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# Young children's alphabet learning as a function of instruction and letter difficulty

Shayne B. Piasta *, Somin Park, Lorianne R. Fitzgerald, Hillary A. Libnoch [1]

*The Ohio State University, United States of America*

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ABSTRACT

Despite the importance of alphabet knowledge for learning to read in English, we continue to have a limited understanding of children's alphabet knowledge learning and how to best support such learning. In this pretest-posttest within-subjects experimental study ($n = 29$), we examined alphabet learning as a function of lessons tailored to individual children's alphabet learning needs and as a function of letter difficulty. Children received instruction on four individually selected target letters and no instruction on four control letters; target and control letters were equated for letter difficulty. Results showed that children were more likely to learn target letters than control letters. Additionally, letter difficulty predicted children's learning of uppercase and lowercase letter names but not their learning of letter sounds. Findings partially substantiate the role of letter difficulty in alphabet learning and support continued research on effective practices for differentiating alphabet instruction to meet individual alphabet learning needs.

For children learning an alphabetic orthography such as English, alphabet knowledge (knowledge of letter forms, names, and sounds) is essential for learning to read and write. Understanding the alphabetic principle and basic letter-sound correspondences is foundational for conventional literacy (Ehri, 2015; Hulme, Bowyer-Crane, Carroll, Duff, & Snowling, 2012). Correspondingly, early alphabet knowledge is one of the best predictors of later literacy achievement (Georgiou, Torppa, Manolitsis, Lyytinen, & Parrila, 2012; Lonigan, Schatschneider, Westberg, & The National Early Literacy Panel, 2008a; Sénéchal, LeFevre, Smith-Chant, & Colton, 2001; Whitehurst & Lonigan, 1998). As children enter school, they exhibit substantial individual differences in alphabet knowledge including disparities associated with socioeconomic status and other characteristics (Denton & West, 2002; Strang & Piasta, 2016). These differences can have long-term consequences, as children with lower levels of alphabet knowledge are more likely to experience reading difficulties (Catts, Fey, Zhang, & Tomblin, 2001; Piasta, Petscher, & Justice, 2012; Torppa, Poikkeus, Laakso, Eklund, & Lyytinen, 2006).

To date, much of the extant literature involves assessing individual differences in children's alphabet knowledge at a static point in time to identify correlates and consequences (cf. Piasta, Logan, Farley, Strang, & Justice, 2021; Roberts, Vadasy, & Sanders, 2018; Strang & Piasta, 2016; Torppa et al., 2006). We continue to have a rather limited understanding of children's alphabet learning or how to best support such learning (Piasta & Wagner, 2010a). Additionally, substantial research has documented letter-specific factors that render certain letters as more or less likely to be known by children (Piasta, 2014). Although this suggests that specific letters may be more or less difficult for children to learn, this premise has not been directly tested. In the current study, we explored alphabet learning as a function of lessons tailored to individual children's alphabet learning needs and as a function of letter difficulty, as both have implications for ensuring that alphabet instruction is effective and efficient.

### 1.1. Alphabet learning and instruction

Young children exhibit a range of alphabet knowledge, with considerable variability across children in the same preschool or kindergarten classroom (Piasta, 2014). Individual differences in

* Corresponding author at: Department of Teaching and Learning and Crane Center for Early Childhood Research and Policy, The Ohio State University, Columbus, OH 43210, United States of America.
*E-mail address:* piasta.1@osu.edu (S.B. Piasta).
[1] Hillary A. Libnoch is now at the Department of Education, Wittenberg University, United Staes of America.

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alphabet knowledge are associated with socioeconomic background, home literacy experiences, family and child risk status for reading disabilities, and children's language abilities (Denton & West, 2002; Heilmann, Moyle, & Rueden, 2018; Piasta et al., 2021; Sénéchal & LeFevre, 2014; Snowling, Gallagher, & Frith, 2003; Strang & Piasta, 2016; Torppa et al., 2006). Preschool-aged children from lower socioeconomic backgrounds, for example, tend to know fewer letter names and sounds than their more advantaged peers (Strang & Piasta, 2016), as do children identified as at-risk for reading disabilities (Snowling et al., 2003). Although many children readily learn letters and sounds as they move through preschool and into kindergarten, a sizeable number continue to need alphabet knowledge support when matriculating to first grade (D'Agostino & Rodgers, 2017; Paige, Rupley, Smith, Olinger, & Leslie, 2018). Moreover, emerging research suggests that children whose alphabet learning trajectories exhibit early delays continue to lag behind their peers in literacy learning and may be at risk for later reading difficulties (Piasta et al., 2021; Torppa et al., 2006).

Effective instruction is key to better supporting children's alphabet learning. Yet, current instructional practices are insufficient towards this end, with little evidence that widely used early childhood practices or curricula promote alphabet learning (Piasta et al., 2021; Preschool Curriculum Evaluation Research Consortium, 2008). In their meta-analysis, Piasta and Wagner (2010a) found only ten studies that focused specifically on alphabet instruction. These studies yielded modest effect sizes on children's alphabet learning and few insights into instructional components comprising effective instruction. Subsequent research has attempted to fill this gap and also provides insights into children's alphabet learning processes. For example, children benefit from instruction that teaches both letter names and sounds (Piasta, Purpura, & Wagner, 2010; Roberts et al., 2018), likely because they can use the names as cues to remember associated sounds (Cardoso-Martins, Mesquita, & Ehri, 2011; Ellefson, Treiman, & Kessler, 2009; Piasta & Wagner, 2010b; cf. Levin, Shatil-Carmon, & Asif-Rave, 2006; Roberts, Vadasy, & Sanders, 2019).

Work by Roberts and colleagues (Roberts et al., 2018, 2019) highlights the paired-associate nature of children's alphabet learning. They studied alphabet instruction comprised of three main components: (1) viewing printed letter forms while hearing/saying letter names and letter sounds (only), (2) attending to articulatory gestures when verbalizing letter names or sounds, and (3) writing letters. Although instruction that combined all components was more effective than alphabet instruction typical of preschool classrooms (Roberts et al., 2018), instruction that simply emphasized printed letters paired with names or sounds was the most effective (Roberts et al., 2019). These findings are somewhat at odds with other studies showing potential benefits of writing for alphabet learning (Hall, Simpson, Guo, & Wang, 2015; Puranik, Patchan, Lemons, & Al Otaiba, 2017) but did not directly test effects of writing versus other instructional components. Further research by Roberts and colleagues has also documented advantages for focusing children's attention on individual letters and sounds as opposed to embedding alphabet instruction within storybook reading (Roberts, Vadasy, & Sanders, 2020; cf. Yeung & Savage, 2020).

