Research Report

The State Kindergarten Entry Assessment Digital Technology Landscape

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RESEARCH REPORT

The State Kindergarten Entry Assessment Digital Technology Landscape

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Over the past 8 years, U.S. kindergarten classrooms have been impacted by policies mandating or recommending the administration of a specific kindergarten entry assessment (KEA) in the initial months of school as well as the increasing reliance on digital technology in the form of mobile apps, touchscreen devices, and online data platforms. Using a sample of KEAs used in 29 states in Fall 2019, in this report I examine the KEA digital technology landscape. Of particular interest was the extent to which states with similar KEA item types incorporated such technology as well as the potential impact of these technology inputs on the role of the kindergarten teacher in the KEA administration, scoring, and report-generating processes. Analyses of the study's data demonstrated that all 29 states incorporate digital technology into their KEAs. However, differences among states' technological inputs suggested four different models of KEAs along a continuum of supplanting versus retaining teachers' active roles in the administration, scoring, and report-generating processes. These findings have implications for short-term research agendas aimed at supporting KEA validity, reliability, and utility.

Keywords Kindergarten entry assessments; early childhood assessment; formative assessment; digital technology; assessment technology

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Over the past 8 years, U.S. kindergarten classrooms have been impacted by two key teaching- and learning-relevant trends. The first trend is state policies mandating or recommending the administration of a specific kindergarten entry assessment (KEA) in the initial months of school with the aim of informing kindergarten teachers' instruction (Daily & Maxwell, 2018). The second trend — and one that has impacted classrooms across the entire PreK – 12 spectrum — is the increasing reliance on touchscreen devices, mobile applications (apps), online data platforms, and other digital technology inputs (Teaching Strategies, 2015a; U.S. Department of Education, Office of Educational Technology, 2016, 2017).

Although these two trends can take place independently, an emerging research base suggests that digital technology has the potential to support the validity, reliability, and utility of formative assessments (Faber & Visscher, 2018; Neumann, Anthony, et al., 2019; Vasquez et al., 2017). Furthermore, early childhood assessment developers have incorporated this technology into the administration, response or evidence recording, scoring, and report-generating processes (e.g., Ackerman & Friedman-Krauss, 2017; Carson, 2017; Halle et al., 2011; Moodie et al., 2014). However, researchers have not yet looked across state KEAs and examined in what ways these measures incorporate digital technology. Given the national focus on integrating technology into the PreK – 12 educational system (U.S. Department of Education, Office of Educational Technology, 2017) and the trade-offs inherent in any assessment design (Pellegrino et al., 2001), the lack of such an overview makes it challenging to provide KEA policy makers and other stakeholders with "state of the field" information about their assessment options (Jiban, 2013). This absence also makes it challenging to inform research agendas aimed at supporting KEA validity, reliability, and utility (Nelson et al., 2009).

In this report, I therefore provide an overview of the Fall 2019 KEA digital technology landscape. Of particular interest were the extent to which the reliance on such technology varies among states with similar KEA item types (e.g., selected response questions and on-demand performance tasks versus developmental rubrics) as well as the potential impact of these technology inputs on the role of the kindergarten teacher in the KEA administration, scoring, and report generating processes. To begin, I provide an overview of the current KEA policy context. Next, I examine the trade-offs policy makers need to keep in mind when considering the ways in which digital technology might enhance KEA validity, reliability, and utility. After sharing the study's results, I conclude with some implications for future KEA technology-focused research.

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Kindergarten Entry Assessments

Thinking about the array of skills and knowledge that entering kindergartners bring to school highlights the potential usefulness of KEA data for informing teachers' beginning-of-the-school-year pedagogical decisions. For example, some kindergartners are learning upper- and lowercase letter names. Other students will have a firm grasp of letter–sound knowledge and the capacity to read a few simple words. Similarly, one kindergartner may be mastering her numeral recognition skills, whereas her classmate will be able to perform simple mathematical operations (Bassok & Latham, 2017; Bernstein et al., 2014). Therefore, to meet the learning needs of all of these kindergartners, teachers need to differentiate their instruction (Dijkstra et al., 2016). However, to plan such instruction, teachers first need data on what students already know or can do (Al Otaiba et al., 2011; Moon, 2005).

One source of such data is KEAs, which have been developed, piloted, field tested, or implemented in at least 40 states and the District of Columbia since 2011 (Center on Standards and Assessment Implementation, 2018). The recent emphasis on KEAs stems, in part, from federal support to 30 states from Race to the Top–Early Learning Challenge and Enhanced Assessment Grant awards (U.S. Department of Education & U.S. Department of Health and Human Services, 2014). Another contributor has been states' efforts to extend the impact of their investments in publicly funded PreK by aligning early primary grade learning standards (Center on Enhancing Early Learning Outcomes & Council of Chief State School Officers, 2017).

One commonality across states' KEAs is their beginning-of-the-school year administration time frame as a means for informing teachers' instruction. Some states also use aggregated KEA data to report district or statewide school readiness rates (Daily & Maxwell, 2018). However, the KEAs used across the United States vary in terms of their domains and the focus on specific constructs within domains. In addition, some KEAs consist solely of selected response questions (e.g., student is prompted to select the letter A from a group of three possible answers) or on-demand performance tasks (e.g., student is prompted to count a prespecified set of objects), whereas other KEAs rely on observational checklists (e.g., teacher indicates if child rarely, sometimes, or consistently displays a specific behavior or skill) or developmental rubrics (i.e., teacher indicates to what degree a child can perform a type of mathematical operation). Both of these latter item types typically require teachers to collect evidence of students' skills while engaged in day-to-day classroom activities and then compare that evidence with the information provided in the item's checklist or rubric (Ackerman, 2018a, 2018b, 2020).

Variations in KEAs are partially due to the ongoing debate regarding appropriate methods for assessing young children (Snow & Van Hemel, 2008). Other contributors include state control of K–12 education, differing standards for what kindergartners should know and be able to do, and the revisions made to KEAs and their policies as they were initially implemented and then scaled up across a state (Ackerman, 2018a, 2018b). One overriding factor that policy makers need to keep in mind is the degree to which the measure has adequate validity, reliability, and utility for the different stakeholders that are expected to rely on its data.

Assessing Young Children: Potential Validity, Reliability, and Utility Trade-Offs

Validity, reliability, and utility are admittedly complex constructs and worthy of their own report. However, generally speaking, *validity* refers to the extent to which there is sufficient evidence to support the interpretation of a measure's scores for a specific purpose and population of students (Bonner, 2013; Kane, 2013). *Reliability* is defined as the degree to which a measure provides consistent results over different assessors or observers, testing occasions (assuming there is a minimal time lapse between testing occasions), and test forms (Livingston, 2018). Finally, *utility* is an assessment's practical cost versus benefit value from the perspective of the individual tasked with using its data for a specific purpose (Snow & Van Hemel, 2008).

It can be challenging to balance these three considerations when the individuals who rely on an assessment do not share identical objectives. For example, policy makers seeking to compile "big picture" data may view an assessment as having a high level of utility due to its reliability across their state's kindergarten classrooms. However, individual teachers may perceive the same measure as having a low level of utility because its item and domain focus, or score report granularity, is not fully aligned with their short-term instructional needs (Goldstein & McCoach, 2011; Mangione et al., 2019). Alternatively, teachers may find their self-made formative measures to be both easy to administer and extremely useful for informing their day-to-day instruction (Blessing, 2019; Ferguson et al., 2013; Pyle & DeLuca, 2017). Yet, because

these assessments vary between classrooms, their data likely will not be as useful to district superintendents or state policy makers (National Center for System Improvement Data Use Service Area Team, 2017).

Given these tensions, policy makers need to consider the validity, reliability, and utility trade-offs that come with different assessment designs (Pellegrino et al., 2001). Because a typical entering kindergartner will not have the capacity to read independently (Bassok & Latham, 2017; Rathbun & Zhang, 2016; Zill & West, 2001) and may still be developing their fine motor skills (Pitchford et al., 2016) and level of self-regulation (Montroy et al., 2016), one salient contributor to the KEA "balance equation" is the role of the classroom teacher in administering and scoring the measure. If that role is to be partially or fully supplanted by digital technology, also to be considered, then, are the tools, funding, and infrastructure needed to successfully support the measure's implementation.

