11.91, p < .001). More specifically, children within implementing classrooms obtained a mean spring ***Pre-reading*** score of 14.97 (SD = 4.57) whereas children in comparison classrooms obtained a mean spring ***Pre-reading*** score of 11.08 (SD = 4.83), slightly above the RD risk cut-point (see Appendix, Table 1). Only 5/17 children (13.5%) in LRA Greenhouse classrooms maintained their fall RD risk status in the spring; in contrast, 18/21 children (48.6%) in comparison classrooms remained at RD risk in the spring. For implementing classrooms, we found 32.4% reduction in RD risk with 54 days of instruction across six months; we found an 8.2% reduction in RD risk for non-implementing classrooms across the same time period.

In addition, between-group differences for ***WM*** and the ***BRS*** were examined. Non-significant differences between the groups in ***WM*** and task engaged behavior ratings were found in the fall (F = .10, p = .76, and F = 1.95, p = .17, respectively), suggesting comparable incoming levels. By spring, significant between-group differences favoring LRA Greenhouse implementing classrooms were found for working memory span (F = 5.30, p = .02), but not task engaged behavior ratings (F = .33, p = .57). Because fall prosocial engaged behavior ratings were significantly different between the two groups (F = 4.31, p = .04), a spring comparison for this measure was untenable (see Appendix, Table 1).

In summary, we found important significant between-group ***Pre-reading*** differences for LRA Greenhouse implementing classrooms, in which children increased their literacy scores, on average, four points. Significant gains in WM span were also found for LRA Greenhouse implementing classrooms, when compared to "business as usual" classrooms. Children in both groups made beneficial gains, on average, in behavior regulation; however, the differences between groups was less clear.

Pilot Study 2

We also examined performance when the LRA Greenhouse was partially implemented (for three, instead of six, months) to see whether similar trends existed. In addition, we recruited more diverse sites to evaluate the generalizability of our Pilot Study 1 findings.

Sample

Prekindergarten Participants. The partial implementation sample (n = 24 four-year old children in four classrooms) comprised 87.5% Caucasian, 8.3% Latino, and 2.9% Pacific Islander backgrounds. On average, the children were 52.4 months old at Time 1 (in the Winter). Forty-six

percent were female, and 6% of children had identified special needs; one pertaining to concomitant English Learning and one related to motor developmental delay.

All classrooms were taught by Caucasian female teachers, ranging in age from 30 - 50 years, with 5 to 30 years of experience across mid-size Oregon city (median household income range across two cities = $50,592 - $56,186) and rural town (median household income = $49,835) locations. Sites included two center- and one home-based locations (reflecting greater diversity in quality rating and locale than Pilot Study 1: one 4-star metropolitan, one 3-star rural, and one 5-star suburban site). Class size ranged from 10 to 20 children, with a minimum of 4 Prekindergarten children per class (children younger than four were excluded from analyses). Teachers used published curricula in their daily practice (e.g., *High Scope*) or a "classroom created" curriculum (using materials either gathered from the internet or self-made) consistent with their unique educational philosophy.

Procedures

Winter and Spring LRA assessment was conducted by either the teacher, with research team support, or completely by the research team. Similar to Study 1 participation, assessments were administered before and after the commencement of instruction. Literacy and Behavior unit activities were implemented as previously described, sans three Literacy and Behavior units. The removed units were taken from the middle of the year so that instruction began with the same first four foundational units (i.e., two each of Literacy and two Behavior Regulation) and ended with the same unit for both Pilot 1 and 2 participants. Fidelity of instruction data were not collected. However, teachers engaged in the same training as described in Pilot Study 1 and similar classroom observation procedures (in terms of duration

and frequency). In general, teachers implemented the activities as intended, and similar to (but less robustly than) Pilot Study 1 participants.