Additional research suggests other instructional components comprising effective alphabet instruction. Jones and colleagues (Jones, Clark, & Reutzel, 2013; Jones & Reutzel, 2012) designed alphabet instruction featuring brief daily lessons, multiple cycles of distributed practice and review, and a variety of teaching sequences derived from factors associated with children's alphabet knowledge (e.g., frequency in children's names or print, alphabet position). Results of an initial quasi-experimental study suggest that kindergarten children who experienced this alphabet instruction were more likely to meet letter naming benchmarks than those who experienced typical, letter-of-the-week instruction (Jones & Reutzel, 2012). Brief alphabet instruction focused on teaching letter sounds via incremental rehearsal has also been found effective (Volpe, Burns, DuBois, & Zaslofsky, 2011). Recent work by Sunde, Furnes, and Lundetræ (2020) suggests that quicker pacing is beneficial; at the end of the year, children whose teachers introduced letters at a faster pace not only had higher letter sound knowledge but also higher word reading skills. Other research has indicated the effectiveness of embedded mnemonics (Ehri, Deffner, & Wilce, 1984; Roberts & Sadler, 2019; Shmidman & Ehri, 2010) and explored the effectiveness of multisensory alphabet instruction (Bara, Gentaz, & Colé, 2007; Bara, Gentaz, Colé, & Sprenger-Charolles, 2004; DiLorenzo, Rody, Bucholz, & Brady, 2011; Schlesinger & Gray, 2017), with the latter producing mixed results.

### 1.2. Efficient and differentiated alphabet instruction

Effective alphabet instruction is critical for children for whom delays in alphabet knowledge puts them at risk for continued literacy difficulties. However, alphabet instruction should also be efficient, not only for these children but all children. Spending a disproportionate amount of time teaching letter names and sounds limits opportunities to learn additional aspects of language, literacy, and other subject areas (Neuman, 2006; Piasta, 2014; Snow & Matthews, 2016). Moreover, alphabet knowledge can be learned to mastery, and children who reach mastery do not require continued alphabet instruction. Yet, these individual differences are not recognized in traditional letter-of-the-week approaches to alphabet instruction, which provide the same instructional content to all children. Furthermore, although recent work has increased efficiency via briefer lessons and quicker instructional pacing (e.g., Jones & Reutzel, 2012; Sunde et al., 2020), these studies have not explicitly attended to children's differing alphabet learning needs. An alternative approach involves differentiated alphabet instruction. Differentiated instruction responds to individual differences among children by modifying the content, process, and/or products of instruction (Puzio, Colby, & Algeo-Nichols, 2020; Tomlinson, 2014). In the case of alphabet instruction, differentiating the content of instruction (i.e., which letters are taught) starkly contrasts with traditional approaches and may be particularly important given accumulating evidence of not only individual differences in children's alphabet knowledge, overall, but also differences across letters (Piasta, 2014).

Research suggests that children are more likely to know certain letters than others, which further supports moving away from approaches that do not differentiate instructional content. For example, children are more likely to know letters that appear earlier in the alphabet than those that appear later in the alphabet (Huang, Tortorelli, & Invernizzi, 2014; Justice, Pence, Bowles, & Wiggins, 2006; McBride-Chang, 1999; Phillips, Piasta, Anthony, Lonigan, & Francis, 2012; Treiman, Levin, & Kessler, 2012; cf. Evans, Bell, Shaw, Moretti, & Page, 2006; Huang & Invernizzi, 2014). Children are also more likely to know letters whose names cue their associated sounds than those whose names and sounds are unrelated, with a particular advantage for acrophonic letters (Ellefson et al., 2009; Evans et al., 2006; Huang et al., 2014; Kim, Petscher, Foorman, & Zhou, 2010; McBride-Chang, 1999; Treiman, Tincoff, Rodriguez, Mouzaki, & Francis, 1998). Children may be more likely to know letters more frequently encountered in printed text (Huang & Invernizzi, 2014; Huang et al., 2014; Pence Turnbull, Bowles, Skibbe, Justice, & Wiggins, 2010; Treiman, Kessler, & Pollo, 2006; Treiman, Levin, & Kessler, 2007; Treiman et al., 2012; cf. Evans et al., 2006; Treiman & Kessler, 2003). Children are likely to confuse letters whose names or associated sounds are visually or phonologically similar to those of other letters (Bowles, Pentimonti, Gerde, & Montroy, 2014; Huang & Invernizzi, 2014; Pence Turnbull et al., 2010; Treiman et al., 2006; Treiman et al., 2007, 2012; Treiman & Kessler, 2003), although children are also more familiar with lowercase letters that are visually similar to their uppercase forms (Evans et al., 2006; Huang & Invernizzi, 2014; Kim et al., 2010; Treiman & Kessler, 2004). Children are less likely to know letter sounds for letters often associated with multiple sounds (Huang et al., 2014; Treiman et al., 1998) and more likely to know letter names that contain earlier-acquired consonant phonemes (Justice et al., 2006).

Notably, letters vary across a number of these factors. Recent studies have accounted for multiple letter factors simultaneously by using item response theory (IRT) to estimate individual letter difficulties (Anthony, Chen, Williams, Cen, & Erazo, 2021; Bowles et al., 2014; Drouin, Horner, & Sondergeld, 2012; Phillips et al., 2012; Piasta, Phillips, Williams, Bowles, & Anthony, 2016). Each letter difficulty reflects the overall likelihood of knowing a specific letter, relative to all other letters. Letters with lower difficulties are more likely to be known, and letters with higher difficulties are less likely to be known. This work has shown, for example, that children are likely to know the letter names for O, A, B, and X (easier letter names) but less likely to know the letter names of Q, U, and V (more difficult letter names; Bowles et al., 2014; Drouin et al., 2012; Phillips et al., 2012). Likewise, children are more likely to know the sounds for B and T (easier letter sounds) than for Y, I, and W (more difficult letter sounds; Drouin et al., 2012; Piasta et al., 2016). These findings suggest a developmental sequence of alphabet acquisition (see Fig. 1), similar to sequences noted for other aspects of development (e.g., motor: Gerber, Wilks, & Erdie-Lalena, 2010; phonological awareness: Phillips, Clancy-Menchetti, & Lonigan, 2008; phonology: Sander, 1972). Although derived from assessing large numbers of children's alphabet knowledge at one particular time point, these findings imply that certain letters may be more or less likely to be learned by children and, correspondingly, that particular letters may require more or less instruction. However, the premise that letter difficulty predicts alphabet learning has yet to be tested.

### 1.3. Purpose of the present study

In the present study, we pilot tested lessons designed to address the need for effective and efficient alphabet instruction (Piasta, 2014; Piasta & Wagner, 2010a). In doing so, we contribute to the literature on alphabet learning and instruction in two key ways. First, we acknowledged individual differences among children as well as differences among letters by differentiating the content of alphabet instruction. Specifically, rather than providing all children with instruction on the same letters as in letter-of-the week or other approaches, we used initial screening data to select and teach letters that individual children had yet to learn. We hypothesized that alphabet instruction would positively affect children's learning of targeted letters, compared to control letters on which children did not receive study-provided instruction, based on the burgeoning alphabet instruction literature (e.g., Piasta et al., 2010; Roberts et al., 2019) and general documented benefits of differentiated instruction for literacy learning (Puzio et al., 2020). Notably, we also expand the current alphabet instruction literature by including outcome measures that fully represent the construct of alphabet knowledge (Anthony et al., 2021). Our primary outcome measures assessed children's abilities to produce the names and associated sounds for both uppercase and lowercase letters. These outcomes reflect key learning expectations in early childhood (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010; Piasta et al., 2012) and have been examined with respect to letter difficulty (Drouin et al., 2012). Our secondary outcome measures assessed children's abilities to recognize uppercase and lowercase letters when presented with their names or associated sounds and to write letters.