Teacher-Dependent Assessment Trade-Offs

Pedagogical Benefits

Teachers have traditionally played an important role in the early childhood assessment process. For example, they can orally provide test directions and selected response item prompts to measure children's constrained skills (e.g., letter recognition). They also can administer on-demand performance tasks to highlight a student's full range of cognitive development. Some noncognitive domains can be measured in a more valid and reliable manner when relying on a teacher-scored observational measure. And, by gathering evidence of student's knowledge and skills as part of their day-to-day classroom activities, teachers can gain a first-hand sense of students' strengths and weaknesses (Denham et al., 2009; Meisels & Atkins-Burnett, 2000; Snow & Van Hemel, 2008).

In addition to bolstering children's capacity to accurately display what they know and can do, involving teachers in the assessment process can have positive spillover effects. For entering kindergartners, having their classroom teacher administer selected response questions or on-demand performance tasks can help establish an initial sense of rapport (Snow & Van Hemel, 2008). In addition, teachers can hear students think "out loud" and understand the strategy they used to sound out a word or solve a mathematics problem (Clements et al., 2015; Cochell & Fulmer, 2017; Downton, 2018). In short, by actively participating in the assessment process, teachers can enhance the validity of assessment data, gain qualitative insight into children's current skill levels, and lay the groundwork for future instructional interactions.

Cautions Regarding Teacher-Dependent Assessments

Yet, teacher-dependent assessments can present potential validity, reliability, and utility challenges, particularly when the results of assessments are aggregated at the school, district, or state level. One obvious concern is teacher fidelity to administering and scoring a measure as intended by its developer. Of course, assessment policy makers need to ensure that teachers receive adequate training (Grisham-Brown et al., 2008). However, even well-trained teachers can make inadvertent selected response or on-demand performance task scoring errors (Harrison et al., 2019) as well as mistakes when manually transferring an individual student's scores to a master score sheet (Clements et al., 2015). Research conducted on observations of teaching quality has also suggested that rating errors are more likely when observers are less experienced using a measure or are using a high-inference rubric (Casabianca et al., 2015). And, scoring reliability may be impacted by the relationship a teacher has with the student being assessed, particularly if the assessment's scores are perceived to contribute to some type of consequential decision for the student, teacher, or program (Harvey et al., 2013; Waterman et al., 2012). While such bias is rarely intentional, it may result in over- or underestimating students' knowledge or skills.

A second challenge stems from the home language of the students being assessed. Specifically, student proficiency in the language in which a test is given can serve as a major source of variation in assessment scores (American Educational Research Association et al., 2014). To mitigate the potential effect of language on the validity and reliability of assessments used with English learners, policy makers may allow these students to hear translations of test directions or item prompts as well as demonstrate what they know or can do in their home language (Guzman-Orth et al., 2017; Lopez et al., 2017). However, teachers cannot be expected to be proficient in all of their students' respective home languages (Ackerman & Tazi, 2015). Not surprisingly, previous research has suggested some validity and reliability concerns when teachers serve as an assessor or observer in classrooms serving young English learners (Hanover Research, 2017; Howard et al., 2017; Lambert et al., 2015; Miller-Bains et al., 2017; Soderberg et al., 2013).

Finally, an emerging research base examines teachers' perspectives on the utility of KEAs that need to be administered on a one-to-one basis. A prime issue across multiple states has been the amount of instructional time lost to assessing every kindergartner within the first few weeks of school (Harvey & Ohle, 2018; Kwon et al., 2018; Loesch-Griffin et al., 2014; Maryland State Department of Education, 2019a; Schachter et al., 2017). States have responded by reducing the total number of items to be administered, dropping items that are more difficult to administer or score, extending the period in which kindergartners need to be assessed, or replacing an entire assessment. Another "fix" has been to incorporate digital technology into some or all aspects of a teacher-dependent KEA (Ackerman, 2018b).

Digital-Dependent Assessment Trade-Offs

Just as assessments are not valid or reliable on their own, the mere inclusion of digital technology does not necessarily mean that any of the teacher-dependent challenges previously highlighted will be sufficiently addressed. However, another emerging research base suggests the potential benefits of replacing some or all teacher-dependent tasks as well as considering the advantages of specific digital inputs for particular constructs or item types.

"Full Supplant" Model

One digital model to consider is to house a selected response question or on-demand performance task assessment on a computer, laptop, or tablet via software or a desktop or mobile app. Doing so offers the potential to fully supplant all teacher-dependent assessment tasks. Specifically, prerecorded assessment directions and item prompts can be played through the device's audio system. In addition, students can indicate their responses through the use of a keyboard, mouse, or interaction with a touchscreen. These responses also can be automatically scored (U.S. Department of Education, Office of Educational Technology, 2017).

By standardizing the administration and scoring process, this model has the potential to support reliability across classrooms. Such standardization can be especially critical in states that aggregate KEA data to examine overall kindergarten readiness rates. And, assuming teachers do not need to complete administration training or set aside instructional time for one-to-one testing, this option may represent a time saver for teachers (K. Carson et al., 2011; Clements et al., 2015; Neumann & Neumann, 2018).

Another potential advantage of the full supplant model is the capacity to preprogram the directions for completing the assessment and its individual item prompts in other languages (Takanishi & Le Menestrel, 2017). Owing to the fact that young children can experience difficulty in developing their mathematics-related vocabulary (Hassinger-Das et al., 2015; Riccomini et al., 2015), item prompt translations may be particularly helpful when assessing young English learners' mathematics knowledge and skills (Robinson, 2010). However (and as is the case with teacher-administered direct assessments), test developers need to ensure that the translations are culturally appropriate and the items have the same level of difficulty as was found in the original assessment (Atkins-Burnett et al., 2012; Clements et al., 2015; Goldfeld et al., 2009).

This model also provides the opportunity to incorporate *adaptive* item banks. This term refers to programming that allows students who correctly answer certain preliminary questions to be routed into more challenging items, whereas students who answer these same questions incorrectly are routed to items reflecting earlier skill levels (Hernandez et al., 2015; U.S. Department of Education, Office of Educational Technology, 2017). By incorporating a larger number of items than are typically available in a paper-and-pencil direct assessment, such adaptive tests have the potential to better inform teachers' instructional planning (Merrell, 2012).

"Partial Supplant" Model

As mentioned above, due to a typical entering kindergartner's developmental level, it can be challenging to assess all of their cognitive and noncognitive skills solely via selected response questions and on-demand performance tasks. As a result, it may be more appropriate to assess some or all skills via observational checklists or developmental rubrics. However, digital technology does not yet offer an option for replacing the key role of the teacher when relying on this type of assessment approach. Furthermore, early childhood assessment policy makers may intentionally wish to retain the role of the teacher in the KEA process due to the positive spillover effects noted earlier. Therefore, a second digital model to be considered is to house observational checklist and development rubric items—or even selected response questions

or on-demand performance tasks—on laptops, tablets, or small mobile devices but to rely on the teacher to deliver item prompts, note students' responses, upload performance evidence, and enter scores or rubric ratings (U.S. Department of Education, Office of Educational Technology, 2017).

When adopting this partial supplant model, the use of web-enabled handheld devices can offer additional advantages. For example, access to an interactive, online assessment offers teachers the opportunity to gather and score observational checklist or developmental rubric evidence on a one-step, real-time basis (Irvin et al., 2016), as opposed to first documenting a student's knowledge and skills on paper, and then subsequently sitting in front of a computer or stationary laptop for the sole purpose of manually uploading the student's scores. I could not identify peer-reviewed published research comparing preschool or kindergarten teachers' perceptions of these two methods, but several qualitative studies document Head Start and kindergarten teachers' negative perceptions of the amount of time necessary to complete the two-step "score on paper and upload later" process (Kim, 2016, 2018; Loesch-Griffin et al., 2014). iPads and other tablets with online access to interactive rubrics may be especially advantageous when rating real-time student performance in classroom settings that make using a laptop or stationary computer impractical, such as the playground (Franklin & Smith, 2015; Howard & Melhuish, 2017; Neumann, Warrall, & Neumann, 2019).