Results

On average, children began with ***Pre-reading*** mean scores of 11.04 (*SD* = 3.29) in the winter, slightly above the risk cut-point. Similar to Pilot Study 1, children generally improved in all areas measured after 3 months (27 instructional days) of LRA Greenhouse use. Gains in mean ***Pre-reading*** scores for the spring were found (*M* = 12.58, *SD* = 3.51), which were significantly different than Time 1 in the winter (t = -2.80, p = .01). Gains were also found for ***WM*** (*M* = .75, *SD* = .79 and *M* = 1.04, *SD* = .75 for Times 1 and 2, respectively) and both parts of the ***BRS*** ($M_{task\ engaged}$ = 49.71, *SD* = 9.54 and *M* = 50.33, *SD* = 8.84 for Times 1 and 2, respectively; $M_{prosocial\ \text{engaged}}$= 52.13, *SD* = 8.78 and *M* = 54.33, *SD* = 8.46 for Times 1 and 2, respectively). However, gains were statistically non-significant (t_{wm} = -1.50, p = .15; $t_{\text{task engaged behavior}}$ = -0.45, p = .65); prosocial engaged behavior regulation gains approached statistical significance (t = -1.88, p = .07). See Appendix Table 2 for all reported scores.

Importantly, ***Pre-reading*** scores for children identified with High Priority Needs RD risk increased 20%, in contrast to a 4.5% increase for non-risk peers, reflective of highly strategic and selective literacy skill building differentiation for the RD risk group. At time 1 (winter), nearly 63% of the Prekindergarten sample was identified with RD risk based on performance below the winter cut-point. By time 2 (spring), however, only 40% maintained their RD risk status, a 23% reduction within just three months of implementation (27 days of instruction).

Pilot Studies 1 and 2 Teacher Feedback

Across pilot studies, Prekindergarten teacher users highly rated the instructional support and resources developed for enabling assessment-guided instructional decision-making. In addition, surveyed teachers (*n* = 6) strongly agreed (*M* = 4.5/5; where 1 = *strongly disagree* to 5 = *strongly agree*) that Activity Plans and support resources were helpful for implementing activities. All six teachers (100%) *agreed* or *strongly agreed* that implementing LRA Greenhouse activities was a valuable experience.

We repeatedly surveyed implementing teachers 39 times over the course of their tool use and found that they would "recommend the activities in this unit to a friend" 87% of the time, and that they judged the activities as developmentally appropriate 95% of the time. In addition, 100% of teachers agreed that the assessment "appropriately identified" children at-risk for RD and that using this information "fit" with their typical approach for helping children develop literacy. Teachers unanimously agreed that they were able to rate behaviors in their class efficiently, and 75% agreed that both administering the LRA and finding test results were easy. Seventy-five percent of teachers agreed that the LRA Greenhouse companion support website was well-organized. Teachers also rated the curriculum activities as very easy to implement (*Median* rating: 5/5 for nearly 80% of surveyed occasions across six months of piloting). In general, teachers reported using other developed resources (e.g., "How To" one-pagers) on a "need to know" basis, as intended.

The main themes that emerged from teacher interviews and survey responses (see Appendix, Tables 5 - 10), which illustrate teachers' reported perceptions about the LRA Greenhouse's suitability were: *Feasibility*, *Accessibility*, *Usefulness*, *Fit*, *Facilitation*, and *Impact*

on Practice. *Feasibility* was assessed across 39 occasions (between 4 - 7 occasions per teacher); 74% of the time teachers reported no "hiccups" or challenges with implementation, were likely to recommend activities to a friend, and found the activities easy to implement and for children to learn (Table 5). In terms of *accessibility*, teachers reported ease of use and efficiency across various aspects of the technological tool (Tables 6a and 6b). In terms of *usefulness,* teachers agreed that the LRA was "useful" (Table 7): LRA results were viewed as appropriate and meaningful for differentiating children to meet their learning needs. In terms of *fit* into their practice, teachers unanimously agreed that LRA items were developmentally appropriate for children, and the results fit with their typical approaches for supporting children's development (Table 8). The tool also was perceived by teachers as *facilitative*, and helpful for knowing who needed strategic literacy-learning help, planning and providing intentional instruction, monitoring progress, and generating new insights (about children and classroom practices). See Table 9.

Finally, 75% of teachers reported an *impact* of tool use on their practice (Table 10) — identifying children who need greater support because they are at-risk for later learning difficulties, modifying how they help these children, and explaining their learning needs to others. Nearly 88% of teachers reported monitoring progress more carefully and being capable of discussing children's learning needs differently with parents as a result of their LRA Greenhouse experience. Thus, our survey findings suggest that LRA Greenhouse use benefitted teacher practice and child learning over time, and enhanced teacher knowledge to create more lasting impacts. Below, we share quotes gathered during the teacher interview process, to highlight their perceptions for each of the categories using their own words.