Second, we examined letter difficulty as a factor in children's alphabet learning. We intentionally selected letters that varied in difficulty and measured children's alphabet knowledge at two time points, allowing us to directly test whether letter difficulty predicted alphabet

**Uppercase Letter Names**

| Letter(s) | Difficulty Value |
|---|---|
| Most likely known | |
| O | -3.3 |
| A | -2.9 |
| X | -2.7 |
| B | -2.4 |
| C | -1.9 |
| K I Z | -1.6 |
| R W H | -1.5 |
| E T P S | -1.4 |
| M N | -1.3 |
| L | -1.2 |
| G D F | -1.1 |
| J | -1.0 |
| Y | -0.9 |
| U | -0.5 |
| Q | -0.4 |
| V | -0.1 |
| Least likely known | |

**Lowercase Letter Names**

| Letter(s) | Difficulty Value |
|---|---|
| Most likely known | |
| O | -3.4 |
| X | -2.4 |
| C Z | -1.6 |
| W | -1.5 |
| I | -1.3 |
| K | -1.2 |
| S | -1.1 |
| J | -0.9 |
| E Y | -0.8 |
| A M | -0.5 |
| G | -0.3 |
| R | -0.1 |
| F | 0.0 |
| H T P V | 0.1 |
| N U | 0.7 |
| B | 1.3 |
| D | 1.4 |
| L | 2.0 |
| Q | 4.9 |
| Least likely known | |

**Letter Sounds**

| Letter(s) | Difficulty Value |
|---|---|
| Most likely known | |
| B | 2.7 |
| Z K T P D | 3.0 |
| J | 3.3 |
| V | 3.7 |
| S A F | 3.8 |
| O | 4.0 |
| R | 4.2 |
| C | 4.4 |
| M | 4.5 |
| X H | 4.6 |
| N | 4.8 |
| E G | 4.9 |
| Q | 5.1 |
| U | 5.3 |
| W I L | 5.8 |
| Y | 6.2 |
| Least likely known | |

**Combined (letter selection only)**

| Letter(s) | *M* Difficulty Value |
|---|---|
| Most likely known | |
| O | 0.3 |
| K Z | 0.8 |
| A X | 1.0 |
| B J T | 1.1 |
| P | 1.2 |
| C S | 1.3 |
| D F | 1.6 |
| R M | 1.8 |
| H V E | 1.9 |
| W | 2.1 |
| G I | 2.2 |
| N | 2.3 |
| U Y | 2.7 |
| L | 3.1 |
| Q | 3.7 |
| Least likely known | |

**Fig. 1.** Note. Approximate difficulty values based on the item response theory (IRT) analysis reported in Drouin et al. (2012). We used exact difficulty values for uppercase letter names, lowercase letter names, and letter sounds (first three sets) reported in Drouin et al. in relevant analyses. We used combined values for purposes of letter selection only. These were computed by first averaging the uppercase and lowercase letter name difficulty values for each letter (e.g., for letter O, average of −3.3 and −3.4 = −3.35), and then averaging that with the letter sound difficulty value (e.g., average of −3.35 and −4.0 = 0.3 combined difficulty for letter O). To select letters, we rank ordered all letters unknown to a given child according to their combined letter difficulty values (e.g., A, X, P, D, F, W, G, I, U, L, Q). We divided the rank-ordered letters into four approximately equal groups (e.g., A, X, P | D, F | W, G, I | U, L, Q) and selected two letters closest on combined difficulty values from each group (A/X, D/F, G/I, and L/Q). We randomly assigned one letter from each pair to be a target letter (e.g., X, F, I, L) and the other to be a control letter (e.g., A, D, G, Q). In this way, for each child, we selected a set of four target and four control letters that were of approximately equivalent difficulty. As reported in text, this selection process resulted in sets of target and control letters that were also equivalent on difficulty values for uppercase letter names, lowercase letter names, and letter sounds.

learning for our primary outcome measures. We hypothesized that, in general, children would be less likely to learn more difficult letters (Bowles et al., 2014; Drouin et al., 2012; Phillips et al., 2012; Piasta et al., 2016). We also explored whether letter difficulty moderated effects of alphabet instruction, to determine whether instruction might mitigate or exacerbate the role of letter difficulty in alphabet learning. Findings pertaining to letter difficulty hold implications for effective and efficient alphabet instruction, in terms of differentiating not only content (which letters are taught) but also process (e.g., the intensity with which certain letters are taught).

### 1.4. Development and overview of alphabet lessons

In the 9 months preceding the pilot study, we engaged in an iterative process to create alphabet lessons that could be used to differentiate the content of instruction. The development process included four phases: (1) initial lesson development, (2) teacher feedback and lesson revision, (3) initial feasibility trials with children and lesson revision, and (4) additional feasibility trials with children using the revised lessons.

In phase one, we used existing theory and research to design an initial set of lessons for a subset of letters that were evidence-based, appropriate, and engaging. Our lesson development was informed by a conceptualization of alphabet learning in which children learn letter forms, names, and sounds through paired-associate learning, varied opportunities to engage with letters, and opportunities to connect letter learning with authentic reading and writing tasks. A critical mechanism for children's alphabet learning (Roberts et al., 2019), paired-associate learning can be supported through systematic, explicit instruction that couples printed letters with their names and sounds (Jones & Reutzel, 2012; Piasta et al., 2010; Roberts et al., 2019). Multiple opportunities to practice these associations facilitates storage and retrieval of letter information from memory (Jones & Reutzel, 2012; Volpe et al., 2011), and use of multiple modalities during learning may enhance memory representations and connections among visual, verbal, and motor information (Bara et al., 2004). Similarly, opportunities to associate new information about letters with existing knowledge (e.g., familiar environmental print and words, when children's attention is explicitly directed to the print; Justice & Ezell, 2004) may also promote memory representations and thus enhance learning (Reynolds, Sinatra, & Jetton, 1996). Finally, connecting alphabet learning to reading and writing tasks highlights the broader purpose of letter learning, and thereby motivates engagement in the learning task (Duke & Cartwright, 2021); it also capitalizes on reading-writing reciprocity and evidence that integrating such tasks can increase learning (Fitzgerald & Shanahan, 2000; Graham, 2020).