A related option to consider is to house the measure on a handheld device, but also incorporate a mobile app. Apps can be useful for facilitating the one-step scoring process just described. However, given that photographs and videos can be useful for documenting evidence of a performance task, rubric, or checklist score (Roller et al., 2019), mobile apps may offer an additional time-saving benefit to teachers. Specifically, research on using a camera as part of the formative assessment process has suggested that a two-step "first photograph and then upload separately" process also can be burdensome (Ferrara & Lambert, 2015). Access to an assessment via a mobile app can potentially address this issue, as teachers can use the device's built-in camera and then directly upload that photo or video evidence to a file for each student (Barnes, 2015a; Kwon et al., 2018; Parnell & Bartlett, 2012; Wakabayashi et al., 2019; Williamson-Leadley & Ingram, 2013). Research on ePortfolios of student learning has also suggested that such technology facilitates more frequent documentation of children's work as compared to relying on a stand-alone camera (Lim, 2017; MacDonald, 2007).

Given that KEAs generally are used as formative measures aimed at helping teachers make short-term instructional decisions, timely access to these data is a critical issue (Jiban, 2013; Kallemeyn & DeStefano, 2009). Therefore, no matter which digital model or device is used, a final option to consider is whether to house teacher- or automatically generated score data on an online platform as a means to provide teachers with the option to generate student- and classroom-specific score reports immediately after concluding an assessment or observation. The software supporting the assessment or observation might also be programmed to group children based on their score profiles. Equally important, prior research has suggested that teachers do not necessarily have the capacity to interpret assessment data and identify the appropriate instructional activities that might address the weaknesses evidenced by individual and classroom-wide assessment scores (Akers et al., 2015; Ginsburg, 2009; Roehrig et al., 2008). And, knowledge of the ways in which young English learners increase their early language and literacy skills is likely necessary to understand how to address assessment results that categorize a student as at-risk in these areas (Ntuli et al., 2014; Orosco & Klingner, 2010).Therefore, such programming also might include targeted activities for both lower and higher performing children (Clements et al., 2015; Wakabayashi et al., 2019). Prior research on direct assessments of preschoolers' language and early literacy skills has suggested that the provision of such guidance can help teachers better target their instruction (Landry et al., 2009).

Cautions About Digital Models

Yet, policy makers and teachers should keep several cautions in mind when considering to what extent either of these digital models might be incorporated into the KEA process. In the case of available paper assessments, developers need to ensure that the paper- and digital-based versions can be considered as equivalent measures of students' knowledge, and equally important, that the digital version does not introduce any device-related validity and reliability challenges (Carson et al., 2011; Csapó et al., 2014; Neumann & Neumann, 2018). This latter challenge is especially salient when assessing young children, as although 4- and 5-year-olds can quickly become proficient with touchscreen-based operational features (Crescenzi et al., 2014), they may not be equally experienced in using digital devices (Barnes, 2015b; Frank et al., 2016; Marsh, 2016). And, when relying on self-administered, computer-based assessments, students at this age may not have sufficient fine motor control to use a computer's mouse or keyboard to advance through an assessment's items or indicate a correct response (Donker & Reitsma, 2007). Assuming an assessment's item-related focus is otherwise developmentally

appropriate for a child's age, consideration also needs to be given to how much teacher or other staff time is required to familiarize students with the directions for completing the assessment (Semmelmann et al., 2016).

Furthermore, the device used for self-administered assessments may present item-specific trade-offs to consider. For example, one study using a sample of fifteen 4- to 6-year-olds with autism compared children's scores when tested with paper and iPad versions of a well-known measure of receptive vocabulary. Although the main focus of the study was to confirm that both test forms were equivalent in terms of raw and scaled scores, an unexpected finding was that the children appeared to be more motivated to participate in the testing session when using the iPad. The researchers hypothesized this finding was due to the device's visual display and interactive platform (Marble-Flint et al., 2019). Another study using a sample of 65 kindergartners found that their scores on an assessment of telling time skills were higher when using an iPad-based clock or toy clock versus a paper-based, black-and-white drawing of a clock (F. Wang et al., 2016). Yet, a third study used a sample of Swedish 8- to 9 1/2-year-olds to examine the comparability of tablet and paper versions of a basic mathematics skills assessment. Researchers found that the two formats were generally comparable. However, there was far less comparability for an item that required students to add or multiply using pictures of items, as opposed to numerical symbols. The researchers hypothesized that the difference between the two formats may have been related to students' inability to use a pencil to touch and count or cross-off items (Hallstedt & Ghaderi, 2018).

KEA stakeholders also need to consider the feasibility of using a digital technology-infused assessment in its intended setting (Blackwell et al., 2013; Gielniak et al., 2017; Greaves et al., 2010; U.S. Department of Education, Office of Educational Technology, 2017). One critical issue is the availability of consistent classroom connectivity to the internet (Bergstrom et al., 2006; Loesch-Griffin et al., 2014; Raber et al., 2017). Research on the initial implementation of KEAs has demonstrated that their online data systems can experience some user "kinks" (Ackerman, 2018b; Bowdon et al., 2019; Golan et al., 2016). Assessment policy makers also need to consider if the mobile apps that have been developed to be used with a particular assessment are compatible with the operating systems or data platforms schools intend to use (Ascate et al., 2019) and do not jeopardize data security and student privacy concerns (Wyatt-Smith et al., 2019).

In addition, the large item banks that are part of computer-adaptive assessments can drive up per-pupil costs (Tomasik et al., 2018). There are financial costs related to purchasing laptops or tablets, as well. And, in the case of the latter device specifically, the availability of a KEA mobile app is a moot point if teachers do not have regular access to a tablet (Ferrara & Lambert, 2016; Raber et al., 2017).

Finally, teachers do not necessarily have the skills, knowledge, or experience needed to effectively integrate digital options into their pedagogical strategies (Blackwell, 2014; Blackwell et al., 2014; Brown & Englehardt, 2017; McGlynn-Stewart et al., 2019). Relatedly, teachers' capacity to access and use a digital technology-based assessment as intended by its developer can impact their perceptions of the utility of the assessment (Kim, 2018). In light of all of these issues, the National Association for the Education of Young Children and the Fred Rogers Center for Early Learning and Children's Media at Saint Vincent College (2012) urge that teachers and education policy makers exercise caution before incorporating digital technology tools into the teaching and learning process.

The Current Study

Owing to the fact that the majority of KEAs have been developed and implemented over the past 8 years, the research base on these assessments is still emerging. For example, one set of studies investigates the extent to which KEAs are valid and reliable for specific purposes and populations of kindergartners (e.g., Bowdon et al., 2019; Gotch et al., 2017; Howard et al., 2017; Irvin et al., 2017; Soderberg et al., 2013; Tindal et al., 2015). Another group of studies examines teachers' perspectives on KEA utility (Harvey & Ohle, 2018; Maryland State Department of Education, 2019b; Raber et al., 2017; Schachter et al., 2017).

This research is critical for understanding how KEAs might be enhanced to better inform teachers, parents, and policy makers. However, to date researchers have not examined in what ways state-mandated or -recommended KEAs incorporate digital technology. Because an emerging research base has suggested that this technology has the potential to support the validity, reliability, and utility of formative assessments, the lack of such an overview makes it challenging to provide KEA policy makers and other stakeholders with up-to-date information about their assessment options, much less inform KEA-focused research agendas.

The current study, therefore, focused on the Fall 2019 KEA technology landscape. The study's research questions were (a) to what extent did KEAs with similar item types (i.e., selected-response questions or on-demand performance tasks

versus observation checklists or developmental rubrics) incorporate digital technology as part of their administration, response or evidence recording, and report generating processes and (b) looking across these KEAs, what is the potential impact of their digital technology inputs on supplanting versus retaining kindergarten teachers' role in the KEA process.

To address these research questions, I relied on a case study methodology. This approach was particularly well suited to the current investigation, as each state and its KEA administration, response or evidence recording, scoring, and report-generating processes represented a single unit of analysis. These states and KEAs also presented the opportunity to conduct cross-case analyses due to sharing similar components and data use goals (Yin, 2014).