Feasibility: **Ease and efficiency of LRA Greenhouse implementation in preschool classrooms**

"I had everything I needed- I only bought coffee cups, and you can make it as extensive as you want."

"It's super organized and straightforward with its directions. For a teacher who is needing help with planning, it would make it time-efficient and easy."

"I liked being able to go to one spot and print off everything I needed."

"I really liked that some of the days the activities were planned for me. Once you get to the days, a lot of my job was done for me outside of the prep…It made planning easier – it focused the calendar for me."

"[It took] about 10-15 minutes each day to set up [and gather materials]. At the beginning of a week, I spent 20 minutes laminating, cutting, printing."

Accessibility: **Simplicity and straightforwardness of access to and use of LRA Greenhouse components**

"I think it's been great. Really easy to use. Everything was easy to find and print out. Worked really well."

"I just pull up the website and enter it [in the tablet app] at home through the website. That is a really nice thing about your program, that everything is accessible on the website, as well as the tablet."

"The program was really user-friendly."

"I liked the way everything [in the training] was broken down to be clear."

"I'm not a natural with technology, but it was definitely helpful to remind me of what I need to do. I am better able to use it… I've got it now- I know how to click through it."

Usefulness: **Effectiveness of LRA Greenhouse at characterizing children's literacy skills and learning needs**

"It was great. The assessment really appealed to me because I have a program that I use and it has assessments, but the benchmarks were hard for me to understand and to use. The curriculum was great for understanding the emotions and the letter activities. It was really appropriate. I liked a lot of how the curriculum encouraged discussion and play-based approach to learning. It's good not only so I can tweak my program, but also show parents how their children have grown. Simple and easy to use."

"I got to see if they were progressing or going backwards because you can't [ordinarily] see that daily. I got to see the growth they were making. It showed me the kiddos I need to pay more attention to and follow up on my part, outside of the learning moment throughout the rest of the day."

"The curriculum had it ready to implement and I had a real score for me to understand [from the LRA], and then there was 3 terms to work with… [to] see the progress."

Fit: **Appropriateness of LRA Greenhouse for preschool classrooms**

"Because there were so many different activities, it helped to include the different learning styles of the kids and allowed them to 'get it' later…it gave me more specific ways to support them and the language I needed, which was nice."

"I still get to plug in my own things that I would do with my typical curriculum because of the days that the Greenhouse curriculum doesn't cover every day."

"The [assessment] tool and activities are aligned with our goals… Fit right with what we were already doing."

"I really like the circle stuff- all of it is on point and the kids really get it all pretty quickly."

Facilitation: **Capacity of LRA Greenhouse to support evidence-informed practices and assessment-guided instructional decision-making**

"I used them [assessment results] as a weekly reminder to see those ones that are struggling. If you're not focused on them, you can forget, so the scores helped me see who I needed to focus on, who needed extra support- it helped me be pro-active."

"I like all of it, but definitely the activities monitoring. I liked having the scores for literacy to help remind me who will need my support."

"I liked the suggested phrasing, especially for the carpet time. It was helpful to keep me focused on where we're supposed to be."

"I was able to give it [the Table Topper resource] to my assistant… to put us on the same page."

"I looked at them [Word lists] beforehand and then when I needed help to think of words. It was especially helpful when we were looking for pictures to put in the classroom."

Impact on Practice**: Impact of LRA Greenhouse on how teachers develop children's literacy skills was a key tool endeavor.**

We found two central areas of impact on teacher practice: (1) teacher mindsets and (2) classroom practices. Teachers reported changes in their thinking and in their approach to helping all children develop crucial literacy skills in time for learning to read in Kindergarten.

Both areas demonstrate the deep level of teacher reflection that grew from having purposeful, doable, and clear aims to reduce children's risk for RD.

(1) Shifting Teacher Mindsets:

"My biggest takeaway is how it's [assessment, curriculum, teaching, learning] all connected. I knew that in the back of my mind, but using this curriculum has reminded me how it's all connected and seeing it all put together really put it to the forefront."