Our lessons reflected this conceptualization of alphabet learning (see Supplemental Material) as well as research-based best practices, reviewed above, for promoting alphabet knowledge. Lessons included explicit instruction following a gradual release of responsibility framework (Pearson & Gallagher, 1983) in which the instructor pairs the letter form with both its name and sound (Piasta et al., 2010; Roberts et al., 2018) and then scaffolds the child's learning using an I Do–We Do–You Do format. Lessons taught both uppercase and lowercase forms (Huang & Invernizzi, 2014; Pence Turnbull et al., 2010), incorporated multisensory techniques (Bara et al., 2007; DiLorenzo et al., 2011), and provided repeated practice and review opportunities (Jones & Reutzel, 2012; Volpe et al., 2011), including connections to environmental print, familiar words/objects, and reading and writing.

To gauge the appropriateness and feasibility of the initial lesson set, seven teachers of preschool-aged children participated in three, 1- to 2-h, semi-structured focus groups in which they reviewed and provided feedback regarding lesson structure, materials, and activities. We used this feedback to revise the existing lessons and create lessons for the remaining alphabet letters. We then trialed the lessons with a small sample of young children. Using analysis of videotaped lessons and progress monitoring data, we revised the lessons a second time and trialed this penultimate, revised set with another small sample of children. Based on the results of this trial, we determined that no further changes to the lessons were necessary, and that the lessons were ready for use in this pilot study.

The final lesson set included (a) three lessons for each letter of the alphabet, (b) cumulative review lessons, (c) a set of keyword picture cards linking each letter to a familiar word or object, and (d) a set of environmental print picture cards linking each letter to print found in children's everyday environments. Lessons require 10 to 15 min each and are designed to be used flexibly, such that children receive instruction only on letters that they have not yet mastered. Children are provided with all three alphabet lessons for a given letter over the course of a few days. Beginning with the second letter taught, each series of individual letter lessons is followed by up to two review lessons. Every alphabet lesson includes an introduction to the target letter and sound (e.g., link to action, link to environmental print), a reading activity (e.g., locating letter in authentic text, sorting pictured objects by initial sound), and a writing activity (e.g., tracing, writing, labeling). Review lessons follow a similar structure. However, rather than focusing on one letter, the first review lesson targets letters that have been taught up to that point, and the second review lesson targets taught letters for which the child was not able to provide the correct name or sound during progress monitoring assessments following the first review lesson. The Supplemental Material provides further details of lesson structure, and all lessons with accompanying documentation are available at https://crane.osu.edu/our-work/alphabet-learning-and-instruction/.

## 2. Method

For the pilot study, we used an experimental within-subjects design to test the efficacy of the alphabet lessons. Letters selected for instruction (or as controls) were differentiated for individual children based on an initial screening assessment. Moreover, we intentionally selected letters of varying difficulties to examine whether letter difficulty influenced participating children's alphabet learning. The university institutional review board approved all study procedures.

### 2.1. Participants

To recruit participants, we sought recommendations from providers or administrators at three local early childhood programs as to children who had not yet learned all 26 letter names and sounds. Each program enrolled children funded through private tuition, Head Start, and state/city subsidies. We distributed information about the study, consent forms, and background surveys to children's families. Fifty-seven parents provided informed consent for their child to participate in the study. The research team reviewed the background surveys to determine whether children met the following eligibility criteria: (a) between 3 and 6 years of age, (b) free of profound disabilities, and (c) proficient in speaking and understanding English. This age range reflects the period during which alphabet knowledge is typically acquired by children, and alphabet learning is emphasized in relevant learning and development standards for children of these ages (Anthony et al., 2021; National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010; Wright, Parks, Wilinski, Domke, & Hopkins, 2021). The other two criteria were reported by parents and in place to ensure that the alphabet lessons and assessments, administered in English, were appropriate for participating children. For the children who met these criteria ($n = 52$), the research team conducted screenings to assess each child's ability to produce the name and associated sound for each letter of the alphabet (both uppercase and lowercase forms). The final eligibility criterion (d) was that children were unable to produce the name and sound for a minimum of eight letters when shown the uppercase or lowercase form (i.e., did not produce the name or sound for either case).

We enrolled 32 children meeting all eligibility criteria in the study.

Three children stopped participating due to changes in their childcare arrangements or frequent absences. Twenty-nine children completed the study and were included in analyses. Sixty-two percent were girls, with an average age of 51.90 months ($SD = 6.97$; range = 3.5 years to 6.0 years). Almost half were Black (48%), 31% were White, 7% were Asian, and 10% were multiracial (4% unreported). The highest degrees earned by children's mothers included a high school diploma (35%), an Associate's degree (14%), a Bachelor's degree (17%), or a graduate degree (17%); 14% of children's mothers did not hold a high school diploma (3% unreported). Annual family incomes were less than $25,000 for 36% of children, $25,001 to $55,000 for 30% of children, $55,001 to $75,000 for 12% of children, and more than $75,001 for 15% of children (7% unreported). None of the children had individualized education plans. As reported by parents, two children spoke a language other than English as their primary language, and five lived in homes in which family members spoke languages other than English. All children exhibited limited alphabet knowledge on the initial screening, correctly naming an average of 3.97 uppercase letters and 2.62 lowercase letters and producing less than one letter sound ($M = 0.97$ for uppercase letters, 0.76 for lowercase letters). All of the early childhood programs that children attended were located in urban communities, and all programs indicated that, although they provided various language and literacy learning experiences, they did not use a specific alphabet curriculum.

### 2.2. Procedures

As noted above, we screened children as to their letter name and sound production to determine study eligibility. Screening and all other assessments were administered individually by research staff.

We used the screening results to select eight letters for which an individual child was unable to produce the name and sound for both the uppercase and lowercase forms. Four of these letters served as target letters (i.e., letters to be taught via alphabet lessons) and four served as control letters (i.e., letters that we would not teach as part of the study). Our letter selection process attended to letter difficulty, both to ensure that those selected represented the range of difficulties of letters unknown to a given child and that letter difficulties were equated across target and control letters.

To select letters for each child, we used the difficulty values provided by Drouin et al. (2012). Because Drouin et al. provide two values for letter naming difficulty (uppercase and lowercase), we first averaged these difficulties and then averaged the letter naming difficulty value with the letter sound production difficulty value (uppercase only) to derive a "combined" difficulty value (see Fig. 1). Next, we rank ordered the letters unknown to each child according to the combined letter difficulty. We divided the rank-ordered letters into four approximately equal groups and selected two letters closest in difficulty from each group. Finally, we randomly assigned one of each letter pair to be a target letter or control letter, such that we selected eight letters (four target, four control) per child (example in Fig. 1 note). *t*-Tests confirmed that the selected target and control letters were equated on letter difficulties: $M_{\text{target}} = -1.19$ and $M_{\text{control}} = -1.27$ for uppercase letter naming difficulties, $M_{\text{target}} = -0.42$ and $M_{\text{control}} = -0.32$ for lowercase letter naming difficulties, and $M_{\text{target}} = 4.21$ and $M_{\text{control}} = 4.23$ for letter sound production difficulties, $ps > .291$.