Methodology

Sample

The study's sample cases consisted of the state-mandated or -recommended KEAs used in 29 U.S. states in Fall 2019. Although the majority of the remaining 21 states and the District of Columbia implemented KEAs as recently as the 2018–2019 school year, I did not include these jurisdictions in the current study because I could not locate online information regarding the Fall 2019 administration of their measures. As can be seen in Table 1, four of the 29 sampled states relied on measures comprised solely of selected response questions or on-demand performance tasks, whereas 14 additional states used KEAs consisting solely of observational checklists or developmental rubrics. The final 11 states relied on an "all of the above" combination of item types.

These 29 states also varied in terms of their KEA domains. Specifically, four states focused solely on literacy or literacy and mathematics, whereas the remainder focused on both cognitive and non-cognitive domains. These latter domains included social–emotional development and other domains such as executive function and physical development. This difference was important to highlight, as the early childhood skill being assessed can drive the selection of KEA item types. A final difference was that 12 states used KEAs that were commercially available measures or state-customized versions of "off the shelf" measures, whereas the remaining jurisdictions relied on KEAs developed by state education agencies. Although this study did not examine the reasons why any of the sample states with similar item types incorporated (or did not incorporate) specific digital technology inputs into their measures, it is important to note that assessment development can involve a significant financial investment (Bennett, 2011; Pellegrino et al., 2001). I therefore identified whether a KEA was commercially available or state developed as a means for potentially informing the study's results.

Data Sources and Analyses

I obtained the majority of my data from publicly available websites related to the sample states' KEAs. Some of the data also came from KEA administration guidebooks, whereas other sources included KEA-relevant memoranda from individual state departments of education, FAQs, orientation webinars, and state outcome reports. The Appendix lists the links to all of these sources.

As I read through all of these data sources, my focus was on evidence of the extent to which digital technology was incorporated into the KEAs that shared similar item types (see Table 2). Specifically, for the KEAs that included selected response questions or on-demand performance tasks, I investigated whether some or all items could be self-administered via a digital device and the types of devices that could be used. In comparison, if teachers needed to administer and score any or all items, I sought information regarding whether the items were housed on a digital device versus paper copies of the KEA. Similarly, when reading through the data sources for the KEAs that included observational checklists or developmental rubrics, I searched for information regarding the opportunity for teachers to use an app versus needing to use a paper copy of the KEA and then manually enter the data into an online platform. Finally, no matter what a KEA's item type(s), I sought information regarding teachers' capacity to use a desktop or mobile app or software to generate student and classroom reports.

Given the small size of the sample, but especially the number of states in each of the three KEA item type subsamples, my analyses for the first research question consisted of generating simple descriptive statistics. For the second research question, I looked across the entire sample and grouped states according to the extent to which their digital technology inputs had the potential to supplant versus retain the role of the teacher in the KEA process. For example, KEAs that were comprised solely of self-administered items would be considered to reflect a full supplant model, whereas measures that required teachers to administer and score all items would be considered as fully retaining the role of the teacher.

Table 1 Sample Kindergarten Entry Assessments (KEAs)

State and KEA	Domain					Commercially available
	Language	Literacy	Math	Social–emotional	Other domain	
Selected response questions and on-demand performance tasks only ($n = 4$)						
Arkansas: Choice of Istation Indicators of Progress/ISIP, NWEA Map Growth, or Star Early Literacy		X	X			X
Florida Kindergarten Readiness Screener (Star Early Literacy)		X	X			X
Idaho Reading Indicator (Istation Indicators of Progress/ISIP)		X				X
Mississippi Kindergarten Readiness Assessment (Star Early Literacy)		X	X			X
Observational checklists or developmental rubrics only ($n = 14$)						
Alaska Developmental Profile	X	X	X	X	X	
California: Desired Results Developmental Profile (DRDP-K)	X	X	X	X	X	
Colorado Kindergarten Readiness Assessment: Choice of Teaching Strategies GOLD, High/Scope COR for K, DRDP-K, or North Carolina Kindergarten Entry Assessment	X	X	X	X	X	Teaching Strategies GOLD and High/Scope COR only
Delaware Early Learner Survey (state-customized Teaching Strategies GOLD)	X	X	X	X	X	X
Illinois Kindergarten Individual Development Survey (KIDS; modified DRDP-K)	X	X	X	X	X	
Kansas Kindergarten Readiness Snapshot (Ages & Stages Questionnaires, Third Edition/ASQ-3 and Ages & Stages Questionnaires: Social–Emotional, Second Edition/ASQ:SE-2)	X	X	X	X	X	X
Louisiana Kindergarten Entry Assessment (Choice: Teaching Strategies GOLD or DRDP-K)	X	X	X	X	X	Teaching Strategies GOLD only
Minnesota Kindergarten Entry Profile (Choice of DRDP-K, Teaching Strategies GOLD, Minnesota Work Sampling System, or Developmental Milestones for Kindergarten [DevMilestones])	X	X	X	X	X	Teaching Strategies GOLD, Work Sampling System, and DevMilestones only
New Mexico Kindergarten Observation Tool (KOT)		X		X	X	X
North Carolina Kindergarten Entry Assessment	X		X	X	X	X
Pennsylvania Kindergarten Entry Inventory (KEI)	X		X	X	X	X
Tennessee Kindergarten Entry Inventory/KEI (DRDP-K)		X		X	X	X
Vermont Ready for Kindergarten!Survey (R4K!S)	X		X	X	X	X
Washington Kindergarten Inventory of Developing Skills (WaKIDS, state-customized Teaching Strategies GOLD)	X		X	X	X	X
Combination of item types ($n = 11$)						
Georgia Kindergarten Inventory of Developing Skills (GKIDS) 2.0 Readiness Check		X		X	X	X
Kentucky's Common Kindergarten Entry Screener (Brigance Early Childhood Screen III)	X		X	X	X	X
Maryland Kindergarten Readiness Assessment (KRA)		X		X	X	X
Michigan Kindergarten Readiness Assessment (KRA)		X		X	X	X
Nevada Kindergarten Entry Assessment (KEA; Brigance Early Childhood Screen III)	X		X	X	X	X
Ohio's Kindergarten Readiness Assessment (KRA)		X		X	X	X
Oregon Kindergarten Assessment (KA)			X	X	X	
South Carolina Kindergarten Readiness Assessment (KRA)	X		X	X	X	X
Texas Kindergarten Entry Assessment (TX-KEA)	X		X	X	X	X
Utah: Kindergarten Entry and Exit Profile (KEEP)	X		X	X	X	
Virginia Kindergarten Readiness Program (VKRP; Phonological Awareness Literacy Screening/PALS, Early Mathematics Assessment System/EMAS, and Child Behavior Rating Scale/CBRS)			X	X	X	

Note. Empty cells under "domain" denote that a domain was not included in the state's KEA. Empty cells under "commercially available" indicate that a state's KEA or KEA options were state developed. $N = 29$.

Table 2 Data Collection Focus

	KEA digital technology inputs		
Item type	Administration	Scoring	Student- and classroom-level report generating
Selected response questions and on-demand performance tasks	Self-administered via software, website or mobile app versus teacher-administered	If teacher administered, automatically versus teacher scored	Teachers provided with opportunity to use app or digital-based platform to generate student- and classroom-level reports immediately after completing domain-relevant sections of, or entire KEA
Observational checklists and developmental rubrics	Digital-based interactive rubric to potentially support "live" scoring versus the option/need to first use a paper form of the KEA	App to facilitate uploading of photo- or video-based evidence or scoring Online platform to manually upload score data	

Results

Research Question 1 focused on the extent to which KEAs comprised of similar item types incorporated digital technology as part of the administration, scoring, and report-generating processes. I therefore break out the results of this question based on the three item type categories displayed in Table 1. All of the data for this research question are reported in the appendix, as well.

Direct Item-Only KEAs

The first cases I analyzed were the KEAs used in four states. As noted in Table 1, these measures consisted solely of selected response questions or on-demand performance tasks and focused on literacy alone or literacy and math. These four states also shared a common reliance on the commercially available Star Early Literacy (Renaissance Learning, 2017) and Istation Indicators of Progress (ISIP; Mathes et al., 2016) measures.