"Even though we did individualizing before Greenhouse, it changed our focus on the children who were behind."

"It really made me take a look at the way kids are doing activities…Previously I didn't think about a preschooler being at-risk because it's not required [that they learn] to read."

"I think it [my teaching] has changed a lot. I see now that we can teach them the skills and behaviors needed rather than just rote memorization of letters."

"It has totally changed how I'm approaching things. The children now do sound when they see letters. Even out and about, they're recognizing those specific [learned] letters."

(2) Shifting Classroom Practices—Enhanced Prevention-Based Skills:

"It helped me remember which kids I wanted to call on [to check on learning progress]. It helped me to put them into groups."

"I would just tie my own planning into the planning, so everything was connected. A lot of times, my days would be based on the activities from LRA Greenhouse."

"It helped me start to be more specific at how I divided up the kids… be more aware that they would need more guidance. I'm trying to find more time to do more 1:1 instead of just as a group."

"It made my support of them [children with High Priority Needs] better, and made me feel confident. It gave me more specific ways to support them and the language I needed, which was nice. It made my support of them better, and made me feel confident."

Regarding changes in *mindsets* (quotes in 1, above), teachers regularly mentioned how the LRA Greenhouse was "specific", and how this perceived specificity helped them to feel clear about their purpose and understanding of how their actions were connected to children's

literacy learning. Teachers also shared that the structure of the tool enabled them to reflect on their *practice* differently (quotes in 2, above—both in terms of building a greater understanding for relations between assessment-guided intentional teaching practices and how they attended to children's learning. In their willingness to implement new strategies for their classrooms, teachers reported changing their practice in ways that they were not explicitly trained, involving instructional planning, grouping, and initiating personalized supports. Anecdotally, teachers admitted that despite the effort they exerted to learn a new program, they were enthusiastic about how they could expand on its use the following school year.

Discussion

We found promising evidence that LRA Greenhouse tool use statistically and meaningfully improved Prekindergarten children's pre-reading levels and positively impacted teachers' mindsets and practices over the course of six months (nine days per month). In particular, through technology-managed and intentional teaching scaffolds, undergirded by relevant and feasible investments in online training, Oregon Prekindergarten teachers working in diverse settings adopted new assessment-guided approaches to literacy learning that sizably reduced RD risk in their classrooms.

A number of important factors contributed to our findings—factors that we argue can inform future developers of Prekindergarten educational tools. First, great care was taken to advance our original research-based ideas to better "fit" with what the early childhood field stated was needed. In this light, we worked to create a bridge between evidence-informed practices known to prevent RD in the schools and quality early childhood practices that are

important for developing "the whole child" (in which, prevention approaches can seem in opposition through their focus on strengthening early identified weaknesses). We developed this tool in close connection with the teachers so that the LRA Greenhouse would be developed *with teachers, for teachers.* Second, our use of technology was purposeful and designed to help remedy support gaps and inequities in the field. We embedded a variety of strategies within the tool to efficiently and effectively provide Prekindergarten teachers an opportunity to learn critical skills and develop greater precision for teaching literacy fundamentals, administer assessment and use the results to provide purpose-driven supports (particularly for children identified with High Priority Needs), and monitor and evaluate the effectiveness of their actions to promote timely learning. Third, we aimed for the LRA Greenhouse to permit instructional flexibility within its structure. Achieving balance in all aspects of development was challenging. Our team regularly weighed the trade-offs of design choices to create a tool that could make effective research-based practices accessible and worth "trying out", yet sustainable over time.

There are also limitations to these findings. First, this tool worked most successfully in higher-quality rated Preschool classrooms with experienced teachers. Teachers in these classrooms had some experience with assessment, and although they had not used it to guide instruction, could envision the benefits of using such information to individually support children at-risk for RD. In most cases, teachers also had supportive leadership, assistants, and parents. These human resources played important roles in both the enthusiasm and sustainability of trying innovative approaches. Second, although pilot study classrooms were diverse in many ways, the racial and ethnic composition of both children and teachers was not representative of all of Oregon nor the broader United States. Consequently, our findings may

have limited generalizability to Prekindergarten sites located in urban or rural areas of Oregon or in other states. Future development might focus on adapting the strategies we found fruitful in more racially and ethnically diverse settings. Third, although the research team was trained to not provide "coaching" (e.g., by recommending improvements in practice or giving specific praise), teachers were appreciative of the partnership that formed with team members over the course of their participation. It is likely that this benefit to participation positively influenced teachers' fairly easy up-take of the innovation and sustained motivation through "bumps in the road". We note this because these results may not be found in cases without this "spill-over" effect.