For the eight selected letters, we administered additional pretest assessments to measure uppercase and lowercase letter name and sound recognition and letter writing. After pretest assessments, research staff implemented the alphabet lessons (described above and in Supplemental Material) to provide instruction on the four target letters individually selected for each child. The order for teaching the four target letters was randomized for each child. We implemented 1:1 instruction for purposes of this pilot study. Although an important next step is to conduct such instruction via flexible small groups, as might be done in a classroom setting, use of small groups was not feasible in the current study given logistical constraints.

We provided three lessons specific to each target letter. After the second, third, and fourth letters taught, we conducted progress monitoring assessments and a review lesson. We provided a second review lesson for additional practice on taught target letters for which the child did not produce the correct name or sound during progress monitoring. We videotaped all lessons and randomly selected 25% to code for implementation fidelity using a checklist. The checklist noted the instructor's adherence to the components of each lesson activity. Trained coders indicated whether each component was implemented correctly (Yes = 1, No = 0) and calculated the total percent adherence for each individual lesson (sum divided by the total possible score). Interrater agreement was high (96%), based on 20% of coded lessons randomly selected for double coding. Across lessons, implementation fidelity averaged 95% ($SD = 0.07$), with a range of 68% to 100%. The average duration of letter lessons selected for fidelity coding was 10 min 18 s (*SD* = 2 min 58 s). For review lessons, the average duration was 12 min 4 s (*SD* = 4 min 27 s).

After administering all letter and review lessons, we conducted posttest assessments for the four target and four control letters. These assessments included uppercase and lowercase letter name and sound production, uppercase and lowercase letter name and sound recognition, and letter writing.

### 2.3. Measures

#### 2.3.1. Letter name and sound production

We administered the following measures to assess letter name and sound production: (a) an uppercase letter naming task, (b) a lowercase letter naming task, (c) an uppercase letter sound production task, and (d) a lowercase letter sound production task. Although none of these measures were commercially published assessments, all were similar to alphabet tasks used in prior work (Phillips et al., 2012; Piasta et al., 2010; Roberts et al., 2019). We administered the uppercase tasks first, then the lowercase tasks. During screening, we assessed all 26 letters. At posttest, we assessed only the eight letters (four target, four control) selected for each child.

We presented letters individually on index cards, with the cards shuffled before each administration to randomize the presentation order for each case for each child. We first showed children each uppercase letter and asked, "What is the name of this letter?" followed by, "What sound does this letter represent?" We deliberately used the word *represent* rather than *make* in this question to avoid confusion; as noted by Jones et al. (2013), letters do not "make" sounds the way, for example, an animal would. Children received corrective feedback on the first two items as necessary (e.g., if provided a sound when asked for the name, we prompted "That's a letter sound, but what is the name of the letter?"). For letters associated with multiple sounds, we considered the sound taught during lessons as correct (e.g., /k/ for C, short vowel sounds). When a child provided an alternative sound (e.g., /s/ for C), we prompted them to provide another sound represented by the letter. We repeated this process for the lowercase tasks.

For each letter, we coded whether the child's response was correct (1) or incorrect (0). In prior literature, reliability for similar alphabet measures ranged from 0.65 to 0.96 (Evans et al., 2006; Piasta et al., 2010). For the current sample, internal consistencies (Cronbach's α) were 0.90 for uppercase letter naming, 0.79 for lowercase letter naming, 0.69 for uppercase letter sound production, and 0.33 for lowercase letter sound production, based on the pretest administration of all 26 letters. The low reliability for lowercase letter sound production may be due to limited pretest performance on this task by children who met all eligibility criteria for the current study (see also Roberts et al., 2019). In comparison, $\alpha = 0.95$ when analyzed for all 52 children who completed screening, and Evans et al. (2006) reported a split-half reliability of .96 for lowercase letter sound production.

#### 2.3.2. Letter name and sound recognition

At pretest and posttest, we administered the following measures to assess letter name and sound recognition for the eight selected letters (four target, four control): (a) uppercase letter name recognition task, (b) lowercase letter name recognition task, (c) uppercase letter sound recognition task, and (d) lowercase letter sound recognition task. Before administering the tasks, the research team member extracted the letter cards for the eight selected letters for the given child. By shuffling the index cards between tasks, we randomized the letter administration order for each task and each child. We first presented the child with a sheet showing all 26 uppercase letters, listed in random order. We asked the child to point to each of the letters named by the research team member. We then asked the child to point to the letter that represented each sound said by the research team member. Children received corrective feedback on the first two items as necessary (i.e., the research team member pointed to the correct letter and said either "This is [letter name]" or "This is the letter that represents [letter sound]" and then "You point to that letter."). We repeated this process using a sheet showing all 26 lowercase letters. For each letter, we coded whether the child's response was correct (1) or incorrect (0). In the literature, internal consistencies for similar uppercase tasks range from .72 to .79 (Piasta et al., 2010). High reliability has also been reported for composite measures of uppercase and lowercase letter name recognition ($\rho = 0.98$; Anthony et al., 2021). We are unable to generate reliability estimates for the current study because, by design, we assessed different letters for each child. However, prior work suggests that measure reliability remains high when assessing subsets of letters (Piasta et al., 2016; Roberts et al., 2019; Tortorelli, Bowles, & Skibbe, 2017).

#### 2.3.3. Letter writing

At pretest and posttest, we administered a letter writing task in which we asked children to write each of the eight selected letters (four target, four control). We adapted the task from Puranik and Lonigan (2011), making some slight modifications to fit the context of this study. Before administering the task, the research team member extracted the letter cards for the eight selected letters for the given child and shuffled these to randomize the administration order. We said the name of each letter aloud and asked the child to write each one "as best you can" on blank pieces of paper. We did not specify letter case and accepted responses written in either uppercase or lowercase form. Trained coders scored responses on a scale of 0–2 following Puranik and Lonigan (2011). A score of 0 indicated no attempt at writing the letter, that the written letter was completely unrecognizable, or that the wrong letter was written. A score of 1 indicated that the written letter contained most key features of the correct letter; however, the letter may have been oriented incorrectly or poorly formed, such that it was only recognizable in the context of the assessment. A score of 2 indicated that the written letter was correct and could be recognized out of context. Interrater agreement was high (93%), based on 15% of letter writing assessments randomly selected for double coding. Puranik and Lonigan (2011) report internal consistency ($\alpha$) as .93.

#### 2.3.4. Letter difficulty

In addition to using letter difficulty values from Drouin et al. (2012) in letter selection, we also used these values in analyses to address the role of letter difficulty in children's alphabet learning. Drouin et al. provide letter difficulty values for each letter for uppercase letter name production, lowercase letter name production, and letter sound production tasks (see Fig. 1). We entered the exact values from Drouin et al. into study databases and included these values in analyses as relevant (e.g., uppercase letter name difficulties when analyzing uppercase letter name production, letter sound difficulties when analyzing letter sound production).