Not surprisingly, my analyses of the data collected for these states demonstrated further uniformity. Specifically, all four states' KEAs were computer-based, self-administered assessments. In addition, these measures were adaptive and automatically scored student responses. Three of the four states reported that their KEAs could be completed on iPads. Finally, in all four cases teachers could use their KEA applications to generate individual student- or classroom-level reports.

Observational Checklist and Developmental Rubric KEAs

The next set of cases consisted of the 14 states with KEAs that relied exclusively on observational checklists or developmental rubrics. The majority of these KEAs focused on language, literacy, mathematics, and social–emotional development. Some of these measures also included other domains such as children's physical development or executive function. As mentioned above, these item types typically require teachers to collect evidence of what children know and can do as part of their day-to-day classroom activities. Teachers then choose an item's score by comparing the evidence with the information provided in its checklist or rubric. To back up that score, teachers can set aside a work sample or take a photo or video of the child displaying that skill or knowledge. Therefore, as part of the analyses for these cases, I focused on the extent to which kindergarten teachers in these states had access to an online or mobile app version of the KEA to potentially support real-time scoring with a laptop, tablet, or mobile phone, as well as the collection of any photo-, video-, or anecdotal-based evidence, rather than relying solely on a paper form. I also sought information regarding whether teachers had the option to use this website or mobile app to generate student- and classroom-level score reports after they completed scoring some or all KEA items.

Table 3 Score Input Options for Observational Kindergarten Entry Assessments (KEAs; $n = 14$)

KEA	Score input website or mobile app
Alaska Developmental Profile (ADP)	Alaska Developmental Profile website
California: Desired Results Developmental Profile (DRDP-K)	DRDPonline website
Colorado Kindergarten Readiness Assessment: Teaching Strategies GOLD; High/Scope COR for K; DRDP-K; or North Carolina Kindergarten Entry Assessment	Colorado Department of Education (CDE) Data Pipeline website
Delaware Early Learner Survey (customized Teaching Strategies GOLD)	MyTeachingStrategies website
Illinois Kindergarten Individual Development Survey (KIDS) (modified DRDP-K)	KIDStech website
Kansas Kindergarten Readiness Snapshot (Ages & Stages Questionnaires, Third Edition/ASQ-3 and Ages & Stages Questionnaires: Social–Emotional, Second Edition/ASQ:SE-2)	ASQ Online website
Louisiana Kindergarten Entry Assessment:	GOLD: MyTeachingStrategies website
Teaching Strategies GOLD or DRDP-K	DRDP-K: Student Information System (SIS) website
Minnesota Kindergarten Entry Profile:	DRDP-K: DRDPonline website
DRDP-K; Teaching Strategies GOLD; Minnesota Work Sampling System; or Developmental Milestones for Kindergarten (DevMilestones)	GOLD: MyTeachingStrategies website Minnesota Work Sampling System: Online System website or iPhone or iPad app DevMilestones for Kindergarten: Online system website
New Mexico Kindergarten Observation Tool (KOT)	New Mexico Public Education Department Early Childhood Observation Tool website
North Carolina Kindergarten Entry Assessment	North Carolina K-3 Formative Assessment Process Online Platform accessed via the NCEDCloud IAM website
Pennsylvania Kindergarten Entry Inventory (KEI)	Pennsylvania Kindergarten Entry Inventory data website
Tennessee Kindergarten Entry Inventory/KEI (Desired Results Developmental Profile [DRDP-K])	DRDPonline website
Vermont Ready for Kindergarten!Survey (R4K!S)	Survey Monkey website
Washington Kindergarten Inventory of Developing Skills (WaKIDS; customized Teaching Strategies GOLD)	MyTeachingStrategies website

Digital Versus Paper Item Delivery and Score Storage

My analyses of the data collected for this set of KEAs suggested that all 14 states offered a password-protected website that teachers were expected to use to record their students' item-level scores (see Table 3). Thirteen of the 14 states also offered teachers the opportunity to use these websites to score their KEAs on a real-time basis via online versions of these measures. The lone exception was Alaska's Developmental Profile. Although this latter measure's items and rubric were available on a password-protected website, teachers were requested to complete paper score recording forms before entering their final scores.

Although real-time scoring was potentially available in 13 of the 14 states, at the time of the study, teachers and other interested stakeholders could freely download and print out the majority of the state-developed KEAs in this group. In addition to the Alaska Developmental Profile (Alaska Department of Education & Early Development, 2008), these KEAs included the DRDP-K (California Department of Education, 2015) and the DRDP-K-based Illinois KIDS Kindergarten Individual Development Survey (Illinois State Board of Education, 2017) and Tennessee KEI (Tennessee Department of Education, 2018). Other state-developed KEAs that could be downloaded and printed were North Carolina's Construct Progressions and Situations (Office of Early Learning, 2017) and the Pennsylvania KEI (Pennsylvania Office of Child Development and Early Learning, 2019). With the exception of Alaska's KEA, I could not determine if the free availability of paper copies of these measures was a proxy for teachers' or policy makers' preference for first scoring on paper and then uploading scores to the state's KEA-relevant website or, instead, due to states not being able to afford to provide all teachers with tablets or laptops to facilitate real-time scoring.

Mobile Apps

The only KEA that appeared to offer a start-to-finish mobile app was the commercially available Work Sampling System (Meisels et al., 2013), one of Minnesota's KEA options. This measure could be accessed via its *Online System* website or an iPhone or iPad app. In addition to entering item-level scores, teachers could use the mobile app to upload photographic, video, or note-based evidence of student's knowledge and skills.

Interestingly, the developers of the KEAs used in nine of these states had created mobile apps prior to the time the study was conducted, but these apps did not appear to be part of the Fall 2019 KEA process. Specifically, teachers using North Carolina's state-developed KEA previously had access to an iOS app, but that app was not available in Fall 2019. The lack of access was due to incompatibility with the web-based platform used to log student scores (North Carolina Department of Public Instruction, 2018).

In addition, the developers of Teaching Strategies GOLD (Heroman et al., 2010) offered a mobile documentation app with the capacity to tag item-specific photo, video, and anecdotal evidence with a child's name and then use a wireless or cellular connection to send that information to the web-based GOLD assessment score data storage platform (Teaching Strategies, 2015b). However, it was not clear to what extent this app was part of the KEA process in Colorado, Delaware, Louisiana, Minnesota, or Washington. In fact, kindergarten teachers in Delaware were not required to upload any documentation (Delaware Department of Education, 2019). Similarly, a web browser-accessed DRDP portfolio app was available at the time of the study, but not directly linked to the DRDP online or KIDStech websites that teachers used to enter their ratings (California Department of Education, Early Learning and Care Division, 2019). Once again, it was not clear to what extent the DRDP portfolio app was used in the six states relying on a KEA based on DRDP-K (California Department of Education, 2015).

Report Generation

Finally, 12 of the 14 states provided teachers with the opportunity to use their websites to generate individual student- and classroom-level KEA score reports. The two exceptions were Alaska and Vermont. At the time of the study, teachers in Alaska entered score data into the KEA's website but did not have the capacity to generate any individual, classroom, or school-wide reports until the Alaska Department of Education returned the data. In Vermont, teachers could only use the online site to generate reports at the classroom level.

"Combination" KEAs

The final set of cases that I analyzed as part of the study's first research question consisted of the states relying on combination KEAs (i.e., comprised of selected response questions, on-demand performance tasks, and observational checklists). Similar to the 14 checklist- or rubric-only KEAs just highlighted, the majority of these 11 states' measures contained items focusing on language, literacy, mathematics, and social–emotional development. Some of these KEAs also included other domains such as children's physical development or executive function. However, in comparison to the observational checklist and developmental rubric-only set of cases, the mathematics and language arts items in the combination KEAs were more likely to rely on selected response questions or on-demand performance tasks (see the Appendix).

Given the reliance on multiple item types, for this set of cases my analyses focused on (a) whether the direct items could be self-administered via computers, interactive screen devices, or mobile apps, and (b) digital options for storing item-level score data and observational checklist evidence as well as generating individual- and classroom-level score reports.