Conclusion

We believe that our preliminary findings are encouraging. Prekindergarten teachers implemented a strategic literacy + behavior regulation curriculum that contained mostly unknown evidence-informed strategies for learning *and* that required the use of technology in all aspects of a 5-step assessment-guided instructional decision-making model. Although we strived to keep instructional preparation, activity plan understanding, and assessment administration relevant and efficient, LRA Greenhouse implementation did initially entail additional prep time beyond typical practices. Our findings from examining teacher fidelity indicated that they could sustain their commitment to reducing children's risk for RD in time for starting Kindergarten through the use of the tool's wrap-around and embedded supports.

Teachers not only adopted new practices, but they deepened their knowledge of their children in ways that improved the quality of children's learning and reduced their risk for RD. Generally speaking, sustainably adopting new evidence-informed approaches involves change

that is never easy, even when simple. Thus, ensuring that new approaches are successful in Preschool requires striking a balance between implementing the research-based strategies that we know work in ways that respect the diverse philosophies and cultures of learning in these settings. Our current and future work on the LRA Greenhouse frames striking this balance as fundamental to ensuring all children successfully transition Kindergarten in ways that prevent the development of persistent RD.

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Appendix

Technical Report Results

Table 1. ***Pilot Study Mean Performance for LRA Greenhouse Implementing and Non-Implementing Comparison Classrooms***

Measure	Total Possible	4 Implementing Classes (*n* = 33)	4 Non-Implementing Classes (*n* = 37)
(F) Pre-reading	0-24	10.79 (4.01)	10.08 (4.25)
(S) Pre-reading		**14.97** (4.57)**	**11.08 (4.83)**
(F) Working Memory	0-5	0.88 (.89)	1.00 (1.00)
(S) Working Memory		**1.58* (.97)**	**1.08 (.83)**
(F) Task Engaged Behavior	0-75	44.06 (13.70)	47.48 (7.38)
(S) Task Engaged Behavior		51.21 (16.48)	49.41 (9.32)
(F) Prosocial Behavior	0-75	**54.47* (9.96)**	**50.00 (5.66)**
(S) Prosocial Behavior		56.70 (11.36)	53.46 (5.74)

Note. ** p = .001, * p < .05. All other comparisons were non-significant.

Table 2. ***Pilot Study Mean Performance for Four LRA Greenhouse Partial Implementing Classrooms (n = 24)***

Measure	Total Possible	Score Range	Mean	Std. Deviation
(W) Pre-reading	0-24	6-21	11.04	3.29
(S) Pre-reading		8-20	**12.58***	3.51
(W) Working Memory	0-5	0-2	0.75	0.79
(S) Working Memory		0-3	1.04	0.75
(W) Task Engaged Behavior	0-75	28-62	49.71	9.54
(S) Task Engaged Behavior		31-64	50.33	8.84
(W) Prosocial Behavior		35-74	52.13	8.78
(S) Prosocial Behavior		37-72	54.33	8.46

Note. * p = .01. All other comparisons were non-significant.

Table 3. ***Reliability for Pre-reading and BRS Components of the LRA by Season***

Pre-reading (Fall): α = .79		
BRS Total (Fall): α = .97	BRS TE(Fall): α = .94	BRS PRS (Fall): α = .95
Pre-reading (Winter): α = .73		
BRS Total (Winter): α = .94	BRS TE (Winter): α = .94	BRS PRS (Winter): α = .92
Pre-reading (Spring): α = .76		
BRS Total (Spring): α = .95	BRS TE (Spring): α = .93	BRS PRS (Spring): α = .93

Note. Due to the nature of the WM task design, in which all items were not administered, alpha could not be calculated.