## 3. Results

By design, no child was able to produce the name or sound of selected target or control letters (in either uppercase or lowercase), our primary outcomes of interest, prior to instruction. Children exhibited minimal knowledge of selected letters at pretest based on the secondary outcome measures: Of the 232 total responses (29 children × 8 letters), children provided 21 correct responses on the uppercase letter name recognition task at pretest, 15 correct responses on the lowercase letter name recognition task, 14 correct responses on the uppercase letter sound recognition task, 11 correct responses on the lowercase letter sound task, and 9 fully or partially correct responses on the letter writing task. Proportions of correct responses at pretest by letter type (target v. control) are provided in Table 1.

Proportions of correct responses at posttest are also provided in Table 1. For target letters, proportions correct ranged from .16 (partially correct letter writing) to .59 (uppercase letter name production). For control letters, proportions correct ranged from .06 (partially correct letter writing) to .26 (uppercase letter name production). In order to statistically test whether children learned more target than control letters, we used hierarchical generalized linear models in which letters (Level-1) were nested within children (Level-2). Such models partition the variance into that due to differences across letters versus differences

**Table 1**
Correct responses for target and control letters on alphabet knowledge outcomes at posttest.

| Outcome | Pretest | | Posttest | | | |
|---|---|---|---|---|---|---|
| | Proportion correct | | Proportion correct | | Modeled probability | |
| | Target | Control | Target | Control | Target | Control |
| Letter name production | | | | | | |
| Uppercase | .00 | .00 | .59 | .26 | .61 | .24 |
| Lowercase | .00 | .00 | .51 | .16 | .50 | .12 |
| Letter sound production | | | | | | |
| Uppercase | .00 | .00 | .57 | .12 | .59 | .09 |
| Lowercase | .00 | .00 | .46 | .08 | .50 | .05 |
| Letter name recognition | | | | | | |
| Uppercase | .08 | .10 | .47 | .21 | .43 | .13 |
| Lowercase | .06 | .07 | .31 | .18 | .25 | .12 |
| Letter sound recognition | | | | | | |
| Uppercase | .05 | .07 | .47 | .09 | .45 | .05 |
| Lowercase | .04 | .05 | .33 | .09 | .27 | .07 |
| Letter writing[a] | | | | | | |
| Full credit (2) | <.01 | <.01 | .18 | .10 | .12 | .05 |
| Partial credit (1) | .03 | .03 | .16 | .06 | .14 | .06 |
| No credit (0) | .97 | .96 | .66 | .84 | .74 | .89 |

*Note.* The values for proportion correct are based on raw data; the values for modeled probability are calculated using coefficients from the hierarchical generalized linear model results. All model estimates control for instructor, and estimates for secondary outcomes also control for pretest letter knowledge (interpreted at pretest = 0). As shown in Table 2, probabilities of learning to produce and recognize names and sounds for target letters were significantly higher than for learning control letters. Likewise, as shown in Table 3, probabilities for scoring a 2 or 1 on the letter writing outcome were significantly higher for target than control letters.

[a] For letter writing, modeled probabilities for scoring at or below each level were calculated using the parameters in Table 3. These were.88 and 0.95 for scoring at or below 1 for target and control letters, respectively, and 0.74 and 0.89 for scoring 0 for target and control letters, respectively; the probability of scoring at or below 2 is 1.00, given that all children received scores at or below the highest category. The differences in probabilities between adjacent scores are then used to calculate the probability of scoring at a particular level as shown in this Table (e.g., probability of scoring a 2 for a control letter = 1.00–0.95 = 0.05; probability of scoring a 1 for a control letter = 0.95–0.89 = 0.06).

across children (see Piasta & Wagner, 2010b) and, in the current study, accounted for the fact that we selected different target and control letters for each child and allowed for incorporation of letter-level predictors of interest (e.g., designation of letter type as target v. control, letter difficulty).

We analyzed data using HLM v7.01 (Raudenbush, Anthony, & Congdon, 2013). For the production outcomes, children's responses to each letter at posttest served as the dependent variable (1 = correct response, 0 = incorrect response). Letter type (target = 1; control = 0) was the Level-1 predictor of interest for examining the effects of alphabet instruction (Model 1). Letter difficulty, plus the letter difficulty x letter type interaction, were added as additional Level-1 predictors to examine the role of letter difficulty in alphabet learning (Model 2). These models were fit using the Bernoulli distribution at Level-1 and penalized quasi-likelihood estimation. The resultant models provide the log odds of correct responses, conditional on predictors, along with associated statistical tests for each predictor. To facilitate interpretation, log odds are converted to estimated probabilities of correct responses using the following general formula, in which *c* represents the coefficient(s) of the intercept plus any predictors:

$$Probability\ (\Phi_{ij}) = \frac{1}{1+e^{-c}}$$

We fit similar models for recognition outcomes, with two exceptions. First, we controlled for children's pretest performance for each letter (1 = correct response, 0 = incorrect response) given that children exhibited some, albeit minimal, knowledge on these secondary measures at pretest. Second, only models examining the effects of alphabet instruction (Model 1) were estimated for secondary outcome measures, as letter difficulty values are not available for all secondary outcomes. The hierarchical generalized linear models fit for the letter writing outcome differed from those for the production and recognition outcomes, given that we scored letter writing on an ordinal scale. For the letter writing outcome, children's scores (0–2) for each letter at posttest served as the dependent variable. Letter type (target = 1; control = 0) was again the Level-1 predictor of interest, and, as for the recognition outcomes, we controlled for children's pretest letter writing scores. The model was fit specifying an ordinal distribution at Level-1 and penalized quasi-likelihood estimation. This model provides the log odds of scoring at or below particular levels (calculated from the intercept and threshold parameter), conditional on predictors, along with associated statistical tests for each predictor. Log odds are converted to probabilities as noted above.

Prior to conducting our main analyses, we examined instructors' implementation fidelity. Fidelity significantly differed among instructors, Welch's $F(2, 26.57) = 15.18$, $p < .001$. One instructor, who conducted the majority of lessons, exhibited significantly higher fidelity ($M = 97\%$) than the other two instructors ($M = 89\%$ for each, $ps < .01$). We thus created a dummy code representing the instructor exhibiting higher fidelity and controlled for this in all analyses.