As seen in Table 4, Georgia, Kentucky, Nevada, Oregon, Utah, and Virginia did not provide the option to self-administer any of their KEA's selected response questions and on-demand performance tasks. However, all six of these states provided teachers with access to an online, username- and password-protected website for entering score data and generating individual and classroom-level reports. Teachers in Kentucky and Nevada—and where their KEA is the commercially available Brigance Early Childhood Screen III (French, 2013)—also had the option to use a tablet app to complete the scoring process. In addition, teachers in five of these six states could use their websites to generate individual student or classroom-level reports. The only KEA for which I could not confirm this capacity was Utah's Kindergarten Entry and Exit Profile (Utah State Board of Education, 2018).

Table 4 Combination Kindergarten Entry Assessment (KEA) Digital Score Input Options ($n = 11$)

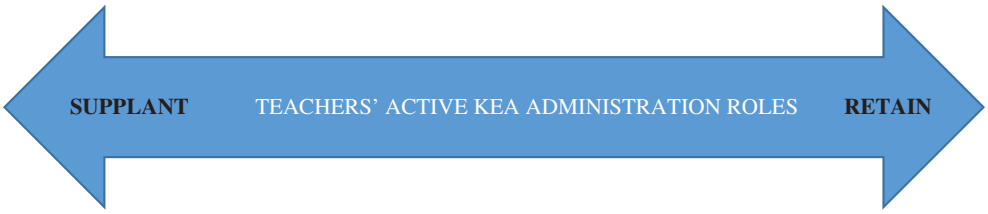
State and KEA	Score input website or app
No self-administered options for administering selected response questions or on-demand performance tasks	
Georgia Kindergarten Inventory of Developing Skills (GKIDS) 2.0 Readiness Check	GKIDS 2.0 website
Kentucky's Common Kindergarten Entry Screener	Curriculum Associates Online Management System website or tablet app; or Infinite Campus website
Nevada Kindergarten Entry Assessment (KEA)	Curriculum Associates Online Management System website or tablet app; or Infinite Campus website
Oregon Kindergarten Assessment (KA)	Student-Level Collections (SSID) website
Utah Kindergarten Entry and Exit Profile (KEEP)	Utah State Board of Ed Data Gateway website
Virginia Kindergarten Readiness Program (VKRP) (Phonological Awareness Literacy Screening/ PALS; Early Mathematics Assessment System/ EMAS; Child Behavior Rating Scale/CBRS)	VKRP website
Included self-administered option for selected response questions or on-demand performance tasks	
Maryland, Michigan, Ohio, and South Carolina Kindergarten Readiness Assessment (KRA)	Ready for Kindergarten (R4K) web-based Online System
Texas Kindergarten Entry Assessment (TX-KEA)	CLI Engage website

In comparison, the remaining five states in this subsample incorporated some self-administered selected response questions or on-demand performance tasks. Specifically, Maryland, Michigan, Ohio, and South Carolina teachers using the Kindergarten Readiness Assessment (KRA; Maryland State Department of Education, 2019a) could access the entire 50-item measure via the Ready for Kindergarten Online System and relied on this web-based system to enter score data and generate individual and classroom reports. In addition, students could self-administer 17 math and language/literacy selected response questions and on-demand performance tasks via the Ready for Kindergarten app, which could be used on tablets or desktops. When using this option, the teacher's (or proctor's) role in administering these items was limited to logging in, giving the device to the student, and monitoring the student to ensure that he or she completed the items. In addition, no physical manipulatives were needed to perform the requested actions, and the items were scored automatically. In an effort to reduce data entry time for teachers—particularly if administering all 50 items—the tablet app also could be used to take a photo of paper score sheets as a means for automatically uploading an individual student's scores. Finally, the Ready for Kindergarten Online System could store optional student-specific notes and artifacts. This system also could be used to generate a language and literacy domain-specific report once that domain was assessed (and to support Third Grade Reading Guarantee Laws in Ohio and Michigan) as well as other reports and interactive data displays to guide instructional groupings and targeted instruction based on students' scores.

The second KEA in this category was the Texas Kindergarten Entry Assessment (Texas School Ready Project, 2018), which provided teachers with the option to assess students in both English and Spanish for any of the domains. This measure included 182 self-administered—and automatically scored—language, literacy, mathematics, science and engineering, and executive function domain items to be completed by kindergartners on a computer, laptop, or tablet. Thirty-five additional language, literacy, and mathematics items were housed on these same devices, but the teacher read the item's prompt and indicated whether the student's verbal response was correct by clicking on a blue or purple button or the keyboard's left or right arrow. In so doing, these items also were automatically scored. The final five teacher-prompted spelling tasks, as well as the 24 social–emotional and motor skill–focused observational checklist items, required the teacher to enter scores directly in the CLI Engage website. Teachers could use this website to upload student-specific notes and artifacts as well as to generate student- and classroom-level reports, guidelines for grouping students by skill level, and suggestions for appropriate instructional activities for each group.

Potential Impact of Digital Technology on Teachers' Active KEA Roles

The study's second research question aimed to look across the entire sample of 29 states and consider the potential impact of digital technology in supplanting versus retaining teachers' role in any aspect of the KEA process. As mentioned above,



	States		
Model A (n = 4)	**Model B** (n = 1)	**Model C** (n = 4)	**Model D** (n = 20)
Computer-based, self-administered KEAs			
Arkansas, Florida, Idaho, Mississippi	None	None	None
Observational Checklist or Developmental Rubric-only KEAS			
None	None	None	Alaska, California, Colorado, Delaware, Illinois, Kansas, Kentucky, Louisiana, New Mexico, Minnesota, Pennsylvania, Tennessee, Vermont, Washington
Combination KEAs			
None	Texas	Maryland, Michigan, Ohio, South Carolina	Georgia, Nevada, North Carolina, Oregon, Utah, Virginia

Figure 1 Potential impact of digital technology on teachers' active KEA administration roles.

there are benefits to teachers being actively involved in administering direct assessment items and collecting evidence for observational items as part of children's day-to-day classroom activities. Yet, one major KEA-specific issue has been the amount of time necessary to assess all kindergartners at the beginning of the school year. Furthermore, there are validity and reliability trade-offs when teachers administer selected response questions or on-demand performance tasks or are responsible for scoring an observational checklist or developmental rubric.

This study admittedly did not examine the actual impact of digital technology in supplanting versus retaining the role of the kindergarten teacher in the KEA process. Yet, the results of my analyses suggested four KEA models along a potential impact continuum. As can be seen in Figure 1, Model A is on the "supplant" side of the continuum and consisted of the KEAs used in Arkansas, Florida, Idaho, and Mississippi, all of which relied on computer-based, self-administered adaptive measures focused on literacy alone or literacy and mathematics. In all four cases teachers could use the KEA software application to generate individual student and classroom-level score reports. Beyond generating these reports or providing logistical support (e.g., providing students' with preliminary instructions), teachers presumably were not directly involved in the KEA administration or scoring process.

Model B is represented by the combination KEA recommended for use in Texas. In this model, students completed the KEA's 182 self-administered (and automatically scored) selected response items on a computer, laptop, or tablet. In addition, to facilitate the automatic scoring of 35 additional items, the teacher read the item's prompt to the student and indicated whether their response was correct by clicking on a blue or purple button or the keyboard's left or right arrow. The five remaining teacher-prompted spelling tasks, as well as the 24 social–emotional and motor skill-focused observational checklist items, required the teacher to score the items and manually enter those scores into the CLI Engage online application. This application could be used to upload optional student-specific notes and artifacts and receive recommendations for instructional groupings and targeted instruction based on students' scores.

Model C consists of the combination KEA used in Maryland, Michigan, Ohio, and South Carolina. Teachers played a key role in the administration and scoring of this entire 50-item measure. However, a distinguishing feature was the option to use the Ready for Kindergarten app to facilitate students' self-administration of 17 selected responses questions and on-demand performance tasks. When using the app, no physical manipulatives were needed and the items were scored

automatically. In addition, the tablet-based Ready for Kindergarten app could be used to photograph and automatically upload individual student score sheets. And, teachers could use the Ready for Kindergarten web-based Online System to upload optional student-specific notes and artifacts and receive recommendations for instructional groupings and targeted instruction based on students' scores.