BRS = Behavioral Rating Scale; TE = Task Engaged component of the BRS; PRS = Prosocial Engaged component of the BRS.

Table 4. ***Pearson Correlations of Prekindergarten LRA Measures Over Time***

Measure	W_LIT	S_LIT	F_WM	W_WM	S_WM	F_BRS	W_BRS	S_BRS	F_BRS.TE	W_BRS.TE	S_BRS.TE	F_BRS.PE	W_BRS.PE	S_BRS.PE
F_LIT	**.77****	**.73****	**.56****	.25	**.40***	**.68****	**.70****	**.71****	**.67****	**.63****	**.69****	**.59****	**.59****	**.59****
W_LIT	1.00	**.80*****	**.46***	**.41***	.18	**.41***	**.50****	**.49****	**.39***	**.40***	**.45***	**.38***	**.49****	**.44***
S_LIT	--	1.00	**.48****	.31	**.40***	**.40***	**.62*****	**.52****	**.38***	**.56****	**.52****	.36	**.52****	**.42***
F_WM	--	--	1.00	.17	.28	**.52****	**.50****	**.50****	**.43***	**.39***	**.39***	**.57****	**.52****	**.55****
W_WM	--	--	--	1.00	.18	.05	.32	.25	.12	.35	.31	-.05	.17	.12
S_WM	--	--	--	--	1.00	**.42***	**.53****	**.47****	**.39***	**.49****	**.41***	**.39***	**.43***	**.476****
F_BRS	--	--	--	--	--	1.00	**.80*****	**.83*****	--	--	--	--	--	--
W BRS	--	--	--	--	--	--	1.00	**.86*****	--	--	--	--	--	--
S_BRS	--	--	--	--	--	--	--	--	--	--	--	--	--	--
F_BRS.TE	--	--	--	--	--	--	--	--	1.00	**.74*****	**.81****	**.77*****	**.55****	**.63*****
W_BRS.TE	--	--	--	--	--	--	--	--	--	1.00	**.81*****	**.52****	**.52****	**.53****
S_BRS.TE	--	--	--	--	--	--	--	--	--	--	1.00	**.57****	**.56****	**.69*****
F_BRS.PE	--	--	--	--	--	--	--	--	--	--	--	1.00	**.81*****	**.86*****
W_BRS.PE	--	--	--	--	--	--	--	--	--	--	--	--	1.00	**.89*****

Note. Pearson correlations were obtained to examine the consistency of construct relations over time (with n = 29 children from 4 classrooms implementing the tool across six months of the school year). **Bolded** correlations are significant ($p \leq 0.05$).

*** = $p < .001$; ** = $p < .01$; * = $p < .05$; F = Fall; W = Winter; S = Spring; LIT = Pre-reading Literacy; WM = Working Memory; BRS = Behavior Rating Scale; TE = Task Engaged regulation (of the BRS); PE = Prosocial Engaged regulation (of the BRS).

Participating teachers' perceptions of tool suitability, reported via individual interviews and online surveys are organized below based on: ***Feasibility***, ***Accessibility***, ***Usefulness***, ***Fit***, ***Facilitation***, and ***Impact on Practice***.

Feasibility — Ease and efficiency of LRA Greenhouse implementation in preschool classrooms

Table 5. ***LRA Greenhouse —Feasibility Across 39 occasions***

Survey Item	***n teachers***	***M***	***Not at all***	***Occasionally***	***Somewhat***	***Mostly***	***Definitely***
How easy was it to implement today's activities (in terms of having/finding what you needed)?	6	4.67	-	1	3	4	31
How easy was it for children to grasp the big ideas from today's activities?	6	4.41	-	-	8	7	24
Did you encounter any hiccups that led you to feel that today's implementation was less than ideal?	6	1.44*	29	3	7	-	-
How likely would you be to recommend the activities in this unit to a friend?	6	4.85	-	-	1	4	34

Note. * Reverse coded, where a lower value denotes a more positive quality (fewer "hiccups"). DA = Developmentally Appropriate.