Results of hierarchical generalized linear analyses are presented in Table 2 and Table 3, with the estimated probabilities based on Model 1

**Table 3**
Hierarchical generalized linear model results predicting children's letter writing outcomes at posttest.

| | Coeff (*SE*) | *p* |
|---|---|---|
| Model 1 | | |
| Intercept[a] | 2.06 (.62) | .003 |
| Instructor | −.24 (.68) | .729 |
| Pretest | −.38 (.61) | .538 |
| Target letter | −1.03 (.34) | .003 |
| Threshold[a] | .95 (.17) | <.001 |
| Variance component | 1.67 (.67) | <.001 |

*Note.* Only model 1 estimated for secondary outcomes. Coeff = coefficient.
[a] In hierarchical generalized linear models with ordinal outcomes, the intercept coefficient is used to calculate the predicted probability of scoring at the lowest category (i.e., score of 0 in this study). The threshold coefficient represents the deviation from the intercept for scoring at or below the next response level (i.e., scoring 1 or lower; note that there is no second threshold in this study because, by definition, all children scored at the highest response level [2] or lower). The threshold is added to the intercept coefficient to calculate the predicted probabilities of scoring at or below ascending response categories. For example, the probability of scoring 0 for a control letter is $\frac{1}{1+e^{-intercept}}$ or $\frac{1}{1+e^{-2.06}} = 0.89$. The probability of scoring 1 or 0 for a control letter is $\frac{1}{1+e^{-(intercept+threshold)}}$ or $\frac{1}{1+e^{-(2.06+0.95)}} = 0.95$. By default, the probability of scoring a 2 or lower is 1.00. These probabilities of scoring at or below a response level, derived from the intercept and threshold, are then used to generate the probabilities for specific scores, as detailed in the note to Table 1. More information about estimating and interpreting these models can be found in O'Connell, Goldstein, Rogers, and Peng (2008).

**Table 2**
Hierarchical generalized linear model results predicting children's alphabet knowledge production and recognition outcomes at posttest.

| | Letter name outcomes | | | | Letter sound outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| | Uppercase | | Lowercase | | Uppercase | | Lowercase | |
| | Coeff (*SE*) | *p* | Coeff (*SE*) | *p* | Coeff (*SE*) | *p* | Coeff (*SE*) | *p* |
| Production | | | | | | | | |
| Model 1 | | | | | | | | |
| Intercept | −1.23 (.49) | .019 | −1.77 (.53) | .003 | −2.30 (.59) | .001 | −3.44 (.75) | <.001 |
| Instructor | 0.05 (.54) | .920 | −.21 (.57) | .714 | 0.01 (.62) | .991 | 0.45 (.73) | .540 |
| Target letter | 1.64 (.31) | <.001 | 1.98 (.35) | <.001 | 2.64 (.38) | <.001 | 2.97 (.48) | <.001 |
| Variance component | 1.03 (.44) | <.001 | 1.16 (.51) | <.001 | 1.39 (.58) | <.001 | 2.05 (.81) | <.001 |
| Model 2 | | | | | | | | |
| Intercept | −1.43 (.55) | .014 | −1.80 (.56) | .004 | −2.31 (.59) | .001 | −3.52 (.77) | <.001 |
| Instructor | 0.10 (.60) | .872 | −.29 (.61) | .645 | 0.01 (.62) | .990 | 0.47 (.76) | .538 |
| Target letter | 1.91 (.34) | <.001 | 2.05 (.36) | <.001 | 2.64 (.38) | <.001 | 3.03 (.49) | <.001 |
| Letter difficulty | −1.08 (.28) | <.001 | −.41 (.19) | .032 | −.08 (.16) | .593 | −.30 (.18) | .090 |
| Variance component | 1.37 (.55) | <.001 | 1.37 (.57) | <.001 | 1.41 (.59) | <.001 | 2.25 (.87) | <.001 |
| Recognition | | | | | | | | |
| Model 1 | | | | | | | | |
| Intercept | −1.85 (.57) | .003 | −1.71 (.57) | .006 | −2.82 (.60) | <.001 | −2.02 (.48) | <.001 |
| Instructor | −.02 (.61) | .978 | −.25 (.62) | .693 | −.03 (.57) | .962 | −.64 (.49) | .196 |
| Pretest | 1.83 (.68) | .007 | 1.25 (.63) | .047 | 1.56 (.72) | .032 | 1.21 (.76) | .112 |
| Target letter | 1.59 (.35) | <.001 | 0.89 (.35) | .012 | 2.63 (.43) | <.001 | 1.67 (.39) | <.001 |
| Variance component | 1.35 (.56) | <.001 | 1.39 (.60) | <.001 | 1.02 (.50) | <.001 | 0.54 (.38) | .011 |

*Note.* Model 1 estimated for all primary and secondary outcomes; Model 2 (including letter difficulty) estimated only for primary outcomes. Coeff = coefficient.

presented in Table 1. Using a Bonferroni-adjusted $p$-value for five outcomes (i.e., .01), letter type significantly predicted children's letter knowledge across all primary and secondary outcomes with the exception of lowercase letter name recognition ($p = .012$). These results indicate that children were more likely to learn target as compared to control letters. For example, the probability of correctly producing the sound of an uppercase letter targeted by instruction was 0.59 whereas the probability of a correct response for a control letter was 0.09 (Table 1). Likewise, the negative coefficient associated with target letters in the letter writing model (Table 3) indicates that lower scores were less likely for target than control letters (i.e., higher scores were more likely for target letters, as seen in the probabilities in Table 1). Given that children were unable to produce the names or sounds for any selected letters prior to instruction, and unable to recognize or write the vast majority of selected letters at pretest (with pretest performance controlled in analyses for these secondary outcome measures), these results show that the alphabet instruction increased children's alphabet learning.

Table 2 also presents results addressing the role of letter difficulty in alphabet learning for the primary outcome measures (Model 2). Although we originally included interactions between letter type and letter difficulty in each of these models, none of the interactions significantly predicted outcomes. Thus, we removed the interaction term for parsimony. Letter difficulty significantly predicted children's abilities to produce the names of uppercase letters, such that more difficult letters were less likely to be learned regardless of whether these were target or control letters. A similar trend existed for lowercase letter naming ($p = .032$). Although the pattern was in the same direction when considering children's abilities to produce sounds of lowercase letters, letter difficulty did not significantly predict letter sound learning.

## 4. Discussion

In this study, we pilot tested a set of alphabet lessons to examine the effects of instruction and letter difficulty on children's alphabet learning. Strengths of our work include iterative development of lessons designed to teach this critical aspect of early literacy within an ecologically valid context, as guided by teacher input, and empirically testing whether these lessons realized intended effects on children's alphabet learning. Our results substantiate the efficacy of the alphabet lessons and suggest that differentiated alphabet instruction warrants further attention in future research.