Finally, Model D is at the "retain" end of the continuum and consists of the 14 states that relied exclusively on observational checklist or developmental rubric-based KEAs, as well as six of the "combination" states that included checklist items plus selected response questions or on-demand performance tasks in their measures. In all 20 cases, reliance on digital technology was limited to each state's online, username- and password-protected website that facilitated real-time scoring but was primarily used for uploading score data. In 17 states, teachers also had the option to use these websites to generate both individual- and classroom-level score reports. These states also were similar in that with the exception of one of Minnesota's KEA options, I could not find evidence regarding the incorporation of mobile apps.

Discussion

In this study I used a sample of 29 U.S. states and their mandated or recommended KEAs to examine the Fall 2019 digital technology landscape. Given the increased state reliance on these measures over the past 8 years as a means for informing teachers' instruction (Daily & Maxwell, 2018), as well as the national focus on integrating technology into the PreK–12 educational system (U.S. Department of Education, Office of Educational Technology, 2017), the focus of this study was salient. Furthermore, by investigating the extent to which states with similar KEA item types incorporated digital technology, as well as the potential impact of these technology inputs for supplanting versus retaining the role of the kindergarten teacher, the study's results offer policy makers some key takeaways related to the Fall 2019 status of KEAs.

The KEA "State of the Field"

This study's first key takeaway about the KEA state of the field comes from its sample. In short—and as has been the case over the past 8 years—the KEAs used across the United States in Fall 2019 were not uniform. Yet, one notable aspect of the sample was that 25 of the 29 states focused on a wide array of cognitive and noncognitive domains. These KEAs also included, or relied exclusively on, observational checklist or developmental rubric items.

Digital technology does not yet offer an option for supplanting the key role of the kindergarten teacher in gathering evidence for and scoring rubric and checklist items. In fact, in light of the quantity of states that included these item types in their KEAs at the time of the study, it is not clear that such an option was even desired by KEA stakeholders. However, this study's second key finding was that technology was being incorporated to facilitate other important teacher-dependent KEA tasks. For example, one digital input across these 25 states' KEAs was teacher access to a password-protected website aimed at uploading and storing score data. Furthermore, in 22 states these websites provided teachers with the opportunity to generate individual- and classroom-level score reports. Finally, 24 of these websites facilitated real-time scoring, which may represent both a time-saving option for teachers and a means for reducing "rate on paper, upload later" score transfer errors.

Given the number of states that included rubric- or checklist-based items in their KEAs, as well as the related tradition of justifying these items' scores via photo- or video-based evidence, a third notable finding was the lack of widespread incorporation of mobile apps. Interestingly, the developers of the commercially available Teaching Strategies GOLD (Heroman et al., 2010) and the state-developed DRDP-K (California Department of Education, 2015)—and therefore the basis for KEAs used in eight states at the time of the study—previously developed mobile apps designed to facilitate the upload of evidence related to their measures. It may be that both of these apps predated the online KEA data platforms used in Fall 2019, as apparently was the case with North Carolina's KEA. Alternatively, this finding may be related to data security or even a lack of funding for handheld devices that might be used as part of the KEA administration and scoring process. This topic would be helpful to explore through future research.

A final notable finding was the extent to which digital technology was incorporated into the Texas KEA and the KRA used in Maryland, Michigan, Ohio, and South Carolina, both of which represented a hybrid approach to documenting what incoming kindergartners know and can do. Specifically, these two measures borrowed from their Model D/retain-the-role-of-the-teacher "cousins" by gathering evidence of children's knowledge and skills across a wide array of domains and including observational checklist items. However, by leveraging available digital technology, these KEAs also mirrored

their Model A/full-supplant counterparts by incorporating self-administered selected response questions and on-demand performance tasks. Assuming states continue to recommend or mandate the use of KEAs, it will be interesting to track whether this hybrid approach becomes more widely adopted over time.

Future Research on the Impact of Digital Technology on KEA Validity and Reliability

All of the current study's findings are useful for documenting the Fall 2019 state of the KEA digital field. Yet, there still is much to be learned about the ways in which the trade-offs of these digital technology models impact the validity, reliability, and utility of KEAs. Two key topics are (a) how the Texas KEA and the KRA used in Maryland, Michigan, Ohio, and South Carolina are functioning in real-world classrooms and (b) the equipment infrastructure, and per-pupil funding needed to fully support their implementation as intended by their developers.

Another important topic to explore is the contribution of digital technology to a KEA's validity across different populations of students, including English learners. The Model A/full- and Model B and C/partial-supplant KEAs incorporated digital technology into the administration of their selected response questions and on-demand performance tasks. As was highlighted earlier in this report, such technology has the potential to provide students with directions and item prompts in their home language. However, prior research on two of the Model A/full-supplant KEAs suggested that state policymakers were not necessarily allowing that option (Ackerman, 2018a). Beyond knowing that Texas' Model B KEA offers teachers the option to assess students in both English and Spanish for any of the domains, to my knowledge, no published research looks across these KEAs and compares to what extent digital technology is being used to facilitate the formative assessment of English learners.

A third topic to explore is the contributions of digital technology to Model B, C, and D teacher scoring reliability, particularly when rating observational checklist or developmental rubric items on a real-time basis. As was mentioned previously, one potential consequence of the reliance on teachers to administer an assessment is inadvertent scoring errors. A small research base also suggests "teacher fatigue" when they are required to first score on paper and then manually upload scores at a later time. Although real-time scoring via a tablet or laptop would seem to offer the same potential for inadvertent scoring errors as when using a paper copy of a measure, having the opportunity to enter scores directly into a KEA's website as part of a real-time assessment may prove to be a more reliable option.

Future Research on Teachers' Perceptions

This study's results also suggest potential value of investigating kindergarten teachers' perceptions of the utility of the digital technology models highlighted in the study's results. Specifically, Models A, B, C, and D varied in the extent to which digital technology appeared to supplant versus retain teachers' active participation in the KEA process. However, the Model A/full-supplant KEAs focused on literacy alone or literacy and mathematics and were self-administered, computer-based assessments, whereas the KEAs in Models B, C, and D focused on a variety of domains but required teachers to play active roles in the KEA administration, evidence gathering, and scoring processes. In light of this dichotomy, one important research topic to explore is teachers' perceptions of the utility of these models for informing their instruction versus the amount of instructional time necessary to generate that data. Given a choice, do teachers prefer one model over another? If so, do these preferences vary based on the larger digital infrastructure support context in which teachers work or the degree to which teachers rely on KEA data (versus other assessment data) to inform their instruction?

A second teacher utility perception topic relates to the capacity to score KEA items on a real-time basis in the majority of Model D/retain-the-role-of-the-teacher-states via their password-protected websites. As was highlighted in the study's results, these websites appeared to be primarily aimed at storing score data and generating individual- and classroom-level score reports. However, in light of research suggesting the amount of time necessary to "score first, upload later," it would be helpful to know to what extent teachers take advantage of the real-time scoring option, and if not, why that is the case.

Relatedly, a third teacher perception topic to explore is teachers' experiences with generating individual- and classroom-level score reports that can be accessed via KEAs' password-protected websites. Research taking place after the initial implementation of some KEAs has identified issues with accessing and using these online websites (Ackerman, 2018b; Bowdon et al., 2019; Golan et al., 2016). It would therefore be useful to know if the report-generating aspect of the KEA process no longer presents a challenge to teachers.

A final commonality across the majority of the KEAs examined in the current study was the lack of mobile apps, which was notable given the reliance on observational checklists and developmental rubrics in the Fall 2019 KEA landscape. Therefore, another topic is the degree to which teachers collect photo-, video-, and anecdotal-based evidence as part of the KEA scoring process, and if so, what process they undertake (if any) to upload that data in the absence of a mobile app. Such information could potentially be used to design a mobile app that makes the process more aligned with the rest of the KEA tasks teachers are expected to undertake.

Study Limitations

The current study has two main limitations that hinder its generalizability. First, although my sample was composed of 29 states, at the time of the study, these states may have been in the process of revising the content of and policies for their KEAs. As a result, the findings presented here may not fully reflect current practices. A second limitation is the reliance on publicly available websites and documents to seek out data related to the study's research questions. Although I attempted to triangulate all of the data reported here, it is possible that the documents I used to address the study's research questions did not fully reflect the extent to which digital technology was incorporated into these states' KEAs as of Fall 2019. This may have especially been the case for the states that did not provide the general public with the option to freely download copies of their measures.