Accessibility — Simplicity and straightforwardness of access to and use of LRA Greenhouse components

Table 6a. ***LRA Behavior Rating Scale (BRS) — Accessibility***				
Survey Item	***n***	***M***	***No***	***Yes***
Creating student list was an easy process.	6	1.00	-	6
Tablet log in/out was easy.	7	1.00	-	7
Finding the BRS and getting into it was easy.	7	1.00	-	7
Screen responding was easy (and sensitive to touch).	7	0.86	1	6
BRS items on the screen were easy to see.	7	1.00	-	7
Task instructions were clear.	7	1.00	-	7
Navigating through the task (i.e., knowing what/where to touch for responding) was simple.	7	1.00	-	7
I completed the task efficiently.	7	1.00	-	7

Table 6b. ***LRA Greenhouse — Accessibility***							
Survey Item	***n***	***M***	***Strongly Disagree***	***Disagree***	***Neutral***	***Agree***	***Strongly Agree***
Tablet log-in and navigation in the app were easy.	8	4.00	-	-	1	2	4
How to administer the LRA and find test score results was clear.	8	4.38	-	-	2	1	5
It would be possible to devote 20 minutes per child (or per small group of children) for administering screening assessments two or three times per year.	8	4.38	-	-	1	3	4

Usefulness — Effectiveness of LRA Greenhouse at characterizing children's literacy skills and learning needs

Table 7. *LRA — Usefulness*							
Survey Item	***n***	***M***	***Strongly Disagree***	***Disagree***	***Neutral***	***Agree***	***Strongly Agree***
The LRA results appropriately differentiated children with different skill and ability levels.	8	4.38	-	-	2	1	5
Children "at-risk" for reading difficulties were appropriately identified by the LRA.	8	4.75	-	-	-	2	6
I understood what the LRA results meant for my class.	6	4.33	-	-	-	4	2

Fit —– Appropriateness of LRA Greenhouse for preschool classrooms

Table 8. ***LRA and Greenhouse —– Fit***							
Survey Item	***n***	***M***	***Strongly Disagree***	***Disagree***	***Neutral***	***Agree***	***Strongly Agree***
The LRA literacy items were developmentally appropriate.	8	4.63	-	-	-	3	5
The LRA working memory task was developmentally appropriate.	8	4.63	-	-	-	3	5
The LRA behavior rating scale items were developmentally appropriate.	8	4.75	-	-	-	2	6
Using information from the LRA to check on how children in my class are doing “fit” with my typical approach to helping children develop.	6	4.75	-	-	-	2	6

Facilitation — Capacity of LRA Greenhouse to support evidence-informed practices and assessment-guided instructional decision-making

Table 9. ***LRA Greenhouse — Facilitation***							
Survey Item	***n***	***M***	***Strongly Disagree***	***Disagree***	***Neutral***	***Agree***	***Strongly Agree***
Knowing about assessment results improved my effectiveness at helping my class learn.	6	4.50	-	-	-	3	3
Knowing about "High Priority Needs" in my classroom helped me identify the children who most needed my support for developing emergent literacy.	6	4.33	-	-	1	2	3
The LRA Greenhouse activities helped me plan and implement appropriate activities to meet the diverse learning needs of children in my class.	8	4.75	-	-	-	2	6
Using the Activities Checklist to monitor children's learning positively impacted how I supported development in my class.	6	4.00	-	-	2	2	2
Implementing LRA Greenhouse activities helped me learn something new about the children in my class.	6	4.33	-	-	1	2	3
Implementing LRA Greenhouse activities gave me insight or new ideas about my typical classroom practices.	6	4.50	-	-	1	1	4

Impact on Practice — Impact of LRA Greenhouse on how teachers develop children's emergent literacy skills

Table 10. ***LRA Greenhouse — Impact on Practice***							
Survey Item	***n***	***M***	***Strongly Disagree***	***Disagree***	***Neutral***	***Agree***	***Strongly Agree***
I am better able to identify children "at risk" of learning difficulties now.	8	4.13	-	-	2	3	3
I monitor children's progress more carefully now.	8	4.38	-	-	1	3	4
I can discuss with parents the needs of their child differently now.	8	4.25	-	-	1	4	3
I can better explain to other educators how to best support the learning needs of children in my class now.	8	4.13	-	-	2	3	3
I have changed the manner in which I work with children identified as having "High Priority Needs" now.	8	4.25	-	-	2	2	4