As hypothesized, the alphabet lessons were effective, showing impacts on children's learning of target letters (names, sounds, and forms) across all but one outcome. A notable feature of our work was the use of a within-subjects design. This design not only afforded differentiating the content of instruction for individual children but provided a rigorous counterfactual (Shadish, Cook, & Campbell, 2002), ruling out selection biases and alternative explanations for effects (e.g., differential opportunities to learn about the alphabet outside of the study). We also used a hierarchical generalized linear modeling approach for data analysis in order to partition letter- and child-level variance and account for letter difficulty (Piasta & Wagner, 2010b). To facilitate comparison with available between-subjects studies, we calculated Cohen's $d$ effect sizes comparing the total number of target and control letters known at posttest, correcting for the correlated outcomes (Lakens, 2013). Cohen's $d$ was greater than 0.99 for all but three outcomes (range of 0.99 to 1.55) which exceeds the modest effect sizes reported in Piasta and Wagner's (2010a) meta-analysis (see also Lonigan, Schatschneider, Westberg, & The National Early Literacy Panel, 2008b). These effect sizes also exceed those reported in prior studies involving preschool-aged children selected for initially low alphabet knowledge (e.g., Piasta et al., 2010) and are of similar magnitude to recent work including initial letter name knowledge as a covariate (e.g., Roberts et al., 2018, 2020). The three smaller effect sizes (i.e., uppercase and lowercase letter name recognition, with $d = 0.76$ and 0.44, respectively, and letter writing, $d = 0.45$) also exceed those noted for alphabet-specific instruction (Piasta & Wagner, 2010a). Altogether, the findings substantiate the use of the newly developed alphabet lessons in future research to identify factors related to alphabet learning and best practices for alphabet instruction (e.g., testing variations in lesson components, intensity). We note that the current study speaks only to lesson effects as compared to whatever formal and informal alphabet learning opportunities participating children experienced outside of study instruction. Important next steps will be to directly test effects of alphabet instruction that is differentiated in terms of content (or process or products) relative to other instructional approaches (e.g., letter-of-the-week) and to trial lessons with small groups of children, rather than 1:1.

Effects were particularly pronounced for letter sound learning. Despite arguably being more critical than letter names for learning to read (Hulme et al., 2012), letter sound knowledge is often not a focus when initially teaching U.S. children about the alphabet (Robins, Treiman, & Rosales, 2014; Treiman, Stothard, & Snowling, 2013). Consequently, U.S. children's letter sound knowledge typically lags behind their letter name knowledge (Anthony et al., 2021; Ellefson et al., 2009; Gerde, Skibbe, Goetsch, & Douglas, 2019; Piasta et al., 2021). Our letter sound findings align with previous work suggesting that young children benefit from alphabet instruction that attends to letter sounds (Piasta & Wagner, 2010a; Roberts et al., 2018).

Effects were less pronounced for recognition compared to production outcomes, particularly for lowercase letters, and children exhibited lower accuracy in the recognition tasks at posttest in general. Although these findings may seem at odds with literature indicating better performance in alphabet recognition than production tasks (Anthony et al., 2021; Drouin et al., 2012), this prior work involved assessing children's knowledge at a static point in time rather than learning over time. At pretest, children in the current sample also exhibited greater, although still limited, success in recognition tasks compared to production tasks. With respect to learning as a function of the alphabet lessons, the lessons emphasized children saying the names and sounds of taught letters, similar to Roberts et al. (2019), with less attention to recognizing letters within an array. We also acknowledge that the recognition task itself, which required locating a specific letter within an array of all 26 letters, may have been particularly challenging for children. A simpler recognition task that presents fewer letters per array (e.g., 6 or 10; Bara et al., 2007; Cardoso-Martins et al., 2011; Shmidman & Ehri, 2010) might have detected greater learning on recognition outcomes.

Notably, our alphabet lessons include a writing component, which does not align with Roberts et al.'s (2019) recent finding that letter writing did not lead to better alphabet learning. We created our lessons prior to publication of Roberts et al. (2019) and based these on research suggesting potential benefits of writing for alphabet learning (Hall et al., 2015; Puranik et al., 2017). Additionally, teachers in our focus groups indicated both a need, due to early learning standards, and a desire to attend to letter formation as part of alphabet instruction (see also Gerde et al., 2019). Our lessons had a modest yet positive effect on children's letter writing, with children receiving full or partial writing credit for 34% of target letters compared to 16% of control letters, but we are unable to discern if this was at the expense of potentially greater effects on other alphabet outcomes. Future research may attend to this and replicating the Roberts et al. (2019) findings.

To our knowledge, ours is the first study to empirically test whether letter difficulty affects learning. Our hypothesis that children would be less likely to learn more difficult letters was partially supported. Children were, indeed, less likely to learn the names of more difficult uppercase letters and, correspondingly, more likely to learn the names of easier uppercase letters. A similar trend was noted for lowercase letters. The difficulty effect appeared to be the same for both target and control letters. We did not propose a directional hypothesis concerning any interactions with instruction, as both mitigation (i.e., overcoming difficulty effects such that all letters were equally likely to be learned in the presence of instruction) and exacerbation (i.e., greater effects on easier letters, given that these letters might be more readily learned in the presence of instruction) seemed possible. Yet, we found no evidence of an interaction between letter difficulty and letter type, either in our statistical models or when visually examining graphs of modeled outcomes. Together, these results suggest that differentiation of instructional processes, such as adjusting instructional intensity or pacing, may be important to consider when teaching more difficult letter names. Future research should test whether providing a greater number of lessons/practice opportunities and/or slower pacing improves learning of more difficult letters. In the current study, we attended to only one aspect of differentiation (i.e., content — which letters were taught). Other aspects of differentiation, including instructional processes, is an important avenue for future research.

Our hypothesis concerning letter difficulty was not supported when considering uppercase and lowercase letter sound production outcomes. In this study, letter sounds were equally likely to be learned regardless of difficulty. We speculate that perhaps once children have begun learning to associate a letter form with one label (e.g., letter names, which U.S. children tend to learn first) through either explicit or implicit instruction, they more readily learn additional labels (letter sounds) when explicit instruction is provided. However, these results should be regarded as preliminary for a number of reasons. First, the sounds considered "correct" and used to generate the difficulty values in Drouin et al. (2012) may not have been the same as in the current study (e.g., for those letters associated with multiple sounds). Second, the letter difficulty values from Drouin et al. (2012) were specific to uppercase letter sound production, and we are not aware of published reports of lowercase letter sound difficulty values (e.g., Piasta et al., 2016 reports difficulty values for presenting uppercase and lowercase letters together). Third, children exhibited very low success rates on both the uppercase and lowercase letter sound outcomes, which may have restricted variability and the ability to detect effects. Altogether, additional research concerning the role of letter difficulty in letter sound learning is warranted, as is research concerning letter difficulty as it pertains to other aspects of alphabet knowledge such as letter recognition and writing, to better guide instructional decisions.

We note that our pilot study findings may not generalize to other samples or contexts. Our sample underrepresented emergent bilingual children, which is an important and growing population in the U.S. (U.S. Department of Education, Office of English Language Acquisition, & National Clearinghouse for English Language Acquisition, 2020), and our sample did not necessarily include children who were formally identified as at risk for later reading difficulties. Additionally, we did not directly test the alphabet lessons in this pilot study against other types of alphabet instruction, including non-differentiated, letter-of-the-week approaches, nor are we able to closely examine learning mechanisms embedded within the lessons as these related to outcomes. Both of these are critical next steps for future work, with attention to the latter perhaps providing further insight into how to improve alphabet instruction and learning. The current results show the potential of our alphabet lessons for improving English-proficient children's learning across most alphabet outcomes (excepting lowercase letter name recognition) and document the role of letter difficulty in letter name learning.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.lindif.2021.102113.

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