Conclusion

This report provides an overview of the KEA digital technology landscape. In light of the national focus on incorporating technology into the PreK–12 educational system and the recent development and implementation of KEAs across the United States, this study provides an important overview of the state of the field. At the same time, there are trade-offs to any assessment design. Therefore, the results reported here also highlight some important KEA digital technology topics to be researched. Because this technology has the potential to impact kindergarten teachers' active roles as KEA administrators, evidence "documenters," scorers, and report generators, one key question to be explored is teachers' perceptions of this technology for increasing the utility of KEA data. A second important question is the extent to which such technology ultimately enhances the validity and reliability of KEA data used by policy makers.

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APPENDIX

State and kindergarten entry assessment(s)	Domains					Digital Options		
	Language	Literacy	Mathematics	Social–emotional	other	Software, website or app administration?	Online or app score input?	Student and classroom report generation?
Selected response questions (SRQs) and on-demand performance tasks (PTs) items only ($n = 4$)								
Arkansas[a] Choice: iStation Indicators of Progress (ISIP); NWEA Map Growth, or Star Early Literacy		X	X			Self-administered on PCs, Macs, Chromebooks, iPads, and Android devices	N/A	Yes
Florida[b] Kindergarten Readiness Screener (Star Early Literacy)		X	X			Self-administered on PCs and Macs	N/A	Yes
Idaho[c] Reading Indicator (ISIP)		X				Self-administered on PCs, Macs, Chromebooks, iPads, and Android devices	N/A	Yes
Mississippi[d] Kindergarten Readiness Assessment (Star Early Literacy)		X	X			Self-administered on PCs, Macs, and iPads	N/A	Yes
Observational checklist (OC) or developmental rubric only ($n = 14$)								
Alaska[e] Developmental Profile (ADP)	X	X	X	X	X	Items and ratings available on ADP website, but teachers were requested to complete paper score recording forms before entering scores	ADP website	No – Alaska Dept. of Education provided districts with ADP data for additional student and classroom analyses

APPENDIX A Continued

State and kindergarten entry assessment(s)	Domains: Language	Literacy	Mathematics	Social – emotional	other	Digital Options: Software, website or app administration?	Online or app score input?	Student and classroom report generation?
California[f] Desired Results Developmental Profile (DRDP-K)	X	X	X	X	X	DRDP Online data entry system		
Colorado[g] Kindergarten School Readiness Assessment Choice:								
Teaching Strategies GOLD	X	X	X	X	X	MyTeachingStrategies website		
High/Scope COR for Kindergarten	X	X	X	X	X	COR for Kindergarten website	Teachers summarized scores into state reporting format and submitted that summary to Colorado Department of Education Data Pipeline website	COR for Kindergarten website
DRDP-K	X	X	X	X	X	DRDPTech website		DRDP Tech District platform
North Carolina KEA (used in Jeffco County district only)	X	X	X	X	X	NC KEA	Teachers uploaded score data to district website	
Delaware[h] Early Learner Survey (customized Teaching Strategies GOLD)	X	X	X	X	X	MyTeachingStrategies website NOTE: teachers were not required to upload documentation; could not located evidence that GOLD documentation app was available or to be used.		
Illinois[i] Kindergarten Individual Development Survey (KIDS) (modified DRDP-K)	X	X	X	X	X	“KIDSTech” (kids.drdptech.org) website		

Continued

State and kindergarten entry assessment(s)	Domains					Digital Options		
	Language	Literacy	Mathematics	Social – emotional	other	Software, website or app administration?	Online or app score input?	Student and classroom report generation?
Kansas[j]: Ages & Stages Questionnaires, Third Edition (ASQ-3) & Ages & Stages Questionnaires: Social – Emotional, Second Edition (ASQ:SE-2)	X	X	X	X	X	ASQ Online interactive website		
Louisiana[k]	X	X	X	X	X	MyTeachingStrategies website		
Choice:								
Teaching Strategies GOLD DRDP-K						Paper only	Student Information System (SIS) website	
Minnesota[l] Kindergarten Entry Profile; Choice:	X	X	X	X	X	DRDPonline website		
Desired Results Developmental Profile/DRDP-K								
Teaching Strategies GOLD	X	X	X	X	X	MyTeachingStrategies website		
Work Sampling System	X	X	X	X	X	Online System website or iPhone or iPad app		
Developmental Milestones for K	X		X	X	X	Online System website		
New Mexico[m] Kindergarten Observation Tool (KOT)	X		X	X	X	New Mexico Public Education Department Early Childhood Observation Tool interactive website		
North Carolina[n] Kindergarten Entry Assessment	X	X	X	X	X	North Carolina K-3 Formative Assessment Process Online Platform accessed via the NCEDCloud IAM website (provided by Teaching Strategies)		
Pennsylvania[o] Kindergarten Entry Inventory (KEI)	X	X	X	X	X	Pennsylvania Kindergarten Entry Inventory data system website		

Continued

State and kindergarten entry assessment(s)	Domains					Digital Options		
	Language	Literacy	Mathematics	Social–emotional	other	Software, website or app administration?	Online or app score input?	Student and classroom report generation?
Tennessee[p] Kindergarten Entry Inventory (KEI) (DRDP-K)	X	X	X	X	X	DRDPonline interactive website		
Vermont[q] Ready for Kindergarten! Survey (R4K!S)	X	X	X	X	X	Survey Monkey website		Classroom only
Washington[r] Kindergarten Inventory of Developing Skills (WaKIDS)	X	X	X	X	X	MyTeaching Strategies platform		
Combination of Item Types ($n = 11$)								
Georgia[s] Kindergarten Inventory of Developing Skills (GKIDS) 2.0	X (PTs)		X (PTs)	X (OC)	X (PTs)	Teacher administered all item prompts and determined all scores	GKIDS 2.0 website	Yes
Kentucky,[t] Nevada: [u] Brigance Early Childhood Screen III	X (PTs)	X (PTs)	X (PTs)	X (OC)	X (OC)	Teacher administered all PT prompts and determine scores	Curriculum Associate's Online Management System website or app; Infinite Campus	Yes
Maryland,[v] Michigan,[w] Ohio,[x] South Carolina:[y] Kindergarten Readiness Assessment (KRA)	X (SRQs, PTs, and OC)		X (SRQs and PTs)	X (OC)	X (OC)	17 math and language/literacy PTs could be administered via desktop or tablet KRA app	Ready for Kindergarten (R4K) website; photo of paper score sheet could be uploaded via KRA app	Yes
Oregon[z] Kindergarten Assessment (KA)		X (PTs)	X (SRQs)	X (OC)		Teacher administered all items and determined scores	Yes via Student-Level Collection (SSID) website	Yes

Continued

State and kindergarten entry assessment(s)	Domains					Digital Options		
	Language	Literacy	Mathematics	Social–emotional	other	Software, website or app administration?	Online or app score input?	Student and classroom report generation?
Texas[aa] Kindergarten Entry Assessment (TX-KEA)	X (SRQs and PTs)	X (SRQs and PTs)	X (SRQs and PTs)	X (OC)	X (SRQs, PTs, and OC)	182 SRQs and PTs were self-administered using a computer, laptop, or tablet via CLI Engage; 35 additional items were CLI Engage-based, but the teacher recorded students' responses via colored buttons; 5 spelling and 24 OC items were electronically scored by teacher in CLI Engage		Yes; instructional resources were also available based on student and classroom-level data
Utah[bb] Kindergarten Entry & Exit Profile (KEEP)	X (PTs)	X (PTs and SRQs)	X (PTs and SRQs)	X (OC)		Teacher administered all items via paper form	Yes: online Utah State Board of Ed Data Gateway	Could not locate evidence
Virginia[cc] Kindergarten Readiness Program (VKRP)		X (SRQs and PTs)	X (SRQs and PTs)	X (OC)		PALS and EMAS administered by teacher via online interface; CBRS programmed into an online form		Yes; instructional resources also available based on student and classroom-level data

Note. Empty Domains cells indicate that the domain was not included in the state's KEA; N/A = Not applicable; SRQs = selected response questions; PTs = on-demand performance tasks; OC = observational checklist; *N* = 29.

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